Thesis
2
2006

This is to certify that the
thesis entitled

INCORPORATING AN AGRICULTURAL EMPHASIS IN
ECOLOGICAL EDUCATION

presented by

JONATHAN MARK VANOVERLOOP

has been accepted towards fulfillment
of the requirements for the

Masters in Science degree in Interdepartmental Biological Science

Major Professor's Signature

25 July 06

Date

# INCORPORATING AN AGRICULTURAL EMPHASIS IN ECOLOGICAL EDUCATION

By

Jonathan Mark VanOverloop

A THESIS

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

MASTERS IN SCIENCE

Department of Science and Mathematics Education

2006

ABSTRACT

INCORPORATING AN AGRICULTURAL EMPHASIS IN ECOLOGICAL EDUCATION

By

Jonathan Mark VanOverloop

This research project studied the effectiveness of using agriculture to demonstrate, clarify, and exemplify the science of ecology. The related lecture content, pedagogical examples, laboratory activities, worksheets, quizzes, and tests were constructed to further the students' understanding of ecology and enrich the students' appreciation for West Michigan's agricultural community. The effectiveness of this unit was evaluated using imbedded assignments, evaluations, anecdotal evidence, surveys, and a pre/post test comparative analysis.

Results from these assessments indicate that the unit was effective. This document also analyses and critiques the related lessons. These lessons will further developed and revised. The agricultural approach to teaching ecology added both to the students' understanding of ecology and to their appreciation for West Michigan's agricultural heritage.

To my wife Katie for her love, encouragement,
and support through the past several years.

To the 2005-06 Biology students for being an
ambitious and enjoyable class.

## ACKNOWLEDGEMENTS

* Dr. Merle Heidemann, for being a role model of a disciplines educator, also for her guidance, advice, and direction.

* Dr. Ken Nadler, for his insights into lab variations and advice

* Dr. Chuck Elzinga and Dr. Jerry Urquhart, for a wild ride through Michigan's ecosystems

* My fellow Summer of 05' classmates, for your emotional support and camaraderie throughout our research weeks together.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

# INTRODUCTION

## Rationale for the Study

The primary goal of this masters project is to determine if infusing my ecology unit with agricultural examples, references, and labs is an effective way to teach and demonstrate ecological principles. Ecology can be defined as the study of the interactions among organisms and the environment. Agriculture is the activity of using the ecosystem in wise ways to producing edible foods. From this perspective it is clear that agriculture is profoundly ecological. Farmers work to implement wise ecological strategies to maximize food production by manipulating both the biotic and abiotic environments in which their plants or animals are grown. Farmers manipulate the biotic environment when they use pesticides or herbicides, when they employ cover-crops in weed suppression, and when they implement the concept of degree days for insecticidal applications. They work with abiotic factors when they add to the clay content of the soils, create irrigation ditches, use plastic to cover the early spring plants, change the pH of the soils, and when they fertilize in a timely manner.

A second reason for implementing this unit is because smart applications of ecological principles in general and in agricultural science, specifically, have been a personal interest of mine for a number of years. I teach my ecology unit in this way because it gives me opportunity to speak about that which I enjoy.

Thirdly, I want students to develop an appreciation for ecology beyond an interest in its death and destruction aspects. Over the years that I've spent teaching ecology, I've noticed a lack of knowledge and a lack of interest for the subtle and minute members of ecosystems on the part of my introductory biology students. They tend to perk-up and remember ecological principles that relate to the blood and gore of lions, tigers, and bears, but hardly blink an eye at the seemingly more peaceful soil ecosystem that they so ignorantly depend on for their very existence. With this unit I try to fascinate my biology students. I want them to appreciate the profound interconnectedness of the various abiotic and biotic aspects of Ecology and especially those aspects found in the soil.

In addition, West Michigan, among other things, is quite agricultural. I felt that the students that take high school biology classes in this locale should be at least acquainted with the science of the rural community through which they pass everyday on their commute to school. I intend to help the students develop a better sense of place and appreciation for the science that underlies their agricultural community.

Also, agriculture provides many hands-on activities and labs that promote involvement among the less enthusiastic learners. Barrick (1989) says that "practice is based upon theory. Agricultural education is more than skill training. The basis for the application phase of teaching is sound theory. Agricultural education goes beyond the "how" to the "why." Or, in another sense, agricultural education moves the "why" to the "how." " Implementing this unit involves students working with the soil as they grow plants in different environments, test for cation exchange capacity, and measure the carbon content of the soils.

Finally, this project enables students to make wise informed decisions regarding the farm, forest, freeway, and ever-expanding city. Giving students opportunity to think about agriculture's place in relation to other urban population requirements is of growing importance in our resource consuming society.

**Demographics of the Study**

Covenant Christian High School is located just west of Grand Rapids, Michigan. A good percentage of the parents do manual work or many own businesses associated with the building trades of one form or another. Nearly all of whom have an aggressive work ethic. In addition to the manual laborers there is a cohort of businessmen, and just a few with advanced degrees. Most of the students come from upper middle class families whose parents have high standards and are quite heavily involved with the behavior and attitudes of their children. All in all, I have a conscientious group of students and lots of support from active and involved parents.

The students with whom I worked during this project were a rather homogeneous group that in large part can be characterized by the acronym WASP (White, Anglo-Saxon, and Protestant.) The Protestant Reformed denomination whose parents support

Figure 1. My 2006 Biology Class.

and govern the school has roots in the Protestant Reformation of the 1500's. If Calvin or Luther said it, the students and parents pretty much believe it (after their own independent reflection and study of course).

The only variety Covenant gets is in some controversy over finer points of doctrine, occasional disagreements over who was the greatest president of all time (George Bush or Ronald Reagan), and that not all are Dutch; some Germans and Polish have "infiltrated" the ranks. Out of 224 students there is only one who is non-Caucasian and she was adopted into a Caucasian family. Although the reader may think that I jest, the description is apt and gives you an idea of those whom I teach. To add one more loaded descriptor of our constituency, I would have to add that they are what some call "fundamentalist Christian." That is, they believe the Bible to be infallible, historically accurate, instructive, and decisive. The purpose of the school is to "make know the truths" that the parents hold dear with the aim of having the students understand them to be true and embracing them as their own. It could be said that the demographics of the school is composed of young sinners beginning to embrace their faith. In fact, for someone to enroll his children at Covenant, a form has to be signed which signifies that you agree with the Three Forms of Unity: the Belgic Confession, the Canons of Dordt, and the Heidelberg Catechism.

Covenant Christian High School is not the only Protestant Reformed School in Michigan. The denomination has four grade schools that send nearly all of their graduates on to Covenant. These include Heritage Protestant Reformed Christian School, Adams Christian School, Hope Protestant Reformed Christian School, and Eastside Christian School. As a quirk of history, Covenant Christian High School is a bit unusual in that it is only comprised of students in grades 10 – 12 and excludes 9$^{th}$ grade. The 9$^{th}$ graders are still educated at the "feeder school" buildings.

Table 1. describes the homogeneousness of the school and my 2006 Biology class.

| | |
|---|---|
| Graduation Rate of School | 99% |
| % below the Poverty Line | 0% |
| % Caucasion | 100% |
| % Christian | 100% |
| # Protestant Reformed | 17 |
| # United Reformed | 1 |
| # American Reformed | 1 |
| Average GPA of the Class | 3.09 |
| Number of Students | 224 |

Table 1. Covenant's Demographics

**Agricultural Education in the Literature**

Discussions of using agriculture as a basis for teaching ecology is rather scarce in the literature and more significantly it is scarce in the classroom as well. The truth of this is evident from the words of Kirby Barrick (1989) of Ohio State University: "Those who have been involved in agriculture throughout their lives often have difficulty with the realization that agriculture, as a science that could and should be studied, did not exist prior to the19th century."

Already in the late 1800's and early 1900's Agriculture was taught as a class in its own right but it is clear that it did not have much of a place in the curriculum. There was no standardized, common, or shared way to teach the subject. Garland Bricker, in his 1915 book *The Teaching of Agriculture in the High School* calls for a philosophy of agricultural education that would serve as a guide for others to follow. He argues that agriculture should be taught in a uniform way and offered as an elective that guides students to be more competent with a view to their future vocations. To make it easier for teachers to implement agriculture classes he provided lesson plans in the book. These lesson plans are interesting because they show that when agriculture was taught it was from a vocational perspective rather than as a guide for understanding ecology or for a deep understanding of the science of soil. In his book, he included such topics as: testing for starch, determining seed quality, determining swine, horse, and cow qualities, and gaining skills in techniques of farming.

Agriculture as an academic field benefited greatly from federal legislation. The institution of the land-grant college or university (of which MSU is an example) can be credited as beginning to change agriculture's lowly status into a viable curriculum subject. Cornell University's College of Agriculture and Life Sciences home page (http://www.cals.cornell.edu/cals/about/overview/land-grant.cfm) suggests that these land-grant colleges are institutions that have been designated by state legislatures or the Congress "to receive the benefits of the Morrill Acts of 1862 and 1890. The original mission of these institutions, as set forth in the first Morrill Act, was to teach agriculture, military tactics, and the mechanic arts as well as classical studies so that members of the working classes could obtain a liberal, practical education." Later in the same article they suggest that, "A key component of the land-grant system is the agricultural experiment station program created by the Hatch Act of 1887. The Hatch Act authorized direct payment of federal grant funds to each state to establish an agricultural experiment station in connection with the land-grant institution there." Clearly the discipline was beginning to get promoted in the late 19th Century with all of this federal backing.

A 1921 thesis written for Michigan Agricultural College entitled "A Century of Progress in Agricultural Education" nicely summarizes the roots of the agricultural movement. In his thesis, Reuben Nye suggests that there were many initial protests to the agricultural initiatives. The public apparently thought that there was no real need for agricultural education because their sons and daughters could learn everything that they would need on the farm. In addition they felt that they possessed more knowledge and expertise than any "city teacher." Others rejected it because they felt that the curriculum was already getting overcrowded. There was no room to squeeze in another academic area. Finally, opposition also came from those who felt that they didn't want their kids stuck on the farm, as they were for their whole life. Dad and mom had "high" aspirations for their children, aspirations which by no means included the back-breaking work of field labor.

Already in 1912 there were 23 Michigan high schools that had fulltime four year courses in agriculture which were being taught by science teachers. In addition many more high schools had Agriculture as at least a 1 or 2 year class. Through the years, these classes often added a business or financial aspect to their curriculum. Many farmers at this time were failing and the counties thought it was necessary to incorporate this aspect into their curricula.

More recently, R. J. Luxmoore in his 1994 book *Soil Science Education: Philosophy and Perspective* shows that even today's curriculum lacks soil concepts at the high school level. He complains that 84-89% of Minnesota secondary education science teachers teach no soil concepts whatsoever. He says that the main "reasons for not using soils concepts were: (i) not part of the curriculum, (ii) lack of current materials for classroom use, (iii) lack of formal soils training, (iv) not part of the textbook, and (v) time constraints." Luxmoore continues to explain that all this negativity exists about agriculture science in high schools despite the fact that the National Science Teachers Association is trying to push soil science. The NSTA "has a commitment to science-technology-society (STS) issues by developing a curriculum called *The Water Planet*. There is a need for soil topics and NSTA would be supportive of efforts to develop them." Even the NSTA sees the lack of soil curricula as a problem and wants to promote its inclusion in the curriculum.

Another article that demonstrates that agriculture is a struggling science that needs more professional educators was written in 1983. This one appeared in *The Journal of the American Association of Teacher Educators in Agriculture*. The author writes, "It is increasingly essential that agricultural education be further developed as a profession. We need leaders in our profession who will work together in charting a new course for the future. We need intellectual discussions and debate concerning the nature of our program. This intellectual discussion and debate will require of us that we become academicians and philosophers." (McCracken, 1983)

Despite the lack of agricultural principles being included in the curriculum, there is a small core of teachers that do teach aspects of agriculture and some of these have published their ideas. One of these involved adapting agriculture to a small setting. In fact, in one "high school, the 600 students enrolled in ag classes mostly work with small animals that fit an urban campus-rabbits, poultry, and fish." (Lewis 2003)

One example of a lesson comes from a 1990 report in *The Science Teacher*. It suggests that using the USDA Soil Conservation Service can make a good lab activity. "These books are free, and available specifically for each state, county, and district. (Mark, 1990)" These contain "aerial photographs of the land, maps, tables of information on the properties and capabilities of each soil type, and detailed descriptions of each soil type." The survey has lines drawn that show the boundaries of each soil type so it is easy to see what type of soil exists in your location. The USDA Soil Conservation Service books can then be used to learn "descriptions of the soil, including depths of each layer, color, natural vegetation, drainage capability, water table depth, and general descriptions of what type of use the soil can be put to." Students then can go outside and check their campus soil for accuracy. The activity can be nicely expanded so that the students compare the ecosystems above the different types of soil. This activity clearly shows the relationship between the soil abiotic factors and the biotic community living in the immediate vicinity.

Some high school teachers have unique opportunities for their high school students and take advantage of them. One in particular is that of Father Raymond Lelii from Gonzaga High School. Some of his students have opportunity to do soybean genetics. "A biology teacher at Gonzaga, lets his students know about our labs at Beltsville [Beltsville Agricultural Research Center], the work we do, and the opportunity for them to do a science fair project by working with us," Devine says. "He brings around 12 students here each October. We interview them and place them with various scientists—including myself—to work on selected aspects of ongoing research."... "We are not talking about mere academic exercises," Devine says, "These students are doing work of real scientific significance. They're making original contributions to our knowledge about soybean genetics." (Miller, 1989)

Another aspect of the literature includes teaching agriculture with ethics in mind. Students should not only be taught the "how" of agriculture but also the "why." The ethical considerations of wise stewardship of the land, conservation, thoughts about genetically engineered crops, crop rotation, and use or pesticides and herbicides can all be brought out in ethical discussions. Zimdahl (2000) in the *Journal of Agricultural and Environmental Ethics* suggests that when agricultural science is taught, it is often devoid of ethical considerations. "Agricultural scientists have not placed ethics at the core of the curriculum. They have dealt with ethics at the margin, or not at all…My observations of my profession lead me to believe that agriculture has ignored ethics for too long and has suffered because of the lack of a carefully articulated ethical foundation." As more and more teachers see the value of educating students about ecology using agricultural ideas, the number of ethical considerations will be growing as well. A teacher can hardly speak of wise farming techniques without referring to concepts such as the reduction of pollution, dust bowl foibles, and soil nutrient depletion.

**Review of the Scientific Principles**

Ecology is the study of the relationships that exist among and between the biotic and abiotic portions of the environment. When most people think of ecosystems they think about large ones such as lakes or biomes. For example, they think of the Coniferous Forest biome, or of the prairie, or the ecosystem that exists in Lake Michigan. However, the majority of ecosystems are on much smaller scales. Shoes are ecosystems, as are deer intestines, and soil aggregates.

Soil aggregates are assemblages of organic particles, microorganisms, and soil that are held together by clays and natural organic compounds. Jacqueline Papez (2006) in an article on soil aggregate formation suggests that the aggregates are stuck together by matrix secretions from natural bacteria, clays, and the mycorrhizal fungi-produced protein glomalin. These aggregates are interesting for ecological science because they are whole ecosystems in and of themselves. There is an inflow of nutrients, a competition for the nutrients, an interaction among the biotic factors, and a release of wastes. The importance of these ecosystems does not lie in the fact that they exist but in what they do for the ecosystem of the soil system at large. Their importance for farmers is that they sequester carbon, house micro organisms, aerate the soil, allow for better water movement, hold plant fertilizers, reduce water loss, and release crucial nutrients from both decomposing organics and from the parent rock. These aggregates are great examples of the fact that ecosystems are not isolated but instead are interdependent. Farmers are sometimes seen sifting soils through their hands. When sifting, one of the things they are looking for is the size and quantity of aggregates.

The ecosystem to ecosystem interconnectedness is clearly illustrated in the ecosystem of soil aggregates but interconnectedness is a trend common to all ecosystems. What occurs in one ecosystem always impacts others in the vicinity. Farm fields are ecosystems in and of themselves. The keystone species or species that more than others hold the whole system together is man. He affects the ecosystem in dramatic ways. Implementation of wise agricultural practices is necessary for the good of the adjacent rivers, ponds, and fields because farming can produce byproducts that are damaging in any number of ways. Poor agricultural practices have historically led to the deterioration of nearby species as was illustrated in the years of the Dust Bowl, in the development of the Dead Zone in the Gulf of Mexico, and in the slash and burn farming occurring in some rainforests. On a less dramatic scale, farming practices have been implicated for river and ground water pollution. Poor farming procedures can lead to high nitrogen levels, low oxygen levels, pesticide and herbicide contamination, and increase water and soil salinity.

Gaining a knowledge and understanding about the structure and function of soils is fundamental for agricultural awareness. It is the soil that provides the minerals that the plants need. The soil to a greater or lesser degree is able to retain water and nutrients for plant uptake. The soil provides the substrate that bacteria, protists, and fungi need for decomposition of organic inputs that, when decomposed, can be made available to plants.

One of the interesting aspects of the soil has to do with its ability to retain nutrients, also known as the Cation Exchange Capacity (CEC). Soils tend to be negatively charged because of the chemical composition of clay particles and the decomposing organic matter called humus. Together the humus and clay form a colloid. This particular colloid "consist of thin, flat plates, and for their size have a comparatively large surface area. For this reason they are capable of holding enormous quantities of cations. They act as a storehouse of nutrients for plant roots." (NSW Department of Primary Industries 2002). Cations such as ammonium (nitrogen based), calcium, magnesium, sodium, and potassium are positively charged and have an affinity for the negative colloid. The significance of these cations is that they are often the limiting nutrients in the soil ecosystem. As a result, those soils that have greater negative charges also tend to be more productive because they are able to hold vital nutrients where as soils that have a lesser CEC tend to allow cations to leach below the level of availability for the roots.

Another aspect of soils is the succession of changes that they undergo with increasing depth. Soils at the surface have a lot of interaction with the environment.

This is often referred to as the O-Horizon. This layer of soil is the direct recipient of organic inputs. This layer also is the host of the microbial and macro-invertebrate community that benefits from the carbon and nitrogen-rich inputs. It is alive with activity, especially decomposition. Another aspect of the O-horizon is that it is aerobic. Its aerobic nature has tremendous implications for the rates of respiration and decomposition that can be achieved. The O-horizon is the most biologically active and the presence of the microbes along with the degraded organics tend to give this aspect of the soil its dark color.

The subsequent layers have various characteristics that result from the obliterated parent rock and the diverse environmental factors interacting with them. The sequence of horizons that follow the O horizon include the A, E, B, C, and R horizons. Each of these naturally occurs as a result of the ongoing biological, chemical, and geological processes. The A horizon is immediately underneath the O horizon and is dark because of all of the organics that are being decomposed. Farmers want to maximize these O and A horizons because this is where the majority of the plant nutrients become available for root uptake. The E horizon, below the A horizon, is a light band that results from the acidic leaching of iron and other minerals from the soil particles. The B horizon is next and is a zone of accumulation in which the leached iron, etc. get deposited. Finally the C and R horizons include the broken bed rock known as rigolith and the natural underlying bedrock itself.

Another major principle that is taught in this unit is the symbiotic relationships among organisms that comprise the communities in ecosystems. The organisms of ecosystems often and almost inevitably interact in one way or another. Informed farmers will use their awareness of these relationships in beneficial ways.

Cows and their resident ruminant populations of microbes are an example of a symbiotic relationship called mutualism that is relevant for farmers. Cows derive nutrition from the food that they eat even though they do not produce the cellulase enzyme required to break down plant cell walls. They are able to do this because the microbes in their stomach do the work of breaking the cellulose down for them. It is interesting to note that the population of bovine microbes that are in greatest abundance is dependent on the type of feed provided. The microbial climax community in the cow is changed as the nutritional basis of the diet changes. This transition period is difficult for the cow because its digestive abilities are greatly reduced as the bacteria colonies that had been in greatest number die back because of their inability to digest the new food source. The other bacterial species present in the gut vie for prominence under the new food source. Farmers experience this when they suddenly change the diet of their cows. For a time the cows can have diarrhea, are lethargic, and don't eat well. After a couple of weeks the microbial populations in the cow will have stabilized with a different climax community and the cow will again derive maximum nutritional benefits from the new feed source.

The relationship between soil bacteria and the crop plant is another example of symbiotic mutualism. Some bacteria release nutrients from organic matter and make it available for the crops. Other bacteria may reside in a nodule of the crop roots and through nitrogen fixation supply the crop with the nitrogen that it needs.

Recently, there has been a growing demand among consumers for food products that are free from pesticides, herbicides, and genetically altered ingredients. The demand has resulted in the supply of organically grown foods. The concept of organic foods is also taught in the unit. Certified organic foods have to meet various requirements. These include being raised on land that has not had applications of synthetic biocides over the past 3 years, no growth or other hormone injections, and no exposure to transgenic nutrition. Stated positively, certified organic farmers raise crops that are "as natural as possible" with the aim of utilizing ecological processes that promote plant nutrition and yet are ecologically friendly as well. Organic farmers have a high regard for the microbial life in the soil since they know that the microbes contribute greatly to plant nutrition. Microbes break down rocks and in doing so increase nutrient and mineral availability for the crops. They also break down organic inputs, releasing various molecules, especially $CO_2$, that the plants can take up. In addition use of genetically engineered materials and radiated materials is prohibited. Also weed suppression has to be limited to physical, mechanical, and biological controls. The biological controls get interesting and can include ingenious ideas such as use of cover crops, refuge strips, and integrated pest management. In this way organic farmers use techniques that maximize the soil ecosystems fertility for the long term, often times foregoing short term gains.

Integrated pest management (IPM) is another component of this unit. IPM is yet another smart application of ecological principles to the discipline of agriculture. In IPM the farmer tries to enhance crops and reduce crop pests (insects and weeds) using natural defenses and pesticides only at strategic times. Rather than running the risk of contaminating the soil and ground water with excessive fertilizers, herbicides, fungicides, and pesticides, the organic farmer will use naturally occurring symbiotic relationships to either deter or promote growth of targeted species. In IPM the application of biocides is accepted but is to be used in intelligent ways. When spraying for insects, for example, one should spray only at the appropriate times. Entomologists know with a high degree of certainty when insects of various species will hatch and as a result be especially vulnerable to pesticides. This can be determined by counting the degree days (the number of days in which the temperature exceeds a specific threshold.) The idea is that temperature controls the developmental rate of some insects. Pesticides should be applied after x-number of degree days because this is when the insects are most vulnerable to the lethal action of the chemical.

Genetically modified organisms (GMOs) are increasingly prevalent in today's society. These are livestock and crops that have been enhanced by the introduction of genes that are not a natural component of the species' gene pool. There are a number of methods that can be used to incorporate these genes but these were not discussed in the unit. Instead the discussion was limited to the objectives of developing GMOs. Some of which include leaner beef, larger fruit, tastier foods, heartier root stocks, faster maturation, insect resistance, cold tolerance, and lengthened shelf-life. In addition the fears that some have about the unforeseen affects of GMO are discussed.

Finally, the human population explosion was related to the green revolution that began in the mid to late 1700's. All populations can grow exponentially in the presence of an ample food supply and in the absence of predation and disease. Humans recently have undergone exponential growth with the advent of scientific understanding. Suddenly humans were able to grow crops and be relatively free of disease. One of the interesting aspects of implementation of new technologies involves the demographic transition. This is a transition that countries undergo in which the number of elderly individuals increase rapidly relative to the number of young in a population. They do so because medical and sanitary improvements make it possible for large percentages of the population to survive into their elderly years. Although the number of elderly in a population are increasing, the number of births tend to decrease. Women of child-baring years in affluent countries tend to chose to avoid pregnancy. The long-term result of this population shift or demographic transition is roughly equal numbers of elderly and young in the population. Consequently, social programs like Social Security and Medicare suffer from an imbalance of those who are contributing to those who are benefiting.

**Teaching Strategies and Review of Pedagogical Literature**

This unit is an amalgamation of several learning theories. The majority of the content of the unit was delivered using classroom lecture. My preferred lecture style involves standing in front of class with an organized and logical sequence of thoughts that I present to the students in an efficient, yet light-hearted way. Students are required to take notes but are also encouraged to ask questions and interact with me. Lecture content is interspersed with anticipatory questions that apply the content just mentioned to the material coming next. An example question during a ecological succession lecture might be, "So, what kinds of factors would you suppose would speed up the rate of succession?" During a symbiosis lecture I might ask these two questions, "Now, how in the world would a wildebeest benefit from an ox pecker? How about another way?" Lecture sessions are invaluable to me for three reasons. First, material can be efficiently imparted to the students. Times for lecture are especially important for content delivery when one's unit has many labs and activities that will require significant blocks of time. Second I can get a feel for how well individuals, especially those with learning problems, are comprehending the material. Finally, it gives me good opportunities to interact with the students and demonstrate how an understanding of science is exciting and relevant.

My lectures are reinforced in two ways. First I try to give pop-quizzes nearly every week. These keep the students reviewing the lecture content and motive students to pay attention. Second, students concentrate during lectures because those who do poorly on tests have to complete a semi-comprehensive outline of the next chapter.

Although lecture is a very efficient method for content delivery and effective when executed properly, it is said to be of limited for long-term retention and hands-on experience so other pedagogical methods were also employed. Darling-Hammond (1997) says it well in an article entitled *Using standards and assessments to support student learning*.

> "Teachers in these [successful] schools offer students challenging, interesting activities and rich materials for learning that foster thinking, creativity, and production. They make available a variety of pathways to learning that accommodate different intelligences and learning styles, they allow students to make choices and contribute to some of their learning experiences, and they use methods that engage students in hands-on learning. Their instruction focuses on reasoning and problem solving."

In addition to classroom lecture, another learning theory or philosophy that was regularly implemented is that of Constructivism. Constructivist thinking has two outstanding contributors who were none other than the likes of Jean Piaget and John Dewey. Their ideas that constructing new meaning requires activity and manipulation of the subject matter, as well as reconciling new information with previous knowledge, form the backbone of this philosophy. Constructivism states that the prior knowledge that students take into the classroom dramatically affects the students' ability to understand and remember new information. "The amount of learning that occurs in the Science classroom, and indeed in any classroom (constructivist learning theory applies to all learning), is largely determined by the pre-knowledge that students bring with them to the lesson. It is the students' prior knowledge that influences what new or modified knowledge they will construct as a result of their learning experiences in the classroom." (Sewell,2002) It also emphasizes that personal contact with the subject matter is important in constructing new knowledge. Hsiao (2005) of the University of Texas says that "knowledge is not a fixed object, it is constructed by an individual through her own experience of that object. Constructivist approach to learning emphasizes authentic, challenging projects that include students, teachers and experts in the learning community." As Colburn (2000) explains, the real goal of Constructivism and all education "involves trying to help students change their beliefs to be more in line with those held by the scientific community. Teaching is about helping students understand how and why scientifically accepted explanations explain and predict what will happen in a given situation better than their intuitive ideas." When students have this level of comprehension, so that they begin to have predictive capabilities, then real education has occurred and the educational endeavor has been successful.

Another educational theory that was used in the unit is that of collaborative learning, also known as cooperative learning. The essence of this theory is aptly expressed by Barbara Davis (1993) in her book, *Tools for Teaching* when she says that, "Researchers report that, regardless of the subject matter, students working in small groups tend to learn more of what is taught and retain it longer than when the same content is presented in other instructional formats." Notice that she says that students actively working in small groups is effective. This is not the same as students doing group work. These are involved students. They have a common task that causes them to discuss the topic. They quite likely have a reward or incentive for doing their work efficiently, yet accurately. In my classroom students also are educating each other because their individual grade is based on the performance of one of the member's performance on the comprehension quiz. Sandra Pratt (2003) emphasizes this when she says to make students "feel pressure to teach one another. Give them incentives if everybody is above a certain grade level or group quizzes." This causes the group to want to educate one another but also gives a feeling of responsibility to each member. In addition, these groups are carefully put together. Students do not have the liberty to quickly jump in with their friends but instead they were prearranged based on the abilities and intelligences of each individual. The groups were composed in a way that the spatial, the verbal, the body-kinesthetic, the interpersonal, the reflective, and the logical people got mixed in ways that resulted in many intelligences being represented in each group.

The benefits of implementing an amount of cooperative learning in my unit are manifold. First it demands student involvement. They can not be thinking about the ballgame yesterday or this weekend's date when fellow group members ask them specific questions. Second they are motivated to learn so that their low grade does not affect the rest of the group too badly. Third they are teaching one another and the act of teaching something is a very effective in memory. Fourth the group is apt to ask questions more quickly than the individual. This is true because they don't have to be heard by the whole student body. Also within the context of conversation they find that others' understanding of concepts in slightly different their own. Fifth, the act of discussing gives such thorough exposure that the concept is remembered and fits in with their prior knowledge in logical ways. Thomas Lord (2001) says it extremely well while promoting cooperative learning in an article in *The American Biology Teacher*. He says that

> "As they discuss biology with their team members, students make adaptations in their understanding of the subject matter. In other words, by attempting to explain what one knows about a topic to someone else, or while trying to understand what is being explained by a colleague, students test the fit of their knowledge of the subject matter. When information being discussed does not match a student's understanding, he or she will attempt to resolve the conflict in his or her mind. When misconceptions are corrected in this way, lasting understanding of the material will result."

Another learning theory in this ecology unit is inquiry-based learning. In this theory students are "exposed to various problems, questions, or tasks that allow them to discover intended course concepts or material."(Hammer, 1997) The supposition is that students have the background information and abilities to be able to discover scientific meaning by experiments, projects, and research that they do to solve some kind of problem or complete a task. "Inquiry-based learning has been praised for requiring the student to do more than just report on a topic. The student must go beyond the simple memorization of facts and regurgitation of information and into the realm of creating new and deeper understanding through identification and subsequent application of solutions to a specific topic" (Owens, Hester, & Teale, 2002).

I agree with Karen Phillips (2002) when she says that it demands a good background understanding to really get involved in good projects. "In actual classroom practice, student participation in science inquiry that approaches the inquiry of practicing scientists requires that they understand the background information which will enable them to make sense out of the activity. Explorations provide students with both the relevant background information about the phenomenon and experience with the experimental apparatus."

One final pedagogical approach that is used in the unit is problem-based learning. Kendler (2004) says that "Problem-based learning (PBL) is a pedagogical approach to learning that involves presentation of a curriculum-related problem or situation whose solution requires students to practice skills of analysis, integration, and application." The premise is that wisdom can hardly be gained by just communicating information to students. Teachers must get them involved by case studies and applications. "The story of a good case study should be based upon real events, have engaging characters, include dialogue, be short, and have relevance to the students' lives. And it should be a "dilemma case," which means it involves decisions that must be made by the characters and students. Ideally we want a case that engages students in the same way that a detective story does." (Herreid, 2005) Also, as Stanley, Smith, Benne, and Anderson (1956) suggested:

> "In devising and developing teaching methods, the teacher will find a major opportunity not only to assist his pupils to become intelligent, self-directing personalities but also to contribute to the contemporary task of social reintegration...teaching methods must incorporate the values inherent in both the scientific method and the democratic point of view...it is not enough that the teacher be skilled in effective and valid methods of solving problems cooperatively. He must find ways of building this skill into the minds and characters of the pupils."

Shinn and Cheek, (1981) in *The Journal of the American Association of Teacher Educators in Agriculture* also emphasize the importance of bringing classroom theory to practice by asking kids to solve problems. They state that "agricultural education must be able to synthesize technical agriculture information and plan programs to help solve the problems associated with energy, productivity, and world trends in the agricultural industry".

**Status of the Agricultural Industry of Michigan in 2004**

Being cognizant of the agricultural heritage of Michigan is important but so also is a comprehension of the prominence of agriculture in our state. The web site http://www.agclassroom.org/kids/stats/michigan.pdf of the Farm Bureau of Michigan has the following statistics under the heading, "A Look at Michigan Agriculture." A printout of the pdf paper can also be found as Appendix A.

- About 1,000,000 Michigan residents are employed in production agriculture and food processing.
- Over 53,000 farms in Michigan produce over $60 billion in commodities each year in annual gross farm sales.
- The export value of Michigan products in 2004 was $919,000,000. The top five exports included: soybeans, feed and grain products, vegetables, fruits, wheat and dairy products.
- Michigan is the national leader in the production of tart cherries growing 149 million pounds in 2004.
- In 2004, 2.2 million acres of Michigan were used for the production of corn.
- Soybeans are the state's 2nd leading crop at 2 million acres.
- Michigan ranks 3rd in the nation in apple production with over 840 million bushels produced in 2003. The estimated farm-level value was $81.6 million.
- Michigan is the top producer of cucumbers grown for pickles, 2nd for celery and carrots and 3rd in asparagus production.
- Over 853,430 tons of fresh market and processing vegetables were grown in Michigan in 2004. The state ranks 8th in fresh market and 5th in processed vegetable production nationally.

- About 307,000 dairy cows produced 6.3 billion pounds of milk in 2004. This ranks Michigan 8th nationally in annual milk production.

- There were over 1,000,000 head of cattle in the state of Michigan January 1, 2005 with an estimated value of $901 million.

- Michigan has many microclimates which support the growth of more than 200 food and fiber products. This makes Michigan the 2nd most diverse agricultural state in the nation.

# IMPLEMENTATION

*Incorporating an Agricultural Emphasis in Ecological Education* was designed to be the very first unit of the Biology course. The unit included everything that I present under the heading of Ecology. Table 2 shows what actually happened on each day of the unit. All of the activities in italics are either new or incorporated new aspects that were developed during my research time at Michigan State University. Following the table is a day by day discussion of the activities that occurred in my classroom while the unit was implemented. Table 2 displays the day by day activities of all 8 weeks.

| * *Activities in Italics are either entirely new or have new parts.* | | |
|---|---|---|
| | Date | Activities |
| | 9-9-2005 | Lecture: Introduction of the Unit<br>*Lab: Begin Rhizobium Lab*<br>*The pretest was Administered* |
| Week 1: | 9-12-05 | *Lab: Begin Microbial Decay Lab*<br>*Lab: Begin Seed Germination Lab* |
| | 9-13-05 | Quiz on Ch. 3-1<br>Lecture: God is Obvious in the biological world<br>*Add 10 ml. of fertilizer to plants* |
| | 9-14-05 | Lecture: God, Man, and Creation<br>*Agricultural Survey*<br>*Add 10 ml. of fertilizer to plants* |
| | 9-15-05 | Memory Work: Belgic Confession Article 2<br>*Lecture: Importance of Understanding Ecology* |

| | | |
|---|---|---|
| | 9-16-05 | Lab: How to use a Compound Microscope |
| Week 2: | 9-19-05 | Price of Ignorance power point<br>*Lab: Restart Rhizobium Lab (too wet, no germination, fungal growth)* |
| | 9-20-05 | Price of Ignorance ppt continued<br>Lecture: Levels of Ecological Organization |
| | 9-21-05 | *Lecture: Levels of Science Organization, Ecosystem Sizes*<br>Biome Poster Project was explained and assigned |
| | 9-22-05 | Ch. 3 Term Quiz<br>*Lab: Bacteria Abundance in Soil Lab* |
| | 9-23-05 | *Lecture: Average and Microecosystems: Aggregates*<br>*Aggregates and Soil Management Lab* |
| Week 3: | 9-26-05 | *Aggregates and Soil Management Lab*<br>*Lecture: Energy Flows* |
| | 9-27-05 | Lecture: Ecosystem Pyramids<br>Class time to work on ecosystem posters |
| | 9-28-05 | Lecture: Nutrient Cycles, Crop Rotation |
| | 9-29-05 | Lecture: Net Primary Production, *Nutrient Limitation*, Review for Test on Chapter 3 |
| | 9-30-05 | Test on Chapter 3 – The Biosphere |
| Week 4: | 10-03-05 | Give Test Back<br>Begin Wolves Video – Populations |

| | | |
|---|---|---|
| | 10-04-05 | Wolves Video Continued |
| | 10-05-05 | *Lecture: Abiotic Factors* |
| | 10-06-05 | *Lecture: Abiotic Factors continued*<br>Niche |
| | 10-07-05 | Rainforest Video – I'm in Pigeon River with Adv. Bio |
| Week 5: | 10-10-05 | *Lab: Cation Exchange Capacity – Electrical Conductivity* |
| | 10-11-05 | *Lab: Cation Exchange Capacity - Dye in Soils* |
| | 10-12-05 | *Lab: Cation Exchange Capacity – Dye in Soils Cont.* |
| | 10-13-05 | Video: Symbiosis |
| | 10-14-05 | Video: Symbiosis cont. |
| Week 6: | 10-17-05 | Lecture: Succession Power Point |
| | 10-18-05 | Review for the Test |
| | 10-19-05 | Ch. 4 Test – Ecosystems |
| | 10-20-05 | No School: Teachers' Convention |
| | 10-21-05 | No School: Teachers' Convention |
| Week 7: | 10-25-05 | Go over Test<br>Video: Little Creatures Who Rule the World |
| | 10-26-05 | Video: Little Creatures Who Rule the World<br>Lecture: Logistic Growth Curves |
| | 10-27-05 | Lecture: DNR, Population Growth Strategies, Density Dependent and Independent Variables |
| | 10-28-05 | Parent Teacher Conferences – ½ Day, No Class |

| | | |
|---|---|---|
| | 10-29-05 | *Lab: Population Density of Worms in Different Soils* |
| Week 8: | 10-31-05 | *Lab: Respirometer Lab* |
| | 11-1-05 | *Lab: Respirometer Lab cont. adjustments* |
| | 11-2-05 | *Lab: Respirometer Lab cont.* |
| | 11-3-05 | *Lecture: Organic Foods* |
| | 11-4-05 | Lab Reports Due<br>*Lecture: Worms* |
| Week 9: | 11-7-05 | Ch. 5 Test – Populations |

Table 2. Basic Schedule of Unit.

The first days of the unit engaged the students in hands-on activities. Day One of the unit involved a small talk in which I introduced myself and let them know what they were going to study. Next, I tried to show the students how little they know giving the pretest. (Appendix C-1). I hoped that it would motivate them a bit and make them realize that they would be learning a lot over the next few weeks. Although that was a real goal of mine, the test was really designed to determine the extent to which students grasped the content before they had ever been exposed to my planned curriculum. It was to serve as a benchmark of their prior knowledge for the study. The pretest is composed of 10 multiple-choice questions followed by eight short answers. Students did poorly on this test and demonstrated that they had a lot to learn.

Following the pretest students began to set up the first of three labs. These labs included the Rhizobium Lab (Appendix E-1), Microbial Decay Lab (Appendix E-9), and Seed Germination Lab (Appendix E-10). It was necessary to get these labs going because they were all long-term labs. I knew that each one was going to take several weeks before observable results would be obtained. These first labs are good ones to begin with because they each allow students to choose exactly what they would like to do. They represent Inquiry-Based pedagogy because students have opportunity to tune the labs to their own interests and the results that are obtained at the end are instructive to the students. Rhizobium Symbiosis is the first lab engaging the class. This lab is designed to demonstrate symbiosis, show the students tangible differences in plants based on abiotic environmental variables, and illustrate some aspects of the nitrogen cycle. I developed this lab at MSU over the 2005 research summer under the close supervision of Dr. Ken Nadler. Soybeans are legumes that have a mutualistic relationship with Rhizobium bacteria. The bacteria do not merely dwell in the soil near the plant but instead inhabit the plant roots themselves, in pockets called nodules. In addition, it has been determined that those plants that need Nitrogen supplementation actually release a pheromone that attracts and promotes Rhizobium proliferation. In this way those plants that are nitrogen deficient are able to recruit bacteria that will provide them with it. To demonstrate this, students planted and grew soybeans in soils that were fertilized differently. Some of the soybeans were planted in soil that was fertilized only with potassium and phosphorus while other plants were given

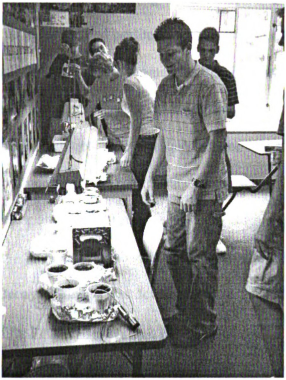


Figure 2. Controlled Soybean Experiments

nitrogen, potassium, and phosphorus. Over the next several days the students were responsible for maintaining their plants. They were asked to fertilize and water their soybeans and keep track of their work and a lab notebook. After 10 days I determined that the Lab was going to be a failure because there was very little germination, evidence of fungal growth on the soil surface, and all of the soils were just too wet. As a result, on Monday of the following week we replanted and restarted the lab. On the second try for this lab we added perlite to make the soil less dense and allow more airflow. You could call this a teachable moment as they learned about even more abiotic factors of the soil and the nature of properly caring for plants. The results this time were a little bit better in that we did get some seed germination and some plants started to grow. Unfortunately root nodules were never found because the plants never grew more than six inches as a result of poor lighting.

A second lab was started on the following Monday. This lab is called Microbial Decay. This lab was developed from the *Soil Science Education Homepage* (http://soil.gsfc.nasa.gov/) on the internet. In this lab a number of leaves are gathered and placed in different bags with different types of soil. The soils differ in that some of them come from a field, others from a forest, others from the soccer field, and others at those same locations but at different depths. In the lab, after the soils are collected and placed in bags with the leaves, they are placed in a darkened

Figure 3. Leaves Decaying in Soil Bags

environment for approximately four weeks. The students only very occasionally took them out to add a little bit of water for the bacteria, molds, and fungus that were doing the decomposing. The theory that is being reinforced in this lab is that soil organisms are vital to agricultural success. Those soils which contained the most bacteria will cause the leaves to decompose the fastest. The decay of organic material is a basic tenant of agriculture today. Maintaining a healthy microbial population in the soil contributes greatly to developing healthy crops. In fact many farmers actively spread compost on their fields to take advantage of this principle. Without the soil microorganisms decomposing the compost into usable molecules the effort would be in vain.

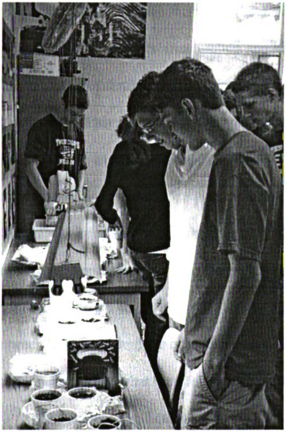


Figure 4. Seed Germination Lab

This lab turned out well. At the end of the six weeks students were able to see a clear difference in the rates of decomposition. Some of the leaves were almost completely broken down while other leaves were almost completely intact. This lab was a new lab that I had never done with a class before. I liked the results and planned to do it again in years to come. This lab demonstrates an inquiry-based approach to teaching. I did not suggest to the students that one type of soil or one depth of soil would have more microbes than another. Instead they were to determine microbial location based on the results of the exercise.

On day two the students also started a seed germination lab. This lab can be found at (http://www.biology.duke.edu/cibl/exercises/seed_germination.doc) which is part of Duke University's Biology department website. The actual lab which is an adopted version of Duke Universities' is Appendix E-10. This lab is intended to demonstrate to the teacher whether students are able to follow the scientific method. In many ways this lab is open-ended. The students are to design the lab and follow-through on it in the weeks that follow. Students grow different plants in two different environments. One is the control and the other has the dependent variable. The variables are subject to the students' imagination and can range from amounts of sunlight, to different types of fertilizer, to testing colors of light, and even the effects of electricity on plant growth. This is the first lab for which students are supposed to write up a detailed lab report, with an introduction, materials and methods, results, and finally a conclusions and discussion.

Days three and four of the unit involved watering their plants but also I officially began to deliver lecture content. Because Covenant Christian High School is a Christian high school I try to began each year by explaining what I believe is the relationship between God, man, and the creation. In addition, on day four I surveyed the students to get an indication of what they felt about agriculture.

The student agricultural survey is Appendix D. In the survey I try to determine the extent to which students plan on working with the soil of their future homes. I asked them if they planned on gardening in the future, and if they would give some thought to working with the ground under their grass in order to maintain a good and healthy lawn. In addition I try to assess the students' attitudes toward pouring oil into the ground, the use of golf course fertilizers, the production of organic foods, and the presence of earthworms in the soil, among other things. Students filled out the survey quite willingly and I believe gave their honest opinions.

Day five of the unit began with a quiz in which they had to write out article two of the Belgic Confession. This article is a confession that most Christians make which states that they believe that God reveals himself not only in his Word, but also in the creation.

In addition to the quiz, I began a lecture entitled, "The Importance of Understanding Ecology." The lecture amounts to a combination of various case studies that show that understanding ecology is important. This lecture is really a PowerPoint® presentation in which I explain to the students the many ways that humans have negatively interfered with various ecosystems. Within the lecture I discuss and point out the faults of Europeans introducing the Nile perch into Lake Victoria, how Salmon populations declined rapidly after the fur traders began to hunt sea otters, also how the Michigan old-growth forests were nearly totally wiped out as Michigan was getting populated, and for an agricultural perspective, how the Dust Bowl developed because of improper farming techniques.

I attempted to make this PowerPoint® to be as visual as possible. There are very few slides that contain notes that students should write down but instead most of the PowerPoint® is pictorial. My goal is for students to retain the information a little bit better because they are receiving the information both auditorilly and visually. This PowerPoint® took 1.5 hours to work through but was spread out over parts of three days.

Day six of the unit involved acquainting students with the compound microscope. This was accomplished with a lab that was taken from the 1991 Prentice Hall Biology *Laboratory Manual* (Appendix E-5) and can be found on pages 37 through 44. The lab teaches students how to determine the magnification at which they are viewing any given object. The lab has the added advantage of being easy to set up and allows students to get good practice at focusing the microscopes at different magnification levels.

Days seven through nine involved briefly finishing the PowerPoint® on the Price of Ignorance, and beginning to lecture about the various levels of ecological organization and ecosystem sizes. In addition, I gave the first long-term assignment which involved students making a poster that depicts the biome of their choice. (Appendix C-3) The goal of this assignment is for students to become familiar with the food webs and food chains of a given ecosystem and identify various members of the different trophic levels. In the poster they are to draw a picture of the ecosystem as one would expect it to be found somewhere in nature. The posters are supposed to give evidence that students can identify organisms as representing standard ecological terms including primary producer, secondary producer, consumer, abiotic factor, biotic factor, herbivore, omnivore, and carnivore.

Day 10 of the ecology unit involved a term quiz on Chapter Three entitled, The Biosphere. I try to incorporate quizzes throughout each marking period so that students are regularly revisiting the vocabulary and committing these to memory well before the test.

In addition to the quiz, I lectured on the importance of a small ecosystem called a soil aggregate. The tiny aggregates or clumps of earth are not only important from an ecological perspective but also from an agricultural perspective. Each aggregate is a harbor of organic material that can be "mined" by the soil bacteria slowly over time. The natural compounds that hold the aggregates together prevent bacteria from accessing them easily. Aggregates act like time-release capsules constantly releasing nutrients for plants.

Figure 5. Sieving out Aggregates

Historically, farmers often did themselves a disservice when they plowed and tilled their land too much. Tilling and plowing break up the aggregates, making the slow and steady release of nutrients more immediate, resulting in future deficiencies. No-till farming is wise not only for erosion control, but also for maintenance of soil aggregates. When most people think of the biotic factors of any given ecosystem, they think of the plants and the animals and totally disregard the most numerous of all organisms, the bacteria. The bacteria and other decomposers are not only numerous but also occupy important niches. Through the lab exercise students realize that there are millions of bacteria in every gram of soil. Farmers must be aware of the bacteria and other decomposers in the soil and even try to enhance them because they break down compost and are an important source of crop nutrition.

Days 11 to 13 involved two labs on aggregates and another lecture on the fact that "energy flows while nutrients cycle." The first lab is entitled *Aggregates and Soil Management Lab* (Appendix E-8.) This is a simple, straight forward lab that I obtained from a Frontiers class at Kellogg's Biological Station. It was lead by Dr. Phil Robertson and was entitled *Carbon Sequestration and Global Warming*. In this lab you simply collect soil samples from several different ecosystems around or near the school. 300 grams of each soil sample are then

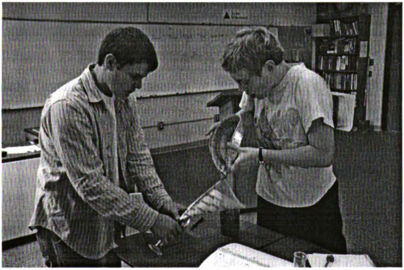


Figure 6. Funneling the Aggregates

weighed out and poured into a sieve. All of the loose soil will have fallen out while that which remains in your sieve is aggregate. These aggregates are weighed. The soils that contain high concentrations of aggregate represent healthy soil. Bacteria in these soils will continue to degrade the aggregates and provide the basic nitrogen, calcium, potassium, and other minerals that the plant roots require. In this lab we tested soils from a farm field, old field, and forest. The old field had much more aggregate than the other locations and incidentally showed to be a healthy soil ecosystem in future labs as well.

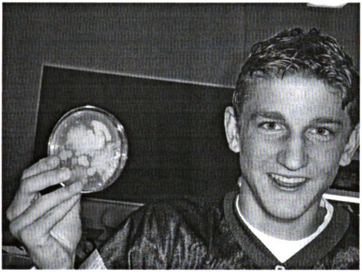


Figure 7. Student Showing Bacteria Colonies

The other lab that we did during days 11-13 was another lab which is new to my Ecology Unit and is entitled *Soil Aggregates and Bacteria Abundance*. (Appendix E-2) It was developed by myself and Dr. Merle Heidemann at MSU over the 2005 research season. My primary goal in this lab is show students just how small ecosystems can be. This lab involves a serial dilution of a soil/water mixture. Students use distilled sterile water to dilute 10 grams

Figure 8. More Bacteria Colonies on Petri Plate

of soil. They dilute all the way down to a 0.0195% solution. After the dilutions students streak agar plates with the contents of the dilutions. These plates are allowed to incubate for 48 hours, allowing the bacteria colonies to grow. The results are impressive for all soil types and at all dilutions. Figure 7 and 8 show how numerous the bacteria samples were even at the highest dilution. It really is a phenomenal demonstration of the quantity of bacteria that exits in healthy soils.

The students had a chance to take a walk out into our school fields when we discuss the idea that energy flows. I usually take them to the soccer field and ask them to all just lay down and relax. My intention was that they all feel the Sun's intensity on their faces. I explained that all of that electromagnetic energy has to go somewhere. Ten percent is taken up by the primary producers while much is re-emitted as infrared radiation and goes into outer space. Next, we found organisms that represent the various trophic levels. In doing so they gain a lot of relevant vocabulary. Next I applied the information to agriculture. I asked how many millions of acres are necessary to feed the cows, pigs, and chickens (primary consumers) that we consume. I point out that if the human population (secondary consumers) would continue to increase, we will have to think seriously about a more vegetarian diet.

Days 14 and 15 included a PowerPoint® lecture on nutrient cycles and nutrient limitation. Each nutrient is introduced separately and in a visual and logical sequence followed through the environment. Unlike energy, nutrients stay around forever. The specific elements that are included are Nitrogen, Carbon, and Phosphorus. In addition to these elements, I also include the water cycle. I remind them that nutrient cycling is very different from energy flowing because energy really flows right through the Earth and out to space. The content of these slides was specifically tied to agriculture. I was sure to remind the students about agriculture during these slides. The growth rate of crop plants are often related to nutrient deficiency. Farmers ensure that the essential elements and minerals are available for proper growth and development of their crops. In addition farmers rotate crops carefully so that the nitrogen-depleting crops like corn are followed by or preceded by a legume such as soybeans that replenish the soils nitrogen content. Students were also reminded that the soil bacteria play a key role in the release of vital nutrients from the aggregates which seem to harbor or sequester them. In addition scientists are becoming increasingly aware that agricultural methods play a large role in carbon sequestering. Soils and their crops can be viewed as a carbon storage units if the soil ecosystem is cared for properly.

On Day 16 students took their first Biology test (Appendix C-5). It covered the contents of Chapter 3 of the Prentice Hall dragonfly Biology book which includes the concepts of biogeochemical cycles, energy flows, food chains, food webs, ecosystem sizes, and net primary production.

Days 17 and 18 were the introduction to community ecology. I began this unit as I do during typical years, with a two day video on the wolves of Yellowstone National Park. Although it is only a 60 minute video it requires two days because when I show videos I expect students to take some notes. I pause the video regularly and explain things or share experiences to ensure understanding. This video shows what happens to a community when it is disrupted. Wolves represented the top predator for many of the food chains in the park. Without the wolf, elk and buffalo populations grow unchecked. Bears and coyotes are no match for the speed of even winter weakened elk and buffalo.

The return of the wolf is benefiting many animals including the foxes as they are no longer suppressed by the coyotes, elk as they are more disease free, and birds of prey because they have more scraps and carcasses to pick over. The park as a whole is in a healthier balance because the keystone species has been returned. During this video students have to take notes and present an outline of the main ideas when it is finished.

Days 19, 20, and 21 involved lectures on the importance of abiotic and biotic factors of the environments as well as a rainforest video. The rainforest video puts both factors together and shows their interrelationships. One aspect of the video that applies to agriculture is the fact that many rainforests are being clear-cut to make room for farming. This practice does not work because the enormous amount of rainfall brings soil nutrients too deep for roots. Good agricultural soils are those that are

Figure 9. Students Work on a Cation Exchange Capacity Lab

Figure 10. Close Up of a CEC set up.

able to retain nutrients despite the prevailing abiotic factors.

The video provides a natural bridge to the discussion of the abiotic factor called Cation Exchange Capacity (CEC) of soils. The CEC is a soil's ability to retain cations because the clay particles and organic matter has a slight negative charge. Many plant nutrients are cations so it is good for soil to have a net negative charge. Days 22-24 were taken up doing two new labs on soil CEC. The first is entitled *Soils as Eletrical Systems* and is Appendix E-3. It was adopted from a lab generated by Dr. John G Graveel. (2004) in a brochure entitled *Demonstrations in Soil Science.* In this lab students mix 60 grams of soil with 500 ml of distilled water. Next they attached wires to the inner beaker wall. After several minutes of electrical flow there was a marked build up of clayey material on the positive wire. This clearly demonstrated to the students that clay is negatively charged. I told them that not only clay but also organic material has a negative charge. These components make soils hold on to the predominantly positive fertilizer molecules. As another example I remind students that farmers used to invite people to drop off clay pots. The farmers would crush these in the field and thereby increase the productivity of the soil.

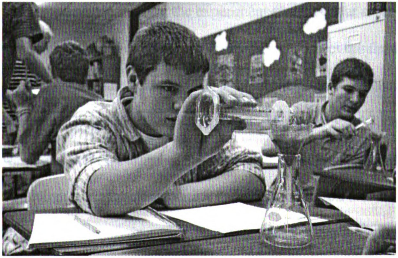


Figure 11. Pouring Eosine Red into the Soil

The other new lab regarding cation exchange capacity is entitled *Chemical Movement in Soils* (Appendix E-4). It was originally developed by Dr. John G. Graveel

(2004) at Purdue by their Agriculture Department. The lab demonstrates that positively charged dyes are sequestered in the soil whereas negative and neutral dyes quite quickly leach through the soil and as a result are not available for plant crop roots. The lab poses the question, "Why does nitrate ($NO_3$) move in soil and ammonium ($NH_4^+$), another form of nitrogen in soil, not move? Let's conduct an experiment using a blue dye (methylene blue) which has a positive charge like ammonium and a reddish-orange dye (eosine red) that has a negative charge like nitrate." The lab involves pouring two different dyes through similar soil samples that are suspended in a funnel. One dye is negatively charged and is colored red while the other dye is positively charged with a blue shade. During the experiment students pour more than 150 ml. of the positively charged dye into just 10ml. of soil and yet the fluid that comes out of the funnel is clear. The soil sequestered all of the positive molecules and pulled them out of the water. By contrast the negative red dye moves through the soil just as readily as the water and is found dripping out of the funnel after pouring only 15 ml of dye into the soil. The lab provides students with a vivid demonstration that the abiotic factor called Cation Exchange Capacity is a very important aspect of the ecosystem. While conducting the lab students discover

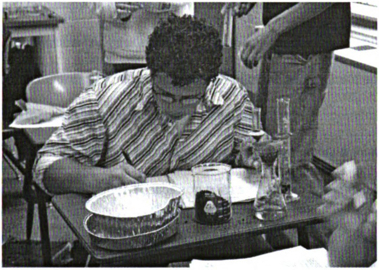


Figure 12. Keeping a Lab Notebook

that negatively charged soil particles are important for retaining the cationic fertilizer particles.

On Days 25 and 26 students watched a video on symbiotic relationships. *Living Together* is part of the popular David Attenborough series entitled, *Trials of Life*. While watching the video students filled out a worksheet in which they identified 25 different relationships as mutualism, commensalism, ammensalism, parasitism, predation, or competition (Appendix C-4). This video breaks the simplistic paradigms that students have regarding how animals dwell together and as such opened the students' eyes to the intricate relationships that actually exist.

On Day 27 I lectured about succession using a PowerPoint® presentation. In the presentation I focus succession with a focus on how it occurs in different ways in different environments. For example, I track the succession of the area around Mt. St. Helens after the 1980 eruption. What's nice about succession at Mt. St. Helens is that parts can be classified as primary and others as secondary succession. Students were guided to understand that succession happens at different rates depending on distance from the seed source, seed mobility, temperature, and precipitation.

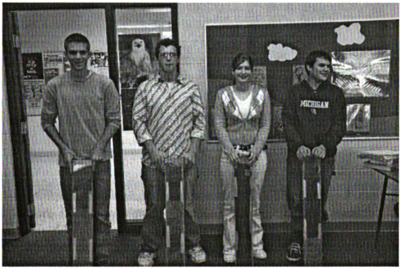


Figure. 13. The Students with Their Soil Horizons

The concept of soil horizons was introduced on Day 28. Soil horizons are evidence that ecology has both biological and geological components. The top layer called the O horizon contains organic material and as such is darker. The organic material decomposes overtime and releases tannic acids which discolor and weather the soil below. Specifically, it strips the iron from those grains and as a result exposes the light colored quartz. This second layer is called the A horizon and is a lighter color. Those weathered portions accumulate below and form a zone of accumulation which is often referred to as the B Horizon. I gave struggling students who were willing to do some work ten points of extra credit for actually digging out these horizons and placing the soil in a representative fashion into four plexi-glass chambers.

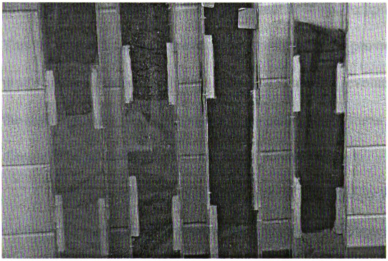


Figure 14. Examples of Soil Horizons that Students Dug

Day 29 of *Incorporating an Agricultural Emphasis in Ecological Education* was spent reviewing for a test on Chapter 4 entitled *Ecosystems and Communities* (Appendix C-6). Review days are structured so that they are enjoyable but educational for the students. Often the rows of desks become teams and I ask questions to all students in the first desks of each row. The student that is able to state the answer first gets to throw two darts at a dart board. I keep a running total of all the rows' scores on the white board. My next question will be directed to all of the students in the second desks of the rows. Students enjoy the opportunity to throw the darts in a high school classroom. Prior to these day students are encouraged to make note cards and during the review they may have their cards out on the desk. In this way they review the ideas in anticipation of a question being asked about that term. On the following day the students took the test.

Days 31 and 32 begin the next unit which focuses on the concept of Populations. I start this unit showing a video on ant populations and how the individuals in the colonies work together. This video is produced by NOVA and is entitled *Little Creatures Who Run The World.* After the video I lectured about population growth curves with an emphasis on human population growth from the 1700's to today. The industrial revolution back in the late 1700's provided tools and equipment that farmers could use. This led to the agricultural revolution which suddenly provided food in abundance for much of the world's population. With the scientific revolution occurring soon afterwards, the human population began an exponential climb as it was suddenly freed from many diseases and had plenty of resources for consumption.

At this time I also gave an assignment entitled *City Planning Project* (Appendix C-9) in which students were asked to redesign Grand Rapids with all of the ideas that they had learned about in mind. It was supposed to be kind of a capstone to everything that they had learned about ecology and was due after the unit was finished. I provided the students with a poster board and with a large map of the Grand Rapids rivers, lakes, and roadways. The students were supposed to start out be recreating the environmental land marks on their posters. These would not change. After this they could totally redesign the expressways and the city zonings. The goal was for students to redesign

Grand Rapids in connection with Governor Jennifer Granholm's Cool City Initiative. These cities are supposed to be socially, economically, environmentally, and agriculturally friendly. I gave them time for some guided brainstorming in which we discussed the good things that Grand Rapids has going for it as well as some problems that we have. From here the individual groups were to think about the ideal ratio of residential, industrial, agricultural and recreational zones. Ultimately, they also needed to defend their designs with a typed report which stated why the made the changes or improvements.

This assignment served as a gauge for me to determine the extent to which students were becoming agriculturally conscious. I was eager to find how much of the land area they would zone as agriculture. Would they give agriculture preferential placement on the maps or would it be an afterthought and simply placed wherever the other zones not yet filled? What percentage of the land area would students dedicate to such an important aspect of our society? The results were going to be quite revealing about students' attitudes about the importance of agriculture.

Day 33 was spent discussing the DNR and how they try to manipulate density dependent and density independent variables to control communities of organisms in healthy balances.

On Days 34 through 37 were again focused on lab activities. First, we did an earthworm population density count (Appendix E-6). After discussing the benefits of earthworms for the soil ecosystem we went out to the field to discover which ecosystem seemed to be the most healthy based on earthworm counts. Conducting this lab requires students to dig a 1.5 foot deep by 1 meter diameter hole in three different environments.

We chose an old field that only gets cut about twice a year, a spot in a wooded area, and a second place in the grassy field right off the school parking lot pavement. The students tossed all of the soil from their holes onto tarps that I provided for them. Next they sifted through the dirt and gathered the earthworms. Overall, students jumped right into this activity. I did give them extra credit incentive for the group that found the greatest number of worms. The results of the lab were that the field environments had most earthworms while the forest had substantially less. 29 worms were recorded in the forest while the field near the parking lot had 43 and the old field yielded 89 worms.

Figure 15. Digging for Earthworms in the Forest.

The second lab was called *Soil Type and Biological Activity Lab* (Appendix E-7). In this lab we measured the amounts of bacteria in different soils by measuring their respiration rate in a respirometer. The idea for this lab can be found on http://www.ekcsk12.org/science/aplabreview/cricketrespirationlab.htm. A respirometer is a contraption that measures the rate at which an organism breathes. This can be measured by sealing a test tube with the organism inside. The respiration rate is observed as a fluid is taken up into a micropipette.

We did this lab, not with a cricket or ants, but with soil. The bacteria in the soil respired in the apparatus over a period of 24 hours, causing a loss of air volume, and as a result the dye moved up the graduated pipettes. This is instructive for agriculture because with this lab one can determine which soils are most productive. The soils that have a good quantity of nutrients will also have a higher percentage of bacteria that are feeding on the nutrients. We tested several soils and they all showed signs of bacteria presence. Each group had a soil and most groups got observable results. Unfortunately, the school is not equipped with enough finely calibrated small pipettes to definitively state that one soil is more productive than another. In addition creating the perfect air tight apparatus turned out to be more difficult that I had anticipated based on my time spent at MSU with MSU's equipment. I'm very interested in doing this lab again next year to see if more groups can't get comparable results.

Figure 16. A Working Respirometer

Days 38 to 40 concluded the eight weeks that the unit took to complete. We discussed the move toward producing and consuming organic foods and the requirements for classification as organic. This lecture was followed by a review day and finally the last test of the unit. This test covered the ideas in Chapter 5, entitled Populations (Appendix C-7). Following the test students once again expressed their opinions on the same agricultural survey that I gave at the beginning of the unit. I delayed giving the posttest for a few days to prevent test lethargy. I wanted students to perform at a high level as it was to be my preeminent benchmark for the effectiveness of the unit.

## Analysis of Pretest and Posttest Scores

From a strictly objective point of view I was very encouraged by the results of the unit. Specifically, the students did well and worked hard through the unit and their hard work paid off as is evidenced by the following data. Students clearly showed that they gained in their knowledge and understanding of the field of ecology. Figure 17 shows the improvement that the students made from their pretests that they took before the unit was

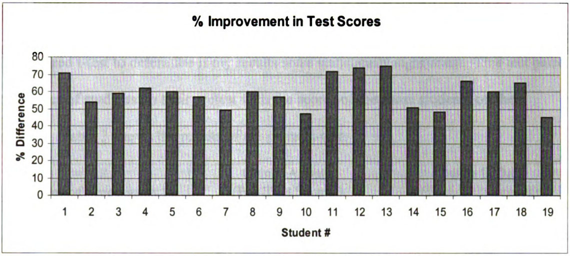



Figure 17. Percent Improvement in Test Scores

taught compared to their posttests after the unit was completed. On average students performed 59.6 percentage points better on their posttests. The actual scores for each student is shown in Figure 18. The average pretest grade was 28.5% while the average posttest grade was 88.1%.

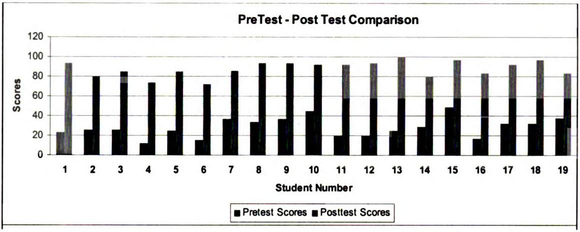



Figure 18. Pretest and Posttest Comparison

I did paired t-test to determine if my results were statistically significant. This test paired the scores of students on their pretest with the scores of the same students on their posttest. Table 3 shows the results of the paired t-test.

| t= -28.1<br>Degrees of Freedom = 18 | Group A Data<br>(Pre-Test Scores) | Group B Data<br>(Post-Test Scores) |
|---|---|---|
| # of Items | 19 | 19 |
| Mean | 28.5 | 88.1 |
| 95% Confidence interval for Mean: | 23.73 -33.32 | 84.25 – 91.96 |
| Standard Deviation | 9.95 | 7.99 |
| Hi Score | 49 | 100 |
| Low Score | 12 | 72 |
| Median | 26 | 92 |
| Average Absolute Deviation from Median | 7.89 | 6.63 |

Table 3. Paired t-test Results

Note that the t value is 28.1. When I matched the degree of freedom (18) with the p value of .01 (for highly statistically significant) on the student's t-distribution table I came up with a t-value of 2.55238

The pretest and posttest results were further analyzed by checking how many points were earned on each of the short answer questions. Because each short answer is worth four points and I have 19 students, all together the whole class on any one questions could earn 76 points on their cumulative test grades. Figure 19 shows that

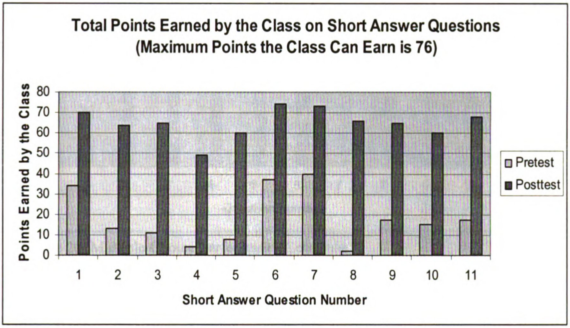



Figure 19. Total Points Earned on Each Short Answer Questions

there were some questions, especially four and eight, which students performed very poorly on at the beginning of the unit. Question four was especially difficult because the students had never been exposed to agricultural jargon. This questions asks, "What does CEC stand for and why is it important for the soil?" Questions eight on the other hand disappointed me. It asks, "What does it mean that a farm is organic?" I did not realize that my students, before the unit, were so ignorant about the nature of organic farming. Some of the responses on the pretest included these:

* Organic farming is farming done not in soil but in water.
* It grows foreign foods.
* Its watered every day and is a special farm.
* That the farm is not an animal farm but a vegetable farm.

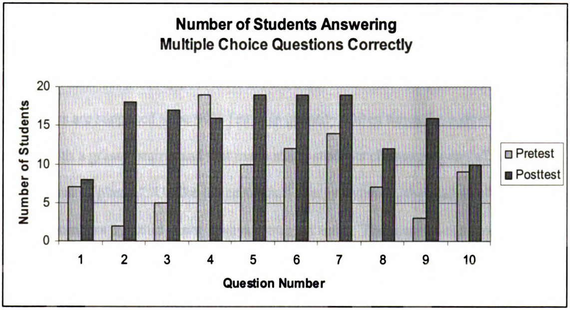



Figure 20. Multiple Choice Performance Comparison

I analyzed the multiple choice portion of the test just as I did the short answer section. Because the nature of multiple choice questions is that one either gets full credit or no credit, I graphed the number of students correctly answering each question rather that counting the total points earned.

An interesting result on the multiple choice section is that although no one had made an error on question four of the pretest, on the post test three people chose a wrong answer. The questions asks, "The stimulus of the green revolution is really rooted in the: a. Scientific Revolution b. French Revolution c. Protestant Reformation

d. Invention of the printing press." The correct answer is that the scientific revolution stimulated the green revolution. Students who got this question wrong must have been really guessing because they choose all different answers. Question one also had poor responses. This questions asks, "In terms of numbers, most life in an ecosystem exists in a. the form of plants b. the primary consumers c. the soils d. the trees." Eleven of my 19 students got that question wrong on the posttest while 12 did on the pretest.

I believe that the students got confused by the ecological numbers pyramid. In this pyramid the primary producers are the most numerous while primary consumers are supposed to be 90% fewer in quantity. Often times the pyramid is shown with a grassy prairie and that made many students choose answer "a" which is "the form of plants." Unlike the ecological energy pyramid, the students forgot that the numbers pyramid is not always a true pyramid. There are exceptions to the rule such as when many small parasites live in one host's body. I think that I over emphasized the idea that there must be more producers than consumers when we spent time on this in the little field trip that we took to lay out on the school lawn and find examples of producers and consumers.

Questions 2 and 9 showed the greatest improvement in test scores. These questions asked students to name the soil layers and asked students to identify where cows get nutrients. These were simply factual, content oriented questions and as I mentioned earlier, the students did well on these. One particularly disheartening question of the survey asked whether they would garden in the future. There were very few who changed their minds. Hopefully they will yet grow to enjoy developing a garden in the future.

**Analysis of Survey Results**

I found the survey (Appendix D) to be a valuable tool for determining how well I taught various aspects of the unit. The questions that had to do with content showed that the students clearly learned the material that I wanted to teach. Unfortunately, evidence that they gained an appreciation for agriculture and a desire to use their new knowledge in the future especially by way of maintaining a garden was clearly lacking. Basically, I

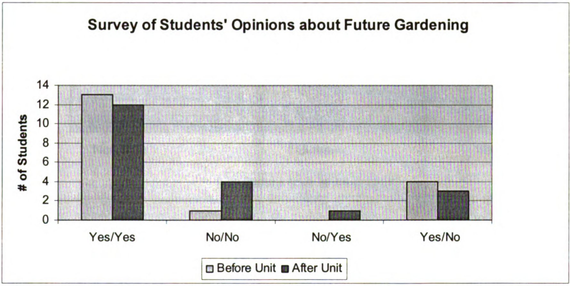



Figure 21. Response to Future Gardening Expectations

was able to teach the content but not pass on enough appreciation for the material to make them change the way that they act. Hopefully, further maturing and the business of the work-a-day world will drive them to enjoy keeping a future lawn or garden.

On the other hand, it seems that the unit developed enough knowledge to make many students decide that developing the soil of their lawn would be a worthwhile activity in the future (Figure 21). Before I taught the unit only four of the nineteen students thought that they would put some work into developing the soil of their lawns rather than just simply throwing fertilizer on the grass. After the unit was finished the numbers change dramatically so that now 12 of the 19 felt that they would work on ensuring the health of the soil of their future lawns.

Question 4a. asked how the students felt about soil science. On a scale of one to

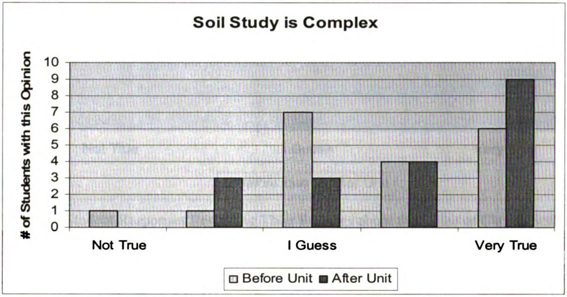



Figure 22. Survey if the Study of Soil is Complex

five the students were to rate how difficult soil science is as a discipline. Before the unit students felt that it was moderately difficult with students rating it at an average of 3.7 (Figure 22). But after the unit was finished students realize just how much there is to know about soil science and now most students where rating the level of content and difficulty at four.

The survey clearly showed that students learned the content well. One particular question asked about the value of clay in soil. Before instruction students overall had a neutral to negative view of the role of clay in the soil. Following the unit all 19 students suggested that clay is an extremely valuable complement of the soil. This showed to be a radical shift in the students thinking and that they clearly were convinced that clay is a good and an important part of soil ecology

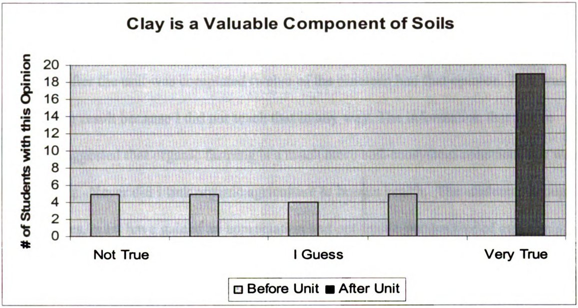



Figure 23. Student Responses Regarding Their Feelings about the Value of Clay in Soil.

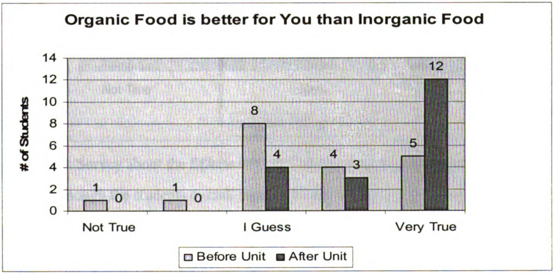



Figure 24. Student Responses to Survey about Organic Foods

The survey showed that students also changed their minds with regard to organic and inorganic foods. Question 4e asked the student to rate on a scale of 1-5 the extent to which they felt that organically grown foods are better for their health than inorganic. Before the unit many of them were at least skeptical about the value of organic foods. Only five of the nineteen suggested that organic foods were definitely better for their health. After the unit was completed twelve of the nineteen had that opinion. This was an interesting result because I did not teach that in any way. The information that I gave merely suggested that organic farming is a much more soil-ecosystem conscientious way of farming. Never did I link organic agriculture to human health. The students, through the lectures, must have gained an appreciation and optimistic perspective of organic farming so that when they saw the survey question for a second time their new perceptions led them to answer positively.

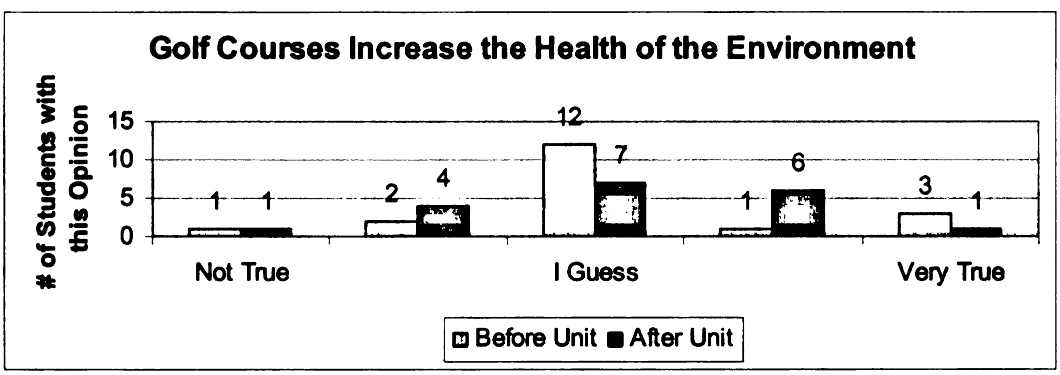



Figure 25. Survey about the Effects of Golf Courses on the Environment

Although the students overall seem to be able to learn the content well as indicated by the pretest and posttest results, they also demonstrated in the survey that they were not able to carryover agricultural ecology ideas to other ecosystems. Many times throughout the unit, it was stressed that adding various pesticides, herbicides, and fertilizers to the croplands of the U.S. actually reduce the health of the environment in various ways. Survey question 4c students were asked to rate the extent to which golf courses increase the health of the environment. Before receiving instruction students over all showed that they did not know the extent to which that was true. After the unit was finished, the surveys showed that if anything students still had not formed an opinion or that they formed a wrong one. In reteaching the unit in the future I will be sure to address this idea more head on and emphasize that over-fertilizing causes access nutrients to get into the water supply and can lead to algal blooms and die-offs.

Finally, there were a few questions that the students answered correctly on the survey before and after the unit and as such do not show any change in their perceptions. These questions included whether pouring used motor oil into the ground should result in a punishment, whether earthworms will ruin plants as they eat the plants' roots, and whether soil bacteria should be killed so that plants can grow.

**Cool City Project Analysis**

One major assignment was that of redesigning the city of Grand Rapids (Appendix C-9). This assignment was given near the end of the ecology unit and was to serve as something of a capstone for the whole unit. I wanted them to apply all of the ideas that we had discussed and create a "Cool City" as coined by Governor Granholm. Implementation of this task was also to serve as a gauge of the extent to which the students had become agriculturally conscious. If the students kept the agricultural community in mind as they did their work that would suggest to me that they gained an awareness of agriculture's importance in the Grand Rapids area. If the students did not organize the city in an agriculturally conscious way then I could conclude that although the students did glean many "farm facts", they had not internalized them and assimilate it enough for it to become part of the natural thought processes.

The task as the students saw it was to redesign Grand Rapids. They were to determine the extent to which the city land should be zoned as agricultural as opposed to industrial, recreational, and residential. Next, I provided a large map of the Greater Grand Rapids area from which they were to lay out major land marks like streams and lakes. They also were to consider a well-organized layout of highways that would provide efficient transportation back and forth among the zoned areas. After some guided thought they began placing their ideas on the map.

The students performed well with making creative "cool cities." They put a lot of thought into how they could zone residential areas near to the industrial ones for quick easy transportation to and from work. They also put lots of thought into protecting rivers, lakes, and wildlife habitats from the industrial community. Many of the lakes and rivers were bounded by recreational forested areas and the wildlife areas had corridors that provided continuous habitat for the animals. Many decided to locate the industrial areas on the east side of the residential ones so that the dominant winds would not blow pollutants over residential lands. Thought was also given to the placement of landfills and waste water treatment plants. These were kept away from residential zones and as much as possible away from the lakes and streams. The students clearly put time and energy into their designs.

Unfortunately, the results for the agricultural sectors were devastating. Many groups placed the landfills and waste water treatment plants in the agricultural areas for lack of knowing where else to place them. Also the agricultural areas seemed to be an afterthought. Every single poster was developed with residential, recreational, or industrial zones receiving the prime land. The land that had not yet been designated as anything else became agricultural. This tendency was clear from both the posters and the paper write-ups. In fact, in their papers many students failed to mention agriculture altogether even though the task was to defend their zoning ideas. On the posters the agriculture was shoved off into the corners or comprised the whole of the top or bottom of the maps. Clearly the ideas in the forefront of their minds had to do with the intelligent placement of the residential and industrial zones. Also they gave much attention to pollution and pollution control, all at the expense of agriculture ingenuity.

In the end only 9 of the 19 students felt that some justification of their agricultural zoning was warranted in their papers. All of the others gave somewhat involved defenses for the other zones but did not even mention agricultural zones. Once the other zones were written about and justified, their thoughts moved on to making a good defense for their highways designs, landfills, and other cool city concepts.

# DISCUSSION AND CONCLUSION

*Incorporating an Agricultural Emphasis in Ecological Education* is a good unit that met the goals that I have and the Michigan Ecology Benchmarks. In addition it incorporated many learning strategies and was an enjoyable unit to teach. Although it was a successful unit, it was not absent of problems.

**Two Problems that were Encountered**

First, the unit was designed to be the content of the first grading period, which lasts six weeks but it actually required eight weeks for complete implementation. There are a couple of reasons for why it took longer than expected. First, there were some unanticipated interruptions. Second, an unexpected amount of time was spent in introducing the course and demonstrating what is expected by way of labs, notes, and classroom behavior. I took the time to redo the Rhizobium Lab because I wanted the students to see the difference in root nodule size. The objective in the lab is for students to grow soybeans while fertilizing them with different amounts of Nitrogen. Only during a photosynthesis lab that I did months later did I realize that my plant grow bulbs were poor. I fault the bulbs for the failure of this lab. I anticipate repeating the lab again next year. However, the hands on experience did teach the students that photosynthetic light is important for plant growth.

The second difficulty that I encountered was that I was not able to make the students internalize the information. Although there was more interest in the unit as evidenced by the questions the students had and the positive attitudes they portrayed, they ultimately demonstrated that agriculture was not highly regarded. This is evidenced by the Cool City Planning Project in which many forgot to defend their agricultural zonings and when students zoned areas as agricultural because they did not know what else to make it.

**My Goals Were Met**

The unit was successful because my goals were met. I had noticed a lack of knowledge about agriculture on the part of my students in past years. The posttest clearly shows that the students know the material in the unit. Students improved their grades by an average of 59.6 percentage points on the posttest compared to the pretest. The average posttest score was 88.1% whereas the average pretest score was only 28.5%.

I had noted a lack of interest in many ecological principals over the past years but the students who took this new unit had an interest. Evidence of this can be found in the length of time it took to present. For example, the PowerPoint® presentation on the importance of understanding ecology took parts of three days to complete. One big reason for the lengthened time was that students asked many questions. I was encouraged to see this high level of interest.

Secondly, agriculture is ecological to the core. I wanted to determine if making regular agricultural references would be an effective tool in teaching ecological concepts. I found that ecological instruction is nicely complemented with labs, references, observations, and lectures that are grounded in agriculture. Agricultural examples, labs, and activities do work well in making ecology conceptual and learnable. The Chemical Movement in Soils Lab (Appendix E-4) clearly shows the importance of abiotic factors in the environment. The positive dye representing positively charged nutrients (NPK fertilizers) was almost completely sequestered by the soil whereas the negative dye leached through the soil quite quickly. The PowerPoint® lecture about ecological ignorance included information about the Dust Bowl of the 1930's. This lecture clearly showed that small ecosystems are immensely important and that local ecosystems effect the surrounding ecosystems. The old practice of tilling and plowing the soils destroyed the aggregates and led to dust and a lack of resistance to wind erosion. The respirometer lab (Appendix E-7) taught students about biogeochemical cycles. They experienced this in a visual way when they noticed that Oxygen was being used up as the water was drawn up into the micropipettes. That agriculture is ecological was also demonstrated in the lecture about Integrated Pest Management. These techniques demonstrate that farmers are taking advantage of the symbiotic relationships among organisms in clever ways to benefit their crops.

In addition, West Michigan, among other things, is quite agricultural. I had a goal to acquaint high school biology students in this locale with the science of the rural community through which they pass everyday on their commute to school. This goal was also met. The students gained knowledge and understanding about the methods that farmers employ. As a result of being taught about agricultural principles and their ecological underpinnings, students now drive by farm fields in a more enlightened fashion.

Also, I hypothesized that that hands-on activities and labs would promote involvement even among the less enthusiastic learners. I found that all of the students were active in the labs and projects. It was encouraging for me to observed that even students who were more reclusive in lecture became dynamic in the activities. For example, digging for worms in the Earthworm Population Density Lab (Appendix E-6) showed me sides of students that I did not see in lecture. They eagerly got to the task and it turned into a bit of a competition among the members within each group to see who could find the most worms. Another example of students coming alive occurred during the Soils as Electrical Systems Lab (Appendix E-3). Students were eager to wire up the beakers and discover what happens when electricity was conducted through the muddy waters.

Finally, my goal to enable my students to make wise informed decisions regarding the farm, forest, freeway, and ever-expanding city was partly met. The *Cool City Planning Project* showed that students were able to make wise ecological decisions regarding the forest, freeway, and the city. They had great ideas about placing industrial zones to the east of the residential zones in the city to take advantage of prevailing winds, to incorporate pollution filtration systems in the smoke stacks of factories, to monitor water quality, and to maintain fresh water. The aspect of the goal about making wise decisions about the forest, freeway, and city was met. They, however, did not show a preference for agricultural zones above industrial and recreational zones as I had hoped. The agricultural zones were placed in parts of the map where nothing else was. These zones were afterthoughts.

**Michigan Benchmarks Were Met**

*Incorporating an Agricultural Emphasis in Ecological Education* definitely covered the Michigan Ecology high school benchmarks. I checked The Michigan Teacher Network (http://mtn.merit.edu/) to find the Ecology benchmarks that are mentioned below.

The first is Benchmark SCI.III.5.HS.1. It suggests that students are able to describe common ecological relationships between and among species and their environments. This benchmark was met in many ways, one of which was on the symbiosis video. Students saw many relationships and had to classify them (Appendix C-4). Most students scored a 100% on this 10 point assignment. From an agricultural perspective the students learned about cover crops, IPM or integrated pest management, and about the effects of changing a cow's diet too suddenly. Question 25 of Test 4 (Appendix C-6) asks, "What is the mutualistic relationship between cows and bacteria?" Students scored an average of 3.47 point out of 4 on that question as they showed that they were able to articulate the idea that microorganism populations change because the nutritional requirements of different species are met to a fuller extent as the cows diet changes. All of these addressed the concept that species are related to one another and the environment.

The second is Benchmark SCI.III.5.HS.2. Students should be able to explain how energy flows through familiar ecosystems. My students know about energy flow in the typical sense, that is, through primary producers, consumers, etc. but also from the agricultural sense. Evidence of student knowledge comes from the fact that they scored an average of 27 out of 30 points on a poster (Appendix C-3) regarding food chains and food webs of a biome. They were also taught about human population growth and its consequences. The amount of land and resources dedicated to feeding the cows, pigs, and chickens that we consume is immense. The fact that 90% of the usable energy is lost at every trophic level demands that we pay attention to our current agricultural practices. Students scored an average of 89.5% on their 3rd test (Appendix C-7) which covered these ideas.

The third ecological Benchmark is SCI.III.5.HS.3. This one wants instructors to be sure that students can describe general factors regulating population size in ecosystems. We covered the logistic and exponential growth curves while studying populations. I also lecture on density dependent and independent factors in population growth. Student scored an average of 9.8 out of 10 on a reading worksheet about exponential growth of white-tailed deer (Appendix C-10). This gives evidence that they understood the concepts. Students also experienced population growth in a tangible way when they grew bacteria colonies on Petri dishes (Appendix E-8). At first they were so small that they could not be seen. There was plenty of resources for them but as they quickly filled the Petri dishes their growth slowed.

The fourth is Benchmark SCI.III.5.HS.4. Students are to describe responses of an ecosystem to events that cause it to change. The succession PowerPoint® included succession not only of the Mt. St. Helens' area and of the state of Michigan as it was logged, but also from an agricultural sense of the abandonment of farm fields. While learning about nutrient cycles, the effects of high nitrogen inputs from agricultural manure was pointed out. The farmer is a valuable but powerful member of the community and has to commit himself to sustainable agricultural practices. The concepts of the Dust Bowl and no-till farming also apply to this benchmark. Students understood this idea as evidenced by Question 31 of Test 3 (Appendix C-5). The question asks, "What was the root cause of the dustbowl of the 1930's." Students demonstrated that they understood that the danger of tilling too often and scored an average of 3.7 out of 4 points on that question. Students were also taught that farmers have changed their methods not only because it is better for them from a financial perspective but also because they are increasingly aware of the environmental changes for which they are responsible as they work to make a living. This demonstrates to the students that ecological understanding is not just head knowledge but also has practical, real life implications.

The fifth is Benchmark SCI.III.5.HS.5. This benchmark requires students to be able to describe how carbon and other soil nutrients cycle through selected ecosystems. This benchmark was met when students learned about nutrient cycles but also in many smart farm practices. Crop should be rotated because some add various nutrients to the soil while others take those out. Soybeans and alfalfa both are legumes and add nitrogen to the soil while corn uses nitrogen heavily. An understanding of the nutrient cycles allows farmers to grow productive crops year after year. Question 29 of Test 3 (Appendix C-5) asks "Why do farmers rotate corn crops with alfalfa and soybeans?" Students remembered the principle of Nitrogen cycling well and scored an average of 3.8 out of 4 on that question. Question 27 of Test 3 (Appendix C-5) asks students to "Compare the movement of energy in the biosphere with the movement of matter through the biosphere." Sixteen of my nineteen students got full credit on this question because they were able to articulate the idea that nutrients move from biotic to abiotic aspects of the ecosystem in a continual cycle while energy comes into out ecosystem and comparatively quickly leaves in the form of infrared energy.

The sixth benchmark is SCI.III.5.HS.6. Students are expected to explain the effects of agriculture and urban development on selected ecosystems. My students had to work directly with this benchmark in the City Planning Project (Appendix C-9). They came up with schemes to minimize the effect of urban development on the ecosystem. Sometimes they thought of their cities and made sure that the industrial area was always East of the residential area because winds predominantly blow from the West. Others placed their landfills in locations that were farthest away from rivers and lakes. Students also came up with interesting wild life corridors that allowed movement to different resources despite urban growth.

**Many Leaning Strategies were Implemented**

*Incorporating an Agricultural Emphasis in Ecological Education* implemented several learning theories. The unit showed elements of constructivism in the way that students have to interact with the subject matter. They were asked to count earthworms, make soil profiles, measure respiration rates of bacteria, grow plants in controlled environments, count aggregates, test different soils for their ability to hold on to positive ions, and grow bacteria cultures. All of these labs were really experiences that added to previous encounters with the subject matter or gave them an initial experience to which even more information could be assimilated in the future. What student has not pulled earthworms for fishing, dug around in the ground and as such experienced soil horizons, observed different types of soil, and been told about washing the dirt off of their hands? By far most of them had experienced all of these. They had a beginning of a knowledge about these aspects of their world and now with these labs and lectures they added to their previous knowledge and can use the Earth's resources in a more careful and productive way.

Another example of constructivist pedagogy happened when I took my students on a walk while I was teaching that energy flows. They have all felt the burning sun and are aware that some of the energy gets captured by the chlorophyll of primary producers but few realize that most of the energy flows right back out to space rather than going through the trophic levels. I build onto their prior knowledge and experiences in this way and help them understand what is actually happening. It is effective to have the students lie down and feel the Sun's intensity and at that point make them conscious that all of this energy has to go somewhere. Energy never gets created or destroyed but just gets re-emitted in different forms. Infra-red energy is emitted from our bodies and the environment and that leaves the Earth and goes into space.

Collaborative learning was also used in this unit. The students were taught by use of collaborative learning in their various sessions of group work. First, students did labs in groups and all of my labs require an amount of discussion. Discussion was required not only to understand the procedure but also because the labs were often followed the next day by a random group member taking a small quiz based on the principles being demonstrated in the lab. The group as a whole was assigned the grade of the "lucky" quiz-taking representative. During lab they concentrated on ensuring that their partners understood what was happening and why rather than wasting time.

Collaborative learning was also implemented in the first agriculture-based lab which involved using the scientific method to design a plant growth experiment. Students had to discuss what to do, how to do it, and show that this was following the steps of the scientific method.

Finally, students had an extensive group task of totally redesigning Grand Rapids to be environmentally, economically, socially, and agriculturally friendly. This task required much discussion, debate, and an open minded willingness to accept the other students' ideas for the project. The guided one another to the final design of a better and brighter Grand Rapids.

The students were also subjected to inquiry based learning in this unit. This is evident when they had to design a city that is good for the economy, agriculture, and society. Many of them thought it wise to develop housing upstream of the industry and farm land. In addition some learned about aspects of the Grand River's ecology including simple ideas such as the direction it flows and the loop that it takes around the North of the city. In addition Inquiry-Based learning occurred in the Soil Microbes Decomposition Lab. In this lab students had to figure out where most bacteria were by doing a lab. They gathered soil samples from different depths ranging from surface level to 1.5 feet and from different ecosystems. They then mixed leaves into those soil samples and added two table spoons of water. Over the next few weeks we watched as the leaves of the different bags decomposed at different rates, clearly showing students that bacteria or at least decomposer abundance is very different in different soils.

Inquiry based learning was also evident in the Soil Aggregates and Bacteria Lab (Appendix E-2). This lab involved determining soil ecosystem health by measuring the rate at which the microbes cumulatively respire. Students were placed in groups and asked to come up with a way to collect the $CO_2$ given of by the microbes. After some classroom guidance the students were led to the idea of collecting the $CO_2$ in a test tube and measuring microbial activity in that way. In the discussion they became excited about actually trying out the idea and working through the lab to find the answer.

One more lab that was inquiry-based is entitled *Chemical Movement in Soils.* This lab asks students "Why does nitrate ($NO_3^-$) move in soil and ammonium ($NH_4^+$), another form of nitrogen in soil, not move?" Students then have to follow instructions that lead them to pour either methylene blue or eosine red onto a small quantity of soil in a small funnel. The students discover that the red dye moves through the soil quickly while the methylene blue seems to have an infinite capacity to hold onto the soil particles. It nicely shows that abiotic factors have a huge impact on the ecosystem.

**Paired t-test Was Significant**

Another determinant of the success of the unit was the statistical comparison between the pretest and the posttest. My t-value is 28.1 which is considerably higher than the 2.55 t-value on the student's t-distribution table. As a result the outcome is highly statistically significant. That means that I can be very confident that I can reject my null hypothesis that teaching the ecology unit from an agricultural perspective made no difference in student test scores. I instead can be sure that this was an effective method of ecological instruction.

**Unit Was Personally Rewarding**

Finally, education would not be a life long career if it were not personally rewarding. *Incorporating an Agricultural Emphasis in Ecological Education* was rewarding for me. I not only enjoyed a well planned smooth running unit, I also enjoyed imparting agricultural knowledge to the students. It is one thing to teach ecology but another to apply smart ecological ideas to real life. This approach to ecological education takes science out of its sterile laboratory or theoretical environment and makes it practical and relevant. Students were able to walk away equipped for future life so that now they understand soils and can actively manage their future lawns and gardens rather than simply mow and fertilize them. It was an enjoyable unit to teach.

APPENDICIES

# APPENDIX A

## A LOOK AT MICHIGAN AGRICULTURE

(Permission has been granted for publication from Michigan Agriculture in the Classroom)

# A Look at Michigan Agriculture

## Michigan

**Capital:** Lansing
**Population:** 10,112,620
**Founded:** January 26, 1837 (26th state)
**State Bird:** Robin
**State Tree:** White pine
**State Flower:** Apple Blossom
**Number of Counties:** 83
**Largest City:** Detroit **Population:** 951,270

## Soil

- **The Kalkaska Series of soils, which cover 750,000 acres of Michigan, were named the state soil on December 4, 1990.**
- **The Kalkaska Series can be found in both the upper and lower peninsulas of the state and in 29 of the 83 counties.**
- **The soil series supports the growth of hardwood timber trees like sugar maple, yellow birch and Christmas trees.**

## Climate

- **Michigan has many microclimates which support the growth of more than 200 food and fiber products. This makes Michigan the 2nd most agriculturally diverse state in the nation.**

## General

- **About one-million Michigan residents are employed in production agriculture and food processing.**
- **Over 53,000 farms in Michigan produce over $60 billion in commodities each year in annual gross farm sales.**
- **The export value of Michigan products in 2004 was $919 million. Top exports included: soybeans and preparations, feed and grain products, vegetables, fruits and preparations, wheat and products and dairy products.**

## Crops

- **Michigan is the national leader in the production of tart cherries, growing 149 million pounds in 2004.**
- **In 2004, 2.2 million acres of Michigan were used for the production of corn. Soybeans are the state's 2nd leading crop at 2 million acres.**
- **Michigan ranks 3rd in the nation in apple production with over 840 million bushels produced in 2003. The estimated farm-level value was $81.6 million.**
- **Michigan is the top producer of cucumbers grown for pickles, 2nd for celery and carrots and 3rd in asparagus production.**
- **Over 853,430 tons of fresh market and processing vegetables were grown in Michigan in 2004. The state ranks 8th in fresh market and 5th in processed vegetable production nationally.**

## Animals

- **About 307,000 dairy cows produced 6.3 billion pounds of milk in 2004. This ranks Michigan 8th nationally in annual milk production.**
- **70% of the state's horse population is located in the southern one-third of the state. The counties with the highest horse population include: Oakland, Jackson, Washtenaw, Livingston and Wayne.**
- **There were over 1-million head of cattle in the state of Michigan January 1, 2005 with an estimated value of $901 million.**

# APPENDIX B

# MASTER COPY OF THE NOTES

# CHAPTER 3 – THE BIOSPHERE

I. Science and Biology
   A. Definitions
      1. Science
         a. Science is the systematic study of God's self-revealing work in creation and of the laws that God uses to sustain that creation.
         b. Examples: Astronomy, Geology, Histology, Anatomy, Limnology, Chemistry, Physics
      2. Biology
         a. Biology is the systematic study of God's self-revealing work in living organisms and of the laws that God uses to sustain those organisms.
         b. Examples: Histology, Cells, Genetics, Biochemistry, Evolution
      3. Ecology
         a. Ecology is the systematic study of God's self-revealing work in the interactions of organisms with each other and the environment.
   B. Scientific Method
      1. The process by which scientists, collectively and over time, endeavor to construct an accurate representation of the world.

      2. Steps:

         a. Observation and description of a phenomenon or group of phenomena.

         b. Formulation of a hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.

         c. Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.

         d. Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments.

      3. Termite Lab
      4. Seed Germination and Growth Experiments Lab.

II. God is obvious in the biological world.
   A. Article 2 of Confession of Faith.
      1. By what means God is made known unto us?
         a. Creation, preservation, and government of the universe
            - Elegant book about God!

- creatures are as so many characters leading us to contemplate the invisible things of god.
  - * Especially power and divinity

B. Romans 1: 20

1. "For the invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead: so that they are without excuse."

C. Psalm 19: 1-3

1. "The heavens declare the glory of God; and the firmament sheweth his handiwork. Day unto day uttereth speech, and night unto night sheweth knowledge. There is no speech nor language, where their voice is not heard."
   a. Creation's voice is heard everywhere that speech is heard!
      - We have to listen for it!

D. World is obviously designed.

1. Irreducible Complexity
   a. Exists when a group of components work together to produce a complex function that is beyond any of the individual component's ability to do .
   b. Air plane… metal does not fly.
   c. Mouse Trap
2. Earth supports life!
   a. Just the correct distance from the sun.
   b. Perfect amounts of vitamins and minerals.
3. Design is recognizable!
   a. A tornado going through a junk yard will never create a 747!
      - Functions like flight require design…and maintenance.
   b. DNA
      - Random processes will never create DNA
   c. Immune system
      - Random processes will never accidentally create the Immune system
   d. Single celled organisms

III. God's relation to the creation.

A. Created it

1. Psalm 104: 24-31
2. $6^{th}$ Day of Creation

B. Blessed them.

1. Genesis 1: 28

C. Sustains them

1. Psalter 286:2
   - The life of each creature the Lord makes His care.
2. Acts 17:25b
   - "giveth to all life, and breath and all things"

3. Psalm 145: 15b,16
    - "givest them their meat in due season"
4. Psalm 104:29b
    - "takest away their breath and they die and return to their dust"

D. God has included creation in the Covenant!
1. Genesis 9: 9,10
    - "I will establish my Covenant with you and with your seed after you; And with every living creature that is with you, of the fowl, of the cattle, and of every beast of the earth with you; from all that go out of the ark, to every beast of the earth.
2. Exodus 11:5
    - "And all the first born in the land of Egypt shall die, form the firstborn of Pharaoh that sitteth upon his throne, even unto the firstborn of the maidservant that is behind the mill; and all the firstborn of beasts.
    - The sign of the blood on the doorposts which is Christ's blood was also shed to save the animals.
3. Romans 8: 21-23
    - "Because the creature itself also shall be delivered from the bondage of corruption into the glorious liberty of the children of God. For we know that the whole creation groaneth and travaileth in pain together until now. And not only they, but ourselves also, which have the first fruits of the Spirit.

IV. Relationship between man and creation.

A. Organic head.
1. Together our job is to glorify God.

B. Creation serves us
1. Article 12 of Confession of Faith

C. We must care for creation
1. Genesis 1:28
2. What does dominion mean?
    - Maintain it to a level in which it is still functional for serving man and glorifying God.
    - Develop the mysteries of creation for the good of man so that we are better able to serve out God.
        * Ex. Books, videos, radio, TV, engines, speakers, etc.

D. We are dependant on the creation for sustenance

Lab 10 - Seed Germination and Growth Experiments

V. Importance of understanding ecology.

A. Organisms are related to one another!
1. God made the whole Earth to be interdependent.
    a. Adam is Earthy.

- b. Detroit's auto plants effect Lake Erie!
- c. Iowa, Illinois, Indiana farmers and Coral Bleaching
  - "Dead Zone!"

2. Relation between single women and single men in England.
   - You think this is obvious but I'll tell you why it is true.
   - a. More single women → more cats → fewer mice → more bumble bees (which are usually eaten by mice) → more clover (pollinated by the bees) → richer farmers who play with toys they buy and don't have a desire to marry.

*B.* Price of ignorance of ecological interactions. Power Point

- a. Lesson learned
  - Important to understand Ecology so that human can properly manage the creation, which the Lord has given us to steward. Must not be ignorant of the Lord's gifts.

VI. The Biosphere

A. Introduction

1. Definition of Ecology
   - Study of the interactions of organisms with each other and the non-living environment.
   - Single men and women in England
2. God created his universe as a complex system that is interdependent.
   - All things exist and are supported by everything else.
   - Plankton → larvae → fish → raccoon → eagle → decaying nutrients
   - Eagle exists only because plants can take up nutrients from decayed organisms to start the whole cycle over again.
   - Wetlands are extremely important!
3. Price of ignorance!
   - Remember Lake Victoria

B. Levels of organization.

1. Individual level
   - An organism's tolerance of change in pH
   - Ability to survive in a harsh climate.
   - One Sow and her ability to have pigs
2. Population level
   - Group of similar individuals
   - Study birth and death rates, population changes, diseases
   - Potatoes – Reading?
   - Earthworm Lecture/Reading
   - worms improve the soil by gently tilling it and creating channels for air, water and roots.
   - Earthworms' secretions bind soil particles together, giving the earth a porous structure.
   - A worm's digestive track also releases plant nutrients locked up in organic materials and even rock particles.

- Earthworms also help chew up and decompose lawn thatch.
- improves soil aeration
- the tunneling activity of worms helps breakup hardpan and other compacted soils
- bring up minerals from deep in the subsurface that are often in short supply in surface layers
- make plant nutrients more available, worms concentrate minerals in their castings in a form that is easy for plants to absorb
- plant growth stimulants such as Auxins are produced in the castings, these hormones stimulate roots to grow faster and deeper.
- worms stimulate microbial populations, nitrogen fixing bacteria are more numerous near earthworm burrows and in their castings. One study on bacteria and actinomycetes found densities from 10-1,000 times greater
- Many species of earthworms actually eat the bad microbes (fungi, bacteria, etc.) that are plant pathogens and in the process they also increase the good beneficial microbes.
- bacteria living in the guts of worms breakdown (detoxify) many hazardous chemicals

3. Community level
    - Several populations of organisms
    - competition, predation, succession, disturbance, nutrient cycling
    - Crops with Refuge strips and beneficial insects.
4. Ecosystem
    - Communities of organisms interacting with the natural environment
    - Climate, soil, habitat, niche
    - Describe the soil ecosystem
        a. Biotic Factors
            * Manure, earth worms, bacteria, # of cattle
        b. Abiotic Factors
            * sun, degree days, fert, clay particles, etc.

C. Ecosystem sizes
1. Ecosphere
    a. Atmosphere, biosphere, hydrosphere, lithosphere
    b. Air, life, water, rock
    c. Everywhere that life can be found.
2. Biomes
    a. Moderate sized ecosystems
    b. Tall grass prairie, Eastern deciduous prairie, Rain forests, Deserts, African Savannah, Pampas.
4. Average ecosystems
    a. a pond, hillside, garden, farming land, parking lot, sand dune

b. Farm

* A community of organisms interacting with the environment.
* Keystone species = man
* Crops, weeds, and soil microorganisms all affect each other.
* Destroy the soil microorganisms = poor crops.

5. Micro ecosystem
   a. Very small, special environment characterized by specific organisms.
   b. Stomach of deer, human intestines, temporary puddle, and pillow (Mites).
   c. Aggregates in the soil.
      * Reduce Soil Erosion.
      * Increases soil porosity
      * Increases aeration
      * Carbon Sequestering
      * Develop a small charge so good for CEC
      * House microorganisms
      * Release crucial nutrients from parent rock.

Lab - Soil Aggregates and Bacteria Abundance

- Streak bacteria on plates after dilution.
- There are some very small ecosystems!!
- Even an aggregate is an ecosystem

E. Harsh does not mean bad.

1. God created some animals to survive best in environments that we would assume hostile.
2. Many creatures will not complete their life cycle unless they are exposed to periodic stretches of harsh conditions.
   a. Jack pine and Kirtland's Warbler
   b. Polar bear and Arctic Ice
   c. Penguins and Antarctic Ice
3. NWF Ice caps protect species
4. It is their natural environment; they'd die in a place that we look at as suitable.

F. Energy and Nutrients

1. The flow of energy
   - Chicken in Space ship problem.
   - Happens in all ecosystems
   - It is a flow! Not a cycle
   - It can not be recycled or used again.
   - The flow

   a. The sun is the source of all energy
   b. Primary producers
      - Autotrophs
      - use the energy to produce sugars and plant parts.

- Plants lose this energy during respiration ($O_2 \rightarrow CO_2$)
- Plankton, trees, grasses, some bacteria, moss, algae
- Can measure net primary production in a community. Diagram-Overhead
- Factors influencing NPP
  * Soil, light, precipitation, temperature, species(productive?), microclimate, succession stage, disease

c. Secondary producers (primary consumers)
- Heterotrophs
- Produce new tissues and use energy derived from eating primary producers.
- carnivores, herbivores, detritivores and omnivores
- These lose a large amount of energy.
  - 25% is feces
  - 5% urine
  - 5% methane (gas)
  - 45% lost as heat
  - 20% body gain

d. Tertiary producers (Secondary Consumers)
- Humans, fox, bear, wolf, insects
- These also lose much energy to heat, feces, urine, and methane.
- Vegetarians have a point
- Cold blooded are much more efficient (much less loss of heat)

e. Decomposers
- Bacteria, maggots, fungi
- leaves don't just fall apart, they are taken apart.

Lab. - Soil Microbes Decomposition Lab
- Over a 4-week period watch how vegetation decomposes when soil (bacteria) is present compared to an equal amount of grass that is not in the presence of soil.

2. Feeding relationships
- All plants and animals are tied together in relationships
- Food Chain
  - Plankton → zooplankton → larvae → minnow → fish → raccoon → eagle
- Food Web
  - Complex mix of many organisms
  - Arrows pointing toward the energy flow
  - Great diversity makes for a stable system.
    - Airplane wings with their support rods.
  - Integrated Pest Management
    * Using insects as a biological control for crops.

3. Biotic Index
    - Measure of the health of a stream.
    - more organisms = more health
4. Ecological pyramids
- Ways of representing information in a graphic way
- General way is via pyramids.
    - Biomass, energy, numbers pyramids.
- Not all are perfect triangles.
    - Parasites (secondary consumer) and a cow (secondary producer)
    - Plankton (not a high biomass, but high reproduction)
    - Energy is always triangular.

G. Biogeochemical cycles (Nutrient cycles)
- Involves nutrients and these cycle.
- Nutrients can be used over and over
- Any substance that can be used by an organism for normal growth and activity
    1. Water cycle
        a. Evaporation and transpiration
            - Gets water air borne
        b. Precipitation and condensation
            - Brings water back to earth
        b. Absorption and run off
            - Back into plants, rivers, and lakes
    2. Nitrogen Cycle
        a. Major pools
            - Atmosphere, Sea
            - Atmosphere is 79% $N_2$
            - Unavailable to plants and animals
            - Must be transformed into usable N and then taken up by plants.
        b. The Cycle
            - Nitrogen Fixation
                * Converts $N_2$ to ammonia ($NH_4$)
                * fertilizers, lightning, or biological
                * nitrifying bacteria that live in legumes (peas, beans, peanuts), blue-green algae can do this.
                - Plants take up the usable Nitrogen
                - Animals eat the plants
                - Denitrification
                    - Bacteria break down the plants as they decay
                    - The Nitrogen is then released into the air.
    3. Carbon - Oxygen Cycle
        - Major pools

- Atmosphere ($CO_2$, $CH_4$,CO)
- Ocean
- Continental land mass
  - Limestone and sedimentary rocks

The Cycle

* $CO_2 \rightarrow$ Glucose $\rightarrow CO_2$ (Plants)
* $O_2 \rightarrow$ Glucose $\rightarrow O_2$ (Animals)

Lab. - Soil Type and Biological Activity Lab

- Respirometer
- Measure the amount of $CO_2$ production from bacteria in different soils.
- You can actually measure the amount of energy being used by measuring the amount of $CO_2$ given off.

Lab. - Carbon Concentrations in Different Soils.

- Measure the mass of dried soils before and after burning.
- Atmospheric $CO_2$ can be reduced by sequestering it in the soil.
- No-till farming greatly increases the amounts of carbon sequestration!!
- Crushed aggregates vs whole aggregates

4. Phosphorus Cycle
   a. Needed for ATP
   b. Very limited
   c. Not in atmosphere
   d. Stores in lake and ocean sediments, rocks
   e. The Cycle
      - Weathering from rocks
      - Plankton, other organisms
      - Eventually go to lakes and oceans
      - Released by some organisms in the lake sediments. (Lake turnovers)

H. Nutrient Limitation

- The nutrient that is in short supply is limiting
- "Limiting nutrient"
- Something must be the thing that slows the process down.
- Often nitrogen or phosphorus is limiting
  - Environment only grows as much as the $N_2$ or P allows it to.
- Oxygen in Lake Victoria
- Killed nearly everything in the lake.

## CHAPTER 4 – ECOSYSTEMS AND COMMUNITIES

I. The Role of Climate
  A. What is climate
    1. Average year to year conditions of temperature and precipitation in a particular region.
    2. Climate is different from weather.
      a. weather is day to day
  B. What causes climate?
    1. Sun, elevation, nearness to water, etc.
    2. Any one ecosystem is shaped by the many abiotic factors that influence it.
  C. Abiotic Factors of an ecosystem
    1. Solar Radiation
      a. Energy from the sun
      b. The effect on latitude
        - Angle of heating
        - 3 main climatic zones
          * Polar
          * Temperate
          * Tropical
      c. The green house effect
        - *Describe the normal situation first.*
        - Caused by increase of greenhouse gasses
          - $H_2O$, $CO_2$, $O_3$, $CH_4$, CFC, etc.
          - Necessary gasses for warmth.
            * Earth would be 54°F cooler
        - Energy penetrates one way only.
          - Not enough energy to go back out.

        - Effects of warming
          * Ocean currents may change.
          * Climate changes
          * Melting ice caps
            - Water levels rise?
      d. Heat transport in the Biosphere
        - Causes wind
          * Why does wind always blow from the west?
        - Spreads heat around
        - Deserts at 30° Latitude.
    2. Ocean currents also cause climate
    3. Tilt of the Earth on its axis
    - God created seasons by having the earth's axis of rotation tilted with respect to its orbit around the Sun.(23.5 )

- Photoperiod = intensity and duration of light on a specific region.
    a. Short and long day flowering plants
    b. Hibernation, estivation
    c. Migratory behavior
        - Arctic tern travels 25,000 miles annually
4. Temperature
5. Elevation
6. Soil type

Lab. - Soil type and Aggregate Mass
- Measure the amounts of aggregates in different soils by sieving out the aggregates and weighing them.
- Amounts of organics corresponds to the amounts of aggregates.

Lab. - Cation Exchange Capacity Lab (Demonstrations in Soil Science -4)
- Place two electrodes in the soil see what happens.
- Minerals have a charge! Soils that contain atoms or compounds with charges (Cations and Anions) will work in keeping your fertilizers and natural minerals in a zone of availability, preventing leaching.

Lab. - Filtering Qualities of Soils (Demonstrations in Soil Science -5)
- Methylene blue dye (+ charge) is poured through several soils and extra is caught in a beaker. Soils rich in anions (clay and organic) will filter out the dye.
- The clays and organic soils have high CECs. These are anionic while the Methylene blue dye is cationic. The mutual affinity will filter the dye out as it moves through the soil.

7. Rainfall
8. Humidity
9. Shape of land (long narrow)
10. Latitude
11. Human interaction
12. Facing sun
13. Gravity
14. Wind
15. Fire

C. All organisms have a niche
1. Full range of physical and biological conditions in which an organism lives and the way it uses those conditions.
2. The specific job God gave it in the ecosystem
    a. Polar Bear – Kill old and unhealthy seals, etc.
    b. Dung Beetle – Recycle manure
    c. Elephant – Deforest the African Safari
3. Competitive exclusion principle

a. Theoretically, no two species share exactly the same niche in any one ecosystem.
b. One goes into exile.
c. Gazelle, Wildebeest, Zebra – Worksheet

D. Community Interactions – Biotic Factors
1. Communities
a. All populations of organisms in a given environment.
- Study both the biotic and abiotic factors
b. Species interact within these communities
- Symbiosis
* Individuals living together.
* Willfully or unwillfully.

Soil community investigation

2. Possible relationships
a. Commensalism
- Benefiting only one of the organisms.
- Epiphytes (orchids on trees)
- Barnacles on gray whales
- Shrimp and sea anemone
b. Mutualism
- Benefiting both organisms
- Cows and gut microbes
* Changing feed = Diarrhea, mood shift.
- Lichens (fungus and algae)
- Termite and protist
- Pollination
* Anther to stigma
- Clownfish and sea anemone
* Chase away anemone eating fish
- Cleaning stations and barracuda

Lab. - Plant soybeans/peas in potting soil. Give one group soil with NPK fertilizer, while another only PK fertilizer. The group with the PK fertilizer will grow with nodules of rhyzobium.

6 small cups: 3 seeds, 2 seeds, 1 seed.

c. Ammensalism
- Negative effect on one
- Large tree and little bush
d. Parasitism
- Negative for one and good for the other.
- The parasite should not get too large so it kills the host.
- Liver Fluke
- Worms
e. Competition
- Negative effect on both organisms.

- Lion and hyena
- Weed species in a confined area
- Do Gazelles, wildabeasts, and zebras all compete for grass on the Savannah?
    * No, each eats their own part of the grass.
    * They follow each other through as the first exposes the next's part.

3. Integrated Pest Management

E. Interactions among ecosystems

1. Ecosystems also interact.
    a. No such thing as an isolated ecosystem.
        - A pond and the environment are very much related.
        - Pond provides frogs and mosquitoes while environment has thirsty animals.
        - Rain washes junk into the pond.

F. Ecological Succession

1. Sequence of changes initiated by a disturbance.
    - farm land recovery
    - lava flow
    - sand dunes
    - Lake → Forest overhead
2. Primary succession
    - Marked by initial vegetation over a piece of land that has never been vegetated before.
    - Sand dune, glacier receded, lava flow, volcanic island
    - Sand Dune Succession
        a. Bare Sand
        b. Small, hardy, fast growing and dying plants
            - deposit nutrients (humus)
            - fungi, algae, moss
        c. Larger, longer lasting dune grasses
            - Replace simple plants and fungi
            - Provide enough shade and protection for insects to live and die amongst them.
            - Adds additional nutrients and builds up the soil.
        d. Shrubs and small trees begin to colonize
            - Additional animals and nutrients.
            - Squirrels, rabbits, birds, Sun tolerant cottonwoods and pines
        e. Oaks
            - These eliminate many of the pines and shrubs because of all the broad leaves.
        f. Beech-maple forest
            - These are the climax community.

- As long as there are no disturbances this community will continue to last.
- Many species of mouse, bird, rabbit, deer, fox, wolf, raccoon

3. Secondary succession
   - Succession in an area that has previously been inhabited.
   - Floods, fire, tillage, logging, road ditches
   - Weeds are the most likely colonizers of such places.
   - Shrubs and such come later.
4. Factors in a fast succession.
   a. Amount of disturbance.
   b. Distance from seed source.
   c. Survivability of parent species.
   d. Soil compatibility with succession plants. (nearest seeds)
   e. Means of transportation to disturbed area.
      - Wind, insect, mammal, water

G. Climax Community
1. That community which is stable and self-sustaining in the prevailing environmental conditions.
2. May also be a mosaic pattern.
   - Grasses and shrubs growing where an old oak died.
3. Often named and are characterized by a specific dominant group of species.
   - Prairies, deserts, mountains, deciduous forests, tundra, and ice caps.
   - Biomes are characterized by having specific climax community characteristics.

H. Land Biomes

Lab. - Soil Monolith Profiles of Different Ecosystems at and around Covenant. Students will construct several soil monoliths for permanent display in the classroom.

1. Tundra
   a. Northern most land biome
   b. Mosses, lichens (algae and fungi), grasses, and a few low shrubs.
      - All near the ground in order to avoid wind and being eaten by wild life.
      - Some migrating animals (Caribou and reindeer) brings with it the wolves, foxes
   c. Permafrost
      - Land is permanently frozen by 1-foot depth.
      - Constant freezing and thawing of surface rips and crushes the plant roots so there is little growth.
   d. Extremely fragile environment.

- Tire tracks can be seen for years, as well as human remains.
- Low rate of decomposition

e. Many ponds and boggy ground
   - Waterfowl, sandpipers, mosquitoes, black flies

2. Taiga (Russian for Coniferous forest)
   - Coniferous forest. (Fir, pine, spruce)
   - Picture mountainous terrain near the tree line.
   - Circumpolar belt
   - Cold water lakes, and rivers.
   - Long cold winters but summers are relatively warm
   - Short growing season
   - Great diversity of animals and plants
   - Many hibernating or migrating
   - Moose, bears, grizzlies, wolves, moose, elk, wolverines, voles, grouse

3. Temperate Deciduous Forest
   - Temp. changes significantly with the seasons
   - Seasons are evenly distributed through the year
   - Dominated by broadleaf trees (oak, hickory, maple, poplar, sycamore, beech)
   - These survive the winter by dropping their leaves and becoming dormant.
   - Creates beautiful seasonal changes
   - Ground level plants are more diverse where light penetrates the canopy.
   - Home of many large predators
   - Bears, wolves, foxes, wildcats, mountain lions
   - Most of these have been displaced by human development.
   - Good store house of nutrients on the forest floor resulting from the leaves and animal decaying. (humus)
   - Abundant precipitation

4. Grasslands
   - A region where the average precipitation is enough to allow grass and a few trees.
   - Precipitation is erratic enough that drought and fire prevent large stands of trees.
   - Shrubs and trees are prevented because of grazing, drought, and fire
   - Found in the interior of continents.
   - If little temp. change and much precipitation change, "Savannas"
   - Other names for the same
     * Prairie (North America)
     * Veld (South Africa)
     * Pampas (Argentina)

        * Steppes (Soviet Union)
    - Many grazing animals
        * Buffalo, wildebeests, elephants, gazelles,
    - Most of the grasses die each year creating a deep, fertile soil
    - Great for farming
5. Tropical Rain Forest
    - Near the equator
    - Hot, moisture laden air rises and drops it's water
    - 100-180 inches of rain/year
    - Not much soil nutrients!
    - Shallow, dense root system.
    - No nutrients in the soil below.
    - Organic matter decomposes readily.
    - NO FARMING
    - Incredible biodiversity
    - Plants and animals
    - Medicines (plants, fungi, bacteria)
    - From chemicals that many of these plants and animals produce to prevent them from getting diseases.
    - Very layered tree structure.
        * Emergent layer
        * Canopy
        * Understory
        * Shrub layer
        * Forest floor
    - Virtually all plan roots have relationships with fungi that quickly transfer nutrients from leaves and plants into the trees.
    - Epiphytes
        * Plants that grow on others
        * Not parasitic but just live on branches, etc.
        * Absorb water and animal wastes that fall on the branches
        * Some grow for years and develop a soil in the high canopy of the forests.
6. Desert
    - Where evaporation exceed precipitation
    - Less than 10 inches per year
    - Sparse, widely spaced, low vegetation
    - 30 degree latitude
    - How plants survive
        a. light color to reflect heat
        b. wax-coated leaves
        c. small leaves
        d. deep roots

e. wide roots
f. secrete toxins for competition
g. fast growing and seeding

I. Soil Profiles

* A series of layers of soil that gets created by natural processes over time.

1. O-Horizon
   a. Organic Matter Horizon
   b. 15-30% Organic content if common
2. A-Horizon
   a. Mineral horizon
   b. Top soil
   c. Humus is mixed in with the minerals, no parent is obliterated
3. E-Horizon
   a. Mineral horizon found only in forests
   b. Characterized by light colored sand and silt.
   c. Weak organic acids have stripped it of its iron leaving the quartz sand grains more exposed.
   d. It must have a B horizon underneath it.
   e. Some call it the leaching layer
4. B-Horizon
   a. Commonly known as the sub-soil.
   b. Catches much of the leached material from above.
   c. Often clay rich because the smallest particles collect and form clay there.
5. C-Horizon
   a. Rigolith = Broken bedrock
   b. Plant roots do not get down this far.
   c. Often below the water table.
6. R-Horizon
   a. Bedrock

Aquatic Biomes

1. Fresh water Biomes
   - rivers, streams and lakes
   - support everything on the continents
     a. Plankton, zooplankton, phytoplankton
   - rivers have different communities based on speed of flow and width of stream.
   - Must not pollute these!
   - How else are we to live?
2. Marine Biomes
   a. Intertidal Zone
      - Tough plants with strong anchors to the ground

- Live in and out of salt water and take the beating of the waves

b. Open-sea Zone
  - Responsible for 80 – 90 percent of photosynthetic activity
  - Photic zone
    * 200 meters deep

c. Deep-sea Zone
  - High pressure, total darkness, cold temperatures
  - Aphotic zone
  - Chemosynthesis

3. Estuaries
   a. boundary of fresh and salt water

4. Wetlands
   a. swamps (water covered, woody vegetation)
      - Water invaded the land
      - shallow
      - high productivity
   b. bog
      - weeds building up on the water.
   c. marshes (tract of soft wet land)

# CHAPTER 5 – POPULATIONS

How populations grow

A. Characteristics of a population.
   1. Population density
      a. Number/area

Lab. – Earthworm density lab in a number of soil types. – Forest, Grass, Old field.

   2. Growth rate
   3. Age distribution
   4. Geographic distribution

B. Factors that cause population size to change
   1. immigration
   2. emigration
   3. # of deaths
   4. # of births

C. Population Growth
   1. Checked or regulated growth.
      - DNR – Balance the growth of populations to the concerns of society.
         - Predators or competition
   2. Exponential Growth ($x^2$)
      - All populations will grow this way unless checked.
      - Bacteria and 18 min.
   3. Population projection table.
      - White - Tailed Deer.
   4. Logistic Growth
      - Graph with K (carrying capacity)
         - Realistic curve.
         - Level off when birth and death rates are = Carrying capacity
   5. Two basic strategies
      a. Many young, little raising effort.
         - Little time investment in each individual
         - One major reproductive event in a life time.
         - All out, no holds barred
         - Usually do and die.
         - Characteristics of these organisms
            * short life span
            * hi reproductive rate
            * small
         - examples
            * Insects, desert flowers, sea turtles, salmon
      b. Few young, huge raising effort.
         - Spend much energy and time on raising the young but have fewer of them.
         - Few young with multiple events.

- Characteristics
  * long life
  * low reproductive rate
  * larger
  * stable habitats
- Examples
  * deer, human, cheetah, elephant

II. Limits to growth

A. Density - Dependent factors

- Factors whose effect on population growth varies in relation to how many animals there are.

1. habitat limitations
   - Crowding
   - food supply
     * WTD and deer line.
     * 10,000,000 for Dinner (article)
2. parasites and disease
   - both increase in crowded habitats
3. predation
   - must be more prey than predators
   - When too many predators, they starve
   - Violent death is necessary to control population
   - Australian rabbits
   - These reduce both survival and natality.
   - Main factor in population control.
4. competition

B. Density – Independent factors

- Factors whose effect on population growth has no regard for the number of animals.
- Examples:
  * Weather, drought, shopping mall, acid rain, temp, $O_2$ levels
  * Stream Ecology – p.15, 16
  * Grasshoppers
    - Lay eggs, if wet, fungus gets at them
    - If dry there are hordes of hoppers
    - Population suppression is density in dependent
  * Wolves
    - Will not reproduce on bad years.
    - Only alpha's mate.

III. GMO Populations

IV. Organic Farming

A. Organic farming is a production system which views the soil as a living system that both develops the activities of beneficial organisms and reduces the activities of harmful ones. It does this while avoiding the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic systems rely on crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests.

B. USDA Organic Standards

1. Crops

- Land will have no prohibited substances applied to it for at least 3 years before the harvest of an organic crop.

- The use of genetic engineering (included in excluded methods), ionizing radiation and sewage sludge is prohibited.

- Soil fertility and crop nutrients will be managed through tillage and cultivation practices, crop rotations, and cover crops, supplemented with animal and crop waste materials and allowed synthetic materials.

- Preference will be given to the use of organic seeds and other planting stock, but a farmer may use non-organic seeds and planting stock under specified conditions.

- Crop pests, weeds, and diseases will be controlled primarily through management practices including physical, mechanical, and biological controls. When these practices are not sufficient, a biological, botanical, or synthetic substance approved for use on the National List may be used.

2. Animals

- Animals for slaughter must be raised under organic management from the last third of gestation, or no later than the second day of life for poultry.

- Producers are required to feed livestock agricultural feed products that are 100 percent organic, but may also provide allowed vitamin and mineral supplements.

- Producers may convert an entire, distinct dairy herd to organic production by providing 80 percent organically produced feed for 9 months, followed by 3 months of 100 percent organically produced feed.

- Organically raised animals may not be given hormones to promote growth, or antibiotics for any reason. Preventive management practices, including the use of vaccines, will be used to keep animals healthy.

- All organically raised animals must have access to the outdoors, including access to pasture for ruminants. They may be temporarily confined only for reasons of health, safety, the animal's stage of production, or to protect soil or water quality.

C. Stats.
 1. The U.S. Department of Agriculture (USDA) reports that certified organic agricultural land within the U.S. increased by 74% between 1997 and 2001.
 2. Only 0.3% of all U.S. agricultural land is certified as organic compared with 3.24% in the European Union

V. Human PopulationGrowth
 A. Historic overview
  1. Green Revolution lead to the population explosion.
 B. Church and population growth discussion.

# APPENDIX C

# GRADED MATERIALS

# APPENDIX C-1

## PRETEST AND POSTTEST

Agricultural Ecology Pre/Posttest

Name ____________________________

## Part 1. – Multiple Choice

Instructions: Choose the best possible answer for each of the following:

1. ________ In terms of numbers, most life in an ecosystem exists in
   a. the form of plants
   b. the primary consumers
   c. the soils
   d. the trees
2. ________ From where do cows gain their nutrients?
   a. from bacteria by-products
   b. from the plants that they eat
   c. from the water they drink
   d. from the water and plants that they ingest
3. ________ What growths do some plant get as a result of the lack of Nitrogen in the soil.
   a. leaf nodules
   b. stem nodules
   c. root nodules
   d. twisted shoots
4. ________ The stimulus of the green revolution is really rooted in the
   a. Scientific Revolution
   b. French Revolution
   c. Protestant Reformation
   d. Invention of the printing press
5. ________ The clumps of dirt that can be found in soils are called
   a. Sphericals
   b. Soiloids
   c. Aggregates
   d. Accumuloids
6. ________ Most fertilizers are combinations of
   a. Nitrogen, Phosphorus, and Potassium
   b. Calcium, Phosphorus, and Iron
   c. Oxilic Acid, Boron, and Manganese
   d. Vitamin D, Vitamin C, and Vitamin A
7. ________ Rice that is made to be rich in Vitamin A was called
   a. A+ rice
   b. Super rice
   c. Magic rice
   d. Golden rice
8. ________ Plants and animals that have genes from other species are known as
   a. GMOs

b. STDs
c. NPPs
d. KLMs

9. ________ The succession of soil layers in various ecosystems are known as
a. soil contours
b. soil silhouettes
c. soil sequences
d. soil profiles

10. ________ The use of beneficial insects in crop disease management is known as
a. integrated pest management
b. insect control programming
c. biological control engineering
d. natural pest utilization

## Part 2. – Short Answer

Instructions: Answer the following questions in complete sentences.

1. List two characteristics of soils that you feel are the most determinate of good farm land. Explain your choices.

2. Why might it not be good for farmers to till their farm land in the Fall?

3. Why might it not be good for farmers to till their farm land in the Spring?

4. What does CEC stand for and why is it important for the soil?

5. What is meant by the term, "Green Revolution"?

6. How are earthworms useful for maintaining soil quality?

7. What are degree days and why are they important?

8. What does it mean that a farm is organic?

APPENDIX C-2

STUDENT AGRICULTURAL SURVEY

Science of Agriculture - Survey

Name ____________________________

Instructions: Answer the following questions in complete sentences.

1. Do you have any experience with farming or with gardening? If so, what?

2. Do you feel that you will have a garden of your own some day? Why?

3. When you own your own home, do you feel that you will work to develop the soil under your grass or will you just throw fertilizer down as prescribed by the manufacturers? Why?

4. Answer the following questions on a scale of 1 – 5.
   1 = Not true 3= I guess 5 = Very True

   a. Studying soil is complex, there's a lot to know. 1 2 3 4 5

   b. People that pour their used motor oil into the ground behind their home should be penalized. 1 2 3 4 5

   c. Golf courses increase the health of the environment. 1 2 3 4 5

   d. Genetically modified organisms are a hazard to the environment and to your health. 1 2 3 4 5

   e. Organically grown foods are better for you than inorganic. 1 2 3 4 5

   f. Clay is a valuable component in soils. 1 2 3 4 5

   g. Soil bacteria slow down plant growth and should be killed. 1 2 3 4 5

   h. Earthworms ruin your plants because they eat roots. 1 2 3 4 5

# APPENDIX C-3

# BIOME POSTER PROJECT

# Biome Drawing Poster Project

Due Date:
Value: 30 pts.
Specifics:

1. Poster must depict a specific Biome of your choice.
2. At least 5 distinct food chains must be represented.
   - A food chain must consist of 4 levels minimum.
   - Each chain must have arrows of a different color so that I can see the 5 more clearly.
3. All animals must be named.
4. The following vocabulary words must appear in the poster:
   * The number behind the words indicate the number of times I want to see that word in the poster.
   - autotroph (3)
   - heterotroph (4)
   - photosynthesis (1)
   - producer (3)
   - consumer (3)
   - herbivore (3)
   - omnivore (2)
   - carnivore (3)
   - decomposer (4)
   - abiotic factor (4)

Other Comments:

* Remember that this poster is supposed to be similar to a drawing or a painting. (Not just a food web.)
* You may use any materials that you would like. Feel free to cut pictures from appropriate books or magazines and paste them on the poster.
* Remember to draw arrows between the members of the food chains. Arrows should always point up the food chain.

* I am partially grading on neatness because that is a great indicator of the level of care with which you created your poster.

# APPENDIX C-4

# SYMBIOSIS VIDEO ASSIGNMENT

Biology Video Assignment - Symbiosis

Name ____________________________

INSTRUCTIONS: In each column, write down the names or types of animals involved in the symbiotic relationship. Next tell me what kind of relationship it represents. Write the name of the animals in the left-hand column and the name of the relationship in the right. Animal names don't have to be technical. You can just write down monkey rather than proboscis monkey. The video sometimes moves quickly so don't worry about getting every group. By the end of the video you must have written down at least 27 diff relationships. Pick the kind of relationship among the following choices:

1. Mutualism (+ +)
2. Commensalism (+ 0)
3. Ammensalism (- 0)
4. Parasitism (+ -)
5. Predation (+ -)
6. Competition (- -)

---

| Animals involved | Relationship |
|---|---|
| 1. | |
| 2. | |
| 3. | |
| 4. | |
| 5. | |
| 6. | |
| 7. | |
| 8. | |
| 9. | |
| 10. | |
| 11. | |
| 12. | |

13.

14.

15.

16.

17.

18.

19.

20.

21.

22.

23.

24.

25.

26.

27.

APPENDIX C-5

CHAPTER 3 TEST – THE BIOSHPERE

## Chapter 3 - The Biosphere

**Name** ______________________________

**Multiple Choice**
*Identify the letter of the choice that best completes the statement or answers the question.*

____ 1. A snake that eats a frog that has eaten an insect that fed on a plant is a
a. first-level producer. b. first-level consumer. c. second-level producer. d. third-level consumer.

____ 2. All of the members of a particular species that live in one area are called a(an)
a. biome. b. population. c. community. d. ecosystem.

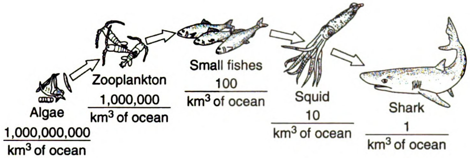



**Figure 3-1**

____ 3. The algae at the beginning of the food chain in Figure 3-1 are
a. consumers. b. decomposers. c. producers. d. heterotrophs.

____ 4. An organism that cannot make its own food is called a(an)
a. heterotroph. b. chemotroph. c. autotroph. d. producer.

____ 5. What animals eat both producers and consumers?
a. herbivores b. omnivores c. chemotrophs d. autotrophs

____ 6. The part of Earth in which all living things exist is called the
a. biome. b. community. c. ecosystem. d. biosphere.

____ 7. The lowest level of environmental complexity that includes living and nonliving factors is the
a. biome. b. community. c. ecosystem. d. biosphere.

____ 8. Organisms that break down and feed on wastes and dead organisms are called
a. decomposers. b. omnivores. c. autotrophs. d. producers.

____ 9. Which of the following is NOT recycled in the biosphere?
a. water b. nitrogen c. carbon d. energy

____ 10. What is the original source of almost all the energy in most ecosystems?
a. carbohydrates b. sunlight c. water d. carbon

____ 11. If a nutrient is in such short supply in an ecosystem that it affects an animal's growth, the
a. animal becomes a decomposer. b. substance is a limiting nutrient. c. nutrient leaves the food chain. d. ecosystem will not survive.

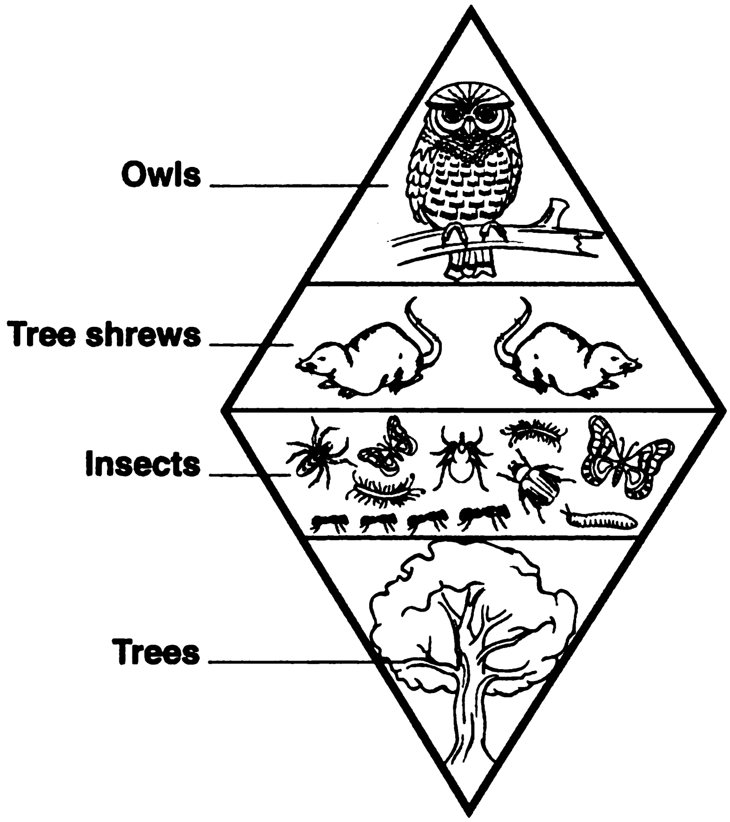



**Figure 3-2**

____ 12. In which way does Figure 3-2 differ from a typical model of trophic levels?
a. Second-level consumers outnumber first-level consumers. b. Third-level consumers outnumber second-level consumers. c. First-level consumers outnumber producers. d. First-level consumers outnumber second-level consumers.

____ 13. An organism that produces its own food supply from inorganic compounds is called a(an)
a. heterotroph. b. consumer. c. detritivore. d. autotroph.

____ 14. Nitrogen fixation is carried out primarily by
a. humans. b. plants. c. bacteria. d. ammonia.

____ 15. Green plants are
a. producers. b. consumers. c. herbivores. d. omnivores.

____ 16. What is an organism that feeds only on plants called?
a. carnivore b. herbivore c. omnivore d. detritivore

____ 17. Which of the following organisms does NOT require sunlight to live?
a. chemosynthetic bacteria b. algae c. trees d. photosynthetic bacteria

____ 18. What is the process by which organisms convert nitrogen gas in the air to ammonia?
a. nitrogen fixation b. excretion c. decomposition d. denitrification

____ 19. The branch of biology dealing with interactions among organisms and between organisms and their environment is called
a. economy. b. modeling. c. recycling. d. ecology.

____ 20. Only 10 percent of the energy stored in an organism can be passed on to the next trophic level. Of the remaining energy, some is used for the organism's life processes, and the rest is
a. used in reproduction. b. stored as body tissue. c. stored as fat. d. eliminated as heat.

____ 21. Which of the following descriptions about the organization of an ecosystem is correct?
a. Communities make up species, which make up populations. b. Populations make up species, which make up communities. c. Species make up communities, which make up populations. d. Species make up populations, which make up communities.

____ 22. Which type of pyramid shows the amount of living tissue at each trophic level in an ecosystem?
a. a numbers pyramid b. an energy pyramid c. a biomass pyramid d. a food pyramid

____ 23. All the interconnected feeding relationships in an ecosystem make up a food
a. interaction. b. chain. c. network. d. web.

____ 24. The repeated movement of water between Earth's surface and the atmosphere is called
a. the water cycle. b. the condensation cycle. c. precipitation. d. evaporation.

**Short Answer**

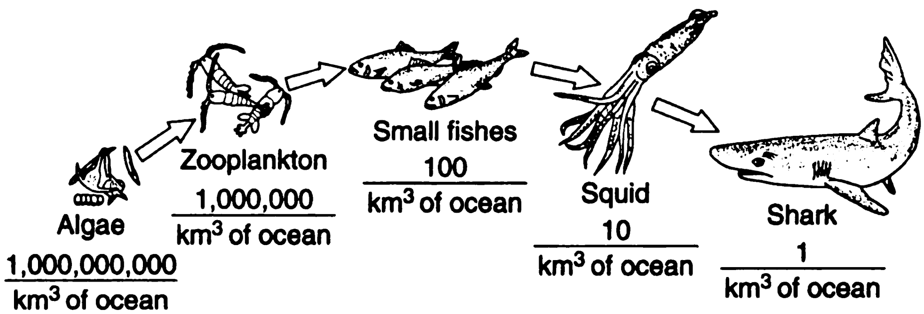



**Figure 3-1**

25. Using Figure 3-1, explain the relationship between sharks and the sun.

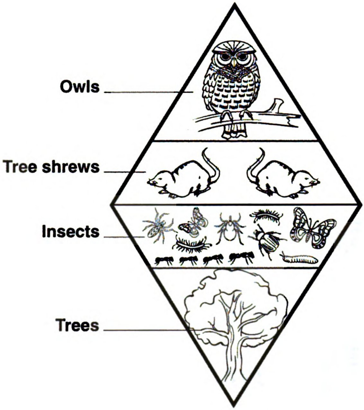



**Figure 3-2**

26. What is the most likely explanation for why Figure 3-2 shows only one organism at its base? In what way would an energy diagram be different?

27. Compare the movement of energy in the biosphere with the movement of matter through the biosphere.

28. What doest the Belgic Confession, Article 2 suggest about the creation?

29. Why do farmers rotate corn crops with alfalfa and soybeans?

30. Give two Biblical evidences (not texts necessarily) for the idea that animals are included in the Covenant.

31. What was the root cause of the dustbowl of the 1930's.

**Other**

**USING SCIENCE SKILLS**

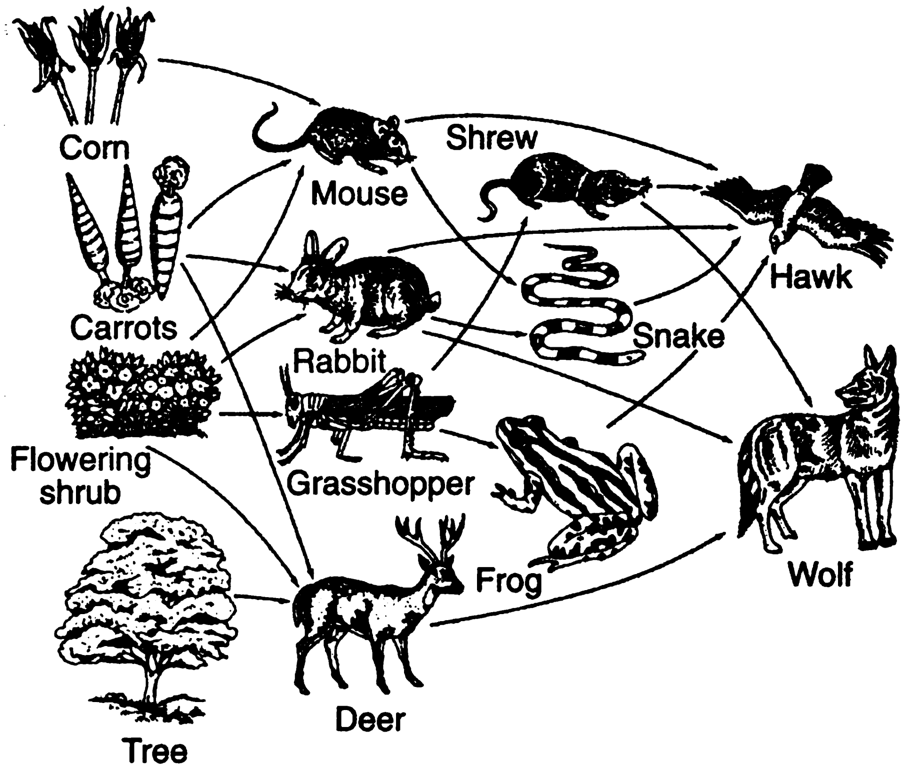



**Figure 3-4**

31. **Inferring** Figure 3-4 shows a food web arranged into trophic levels. How many energy-transferring steps away from the sun is the wolf? How do you know?

32. **Interpreting Graphics** In Figure 3-4, how many first-level consumers are there for each producer?

33. **Comparing and Contrasting** In Figure 3-4, compare the amount of energy available to the wolf if it eats a rabbit with the amount of energy available to the wolf if it eats a shrew.

34. Extra Credit: How are single men and single women related ecologically?

# APPENDIX C-6

# CHAPTER 4 TEST – ECOSYSTEMS AND COMMUNITIES

Biology Test – Ch. 4 – Ecosystems and Communities

Name ______________________

Answer the following questions in complete sentences unless I ask you to list, then just list.
You may skip 1 question on EACH page.

1. What greater advantage does a barnacle have when it is attached to a whale?

2. Why does it rain in the tropical rainforests?

3. The lion and hyena have a relationship. What is it and does it benefit either?

4. What is dune grass's official name and what special property does it have that makes it able to recover from sand piling up during the winter months?

5. What are epiphytes?

6. If Michigan and Iowa are at the same latitude line, then why is Iowa prairie and Michigan forest?

7. What are the stages of sand dune succession?

8. Why are bogs acidic?

9. List two properties of rich soils.

10. Why is much of Europe as temperate as the USA when their latitude is North of ours? Sketch a quick map to explain.

11. Why is it dry in the desert? Draw a quick diagram in your explanation.

12. Why is it so cold at night in the desert?

13. What is a Refuge Strip? Explain the concept of these.

14. Barracuda have a mutualistic relationship with something. Describe the relationship.

15. Why are tropical rainforest soils poor for farming?

16. Define community.

17. Give and briefly explain one ammensalistic relationship.

18. What might be different about the north and south facing slopes of hills? Why is this true?

19. According to scientists, why are greenhouse gasses making the atmosphere thicker?

20. Explain why a thicker atmosphere may result in a warmer Earth.

21. List three adaptations that desert plants have.

22. Why are gazelles dependent on zebras and wildebeests. Be somewhat specific.

23. Why is there little decomposition in bogs?

24. List three things that would make succession go faster.

25. What is the mutualistic relationship between cows and bacteria?

# APPENDIX C-7

# CHAPTER 5 TEST – POPULATIONS

## Chapter 5 – Populations Name ______________________

**Multiple Choice**
*Identify the letter of the choice that best completes the statement or answers the question.*

____ 1. There are 150 Saguaro cacti plants per square kilometer in a certain area of Arizona desert. To which population characteristic does this information refer?
a. growth rate b. geographic distribution c. age structure d. population density

____ 2. Demography is the scientific study of
a. democratic societies. b. modernized countries. c. human populations. d. economic transitions.

____ 3. Which of the following describes how fast the human population is growing?
a. slowly b. The population is remaining stable. c. exponentially d. The population is decreasing.

____ 4. A disease resulting in the deaths of one-third of a dense population of bats in a cave would be a
a. density-dependent limiting factor. b. result of the demographic transition. c. density-independent limiting factor. d. result of social and economic factors.

____ 5. The number of organisms that an environment can support over a relatively long period of time is called
a. carrying capacity. b. logistic growth. c. exponential growth. d. limiting factor.

____ 6. Which would be least likely to be affected by a density-dependent limiting factor?
a. a small, scattered population b. a population with a high birthrate c. a large, dense population d. a population with a high immigration rate

____ 7. Which of the following tells you population density?
a. the number of births per year b. the number of frogs in a pond c. the number of deaths per year d. the number of bacteria per square millimeter

____ 8. Human population growth has slowed down in
a. China. b. the United States. c. India. d. Africa.

____ 9. Which are two ways a population can decrease in size?
a. immigration and emigration b. increased death rate and immigration c. decreased birthrate and emigration d. emigration and increased birthrate

____ 10. In a logistic growth curve, exponential growth is the phase in which the population
a. reaches carrying capacity. b. grows quickly and few animals are dying. c. growth begins to slow down. d. growth stops.

____ 11. What occurs in a population as it grows?
a. The birthrate becomes higher than the death rate. b. The birthrate stays the same and the death rate increases. c. The birthrate becomes lower than the death rate. d. The birthrate and the death rate remain the same.

____ 12. Which of the following is a density-dependent factor?
a. earthquake b. disease c. emigration d. immigration

____ 13. When organisms move into a given area from another area, what is taking place?
a. immigration b. emigration c. population shift d. carrying capacity

____ 14. When organisms move out of the population they were born in, it is known as
a. emigration. b. abandonment. c. immigration. d. succession.

____ 15. The demographic transition is change from high birthrates and high death rates to
a. exponential growth. b. a low birthrate and a low death rate. c. a low birthrate and a high death rate. d. indefinite growth.

____ 16. Which of the following is NOT one of the four factors that play a role in growth rate?
a. immigration b. death rate c. emigration d. demography

**Short Answer**

17. What is a density-independent limiting factor? Give two or three examples.

18. What is the job of the DNR when it comes to deer populations?

19. Many people don't want food that has been sprayed with chemicals or that is genetically engineered. As a result the organic farming movement has begun to become more popular. What is organic farming?

20. What are the two basic strategies that animals use for growing their populations?

21. Draw a logistic growth curve. Label the axes. Name three parts.

22. Why might killing deer with bullets and arrows actually be good for the deer?

23. Describe how birth and death rates change as a country goes from a 3rd World country to an industrialized one.

24. List 4 benefits that soil receives from earthworm populations.

25. What is biological pest management? Give two examples of this being done.

26. What two main factors led to the human population explosion?

**Other**

**USING SCIENCE SKILLS**

Graph I shows the growth curve for a culture of *Paramecium aurelia*. Graph II shows the growth curve for a culture of *Paramecium caudatum*, a larger species. Graph III shows the growth curves of each species when they are grown together.

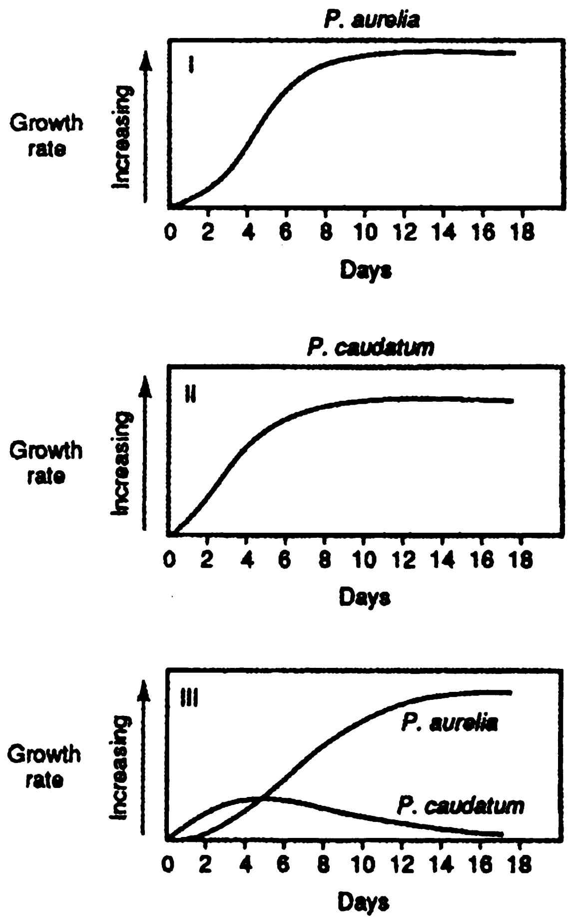



**Figure 5-2**

18. According to Figure 5-2, which species has the greatest initial growth rate when they are grown in separate cultures?

19. From Figure 5-2, which species has the greater growth rate overall when grown together? Describe the growth curve of *P. caudatum* in Graph III.

20. What type of population growth curve can be observed in Graphs I and II of Figure 5-2?

21. Give a likely explanation for the decline of the *P. caudatum* shown in Graph III of Figure 5-2?

# APPENDIX C-8

# LAB REPORT FORMAT

# Lab Report Format

Lab reports should be written in paragraph form with the following side headings:

- *Introduction*: A short summary of the rationale of the experiment. This may include a statement of the hypothesis and a short summary of the results.

- *Materials and methods*: Include enough detail so that if someone wanted to reproduce your experiment, he would know just what to do. It can be difficult to decide how much is enough without saying too much. Discuss this with your friends and your teacher.

- *Results*: Your report should include both *tables* of data and *graphs* of those same data, organized in a way that confirms or denies your hypotheses. If your working data sheets are organized and legible, you may turn them in as your *tables*. Even if an experiment is a complete failure and no plants grow, please include graphs with no data or graphs showing your negative results. This is to demonstrate that you understand how to set up such graphs with appropriate axes.

- *Conclusions and Discussion*: This is your opportunity to interpret your results. Explain or speculate on why you got the results you did. This is also the place to explain negative results if your plants never germinated. What may have gone wrong? What would you change if you were to do your experiment again? What other experiments would you suggest for testing this or similar hypotheses?

APPENDIX C-9

CITY PLANNING PROJECT

# City Planning Project

You and your group of 4 students have the opportunity to time travel back 100 years. You are to serve on Grand Rapids' City Counsel and plan the layout of the city. Your job is to take the information that you know about Grand Rapids today and design the city to be environmentally, agriculturally, socially, and economically friendly. Your will be able to draw in the highways and everything just as you'd like to make an ideal "Cool City."

1. List some good things that Grand Rapids has going for it today.

2. List some problems that Grand Rapids has today.

3. List some things that Grand Rapids should have today.

4. Parts of cities are zoned for various functions. Some areas are residential, some agricultural, some industrial, and some recreational. Any part of the city can be zoned in any combination of ways. Determine what percentage of Grand Rapids should be zoned as:

    a. Agricultural

    b. Residential

    c. Industrial

    d. Recreational

5. Get a topographic map of Grand Rapids area and begin to sketch in some ideas. Be creative as you determine where the following things should be located. On scratch paper, write down some reasons for why you placed certain things in the places that you did. Remember that districts can be any size or shape that you want.
    a. Radio/TV/Cell Phone Towers
    b. Farm Districts

c. Business Districts
d. Industrial Districts
e. Recreational Districts
f. Sewage Treatment Plants
g. Land fills
h. Water Towers
i. Free ways

6. Now that you have some ideas, begin making a poster showing the Greater Grand Rapids area. For now, you need to do this just by showing the major rivers and a few of the lakes. Leave a little space on top for a title but make the rest so that it is large enough to fill the whole poster.

7. After your rivers and lakes are drawn on your poster, begin to lay out your zones and draw in the free ways.

8. Next draw in some of the other major roads and the rest of the items from # 5.

9. Draw in any other minor details that you'd like. These may be baseball fields, parks, etc.

10. Each of you will now be responsible to justify your poster with a 1-page typed report. The report simply has to justify your city design. Essentially you are answering the question: Why did you place the various zoned areas and other items where you did? Make sure that each of your group has notes about why you placed things where you did so that it is easy to type your poster.

11. Hand in your poster.

APPENDIX C-10

EATING THEMSELVES OUT OF HOUSE AND HOME
READING WORKSHEET

Eating themselves out of house and home.
Reading Worksheet.

Name ________________________

1. What does the article mean when it says that seasonal thinning would be appropriate?

2. Why has the deer population spiked in the past years?

3. Give two reasons why an abundant deer population is not a good thing.

4. Besides shooting the deer, what other population control methods have been used?

5. What is significant about Sharon Woods' vegetation from 6 feet high to the forest floor?

6. What can deer populations do to the diversity of tree species in some areas?

7. What can deer populations do to the diversity of bird species in some areas? (Be "tree-height specific.")

8. How do you personally feel about hunting and deer population control?

APPENDIX D

STUDENT SURVEY

Science of Agriculture - Survey

Name ____________________________

Instructions: Answer the following questions in complete sentences.

5. Do you have any experience with farming or with gardening? If so, what?

6. Do you feel that you will have a garden of your own some day? Why?

7. When you own your own home, do you feel that you will work to develop the soil under your grass or will you just throw fertilizer down as prescribed by the manufacturers? Why?

8. Answer the following questions on a scale of 1 – 5.
   1 = Not true 3= I guess 5 = Very True

   a. Studying soil is complex, there's a lot to know. 1 2 3 4 5

   b. People that pour their used motor oil into the ground behind their home should be penalized. 1 2 3 4 5

   c. Golf courses increase the health of the environment. 1 2 3 4 5

   d. Genetically modified organisms are a hazard to the environment and to your health. 1 2 3 4 5

   e. Organically grown foods are better for you than inorganic. 1 2 3 4 5

   f. Clay is a valuable component in soils. 1 2 3 4 5

   g. Soil bacteria slow down plant growth and should be killed. 1 2 3 4 5

   h. Earthworms ruin your plants because they eat roots. 1 2 3 4 5

# APPENDIX E

# LABORATORY ACTIVITIES

# APPENDIX E-1

# RHIZOBIUM SYMBIOSIS LAB

# Lab - Rhyzobium Symbiosis

Purpose: Many plants, especially legumes, live in a mutualistic relationship with bacteria. These bacteria live in special growths on the roots of the plants called nodules. They have the essential ability to convert atmospheric nitrogen into forms that plants can use. This process is called Nitrogen Fixation. In this lab we will show how this symbiotic relationship gets expressed to a greater extent during times in which the plant is undergoing nitrogen limitation. The idea is to show that plants that are not being supplied with nitrogen will have a larger bacteria population supporting it so that it is supplied with the amount of nitrogen that it needs for growth. Evidence of the greater abundance of bacteria will be that the root nodules will be more abundant and larger on the plants that require lots of N-fixation.

Procedure:

1. Gather materials and bring them to your lab table.
    a. 2 cups with potting soil
    b. 4 seeds
2. Poke two small holes at the bottom of each cup for water drainage.
3. Plant two seeds about ½ inch deep in the soil of both cups.
4. Label the cups with the your names, the type of bean you choose, and in addition label one cup NPK and the other PK
    a. NPK labeled cups will be supplied with fertilizer water that has all three limiting factors: Nitrogen, Phosphorus, and Potassium
    b. PK labeled cups will be supplied with fertilizer water that has only Phosphorus and Potassium.
5. Pour equal amounts of fertilizer water into each cup. Be sure to pour the right fertilizer into the right cup or your lab will not work out.
6. Place your cups in nearly equal positions under the plant growth bulbs in the room.
7. It will now be your responsibility over the next couple of weeks to water your plants when needed as you come into the room for class. Part of your grade for this lab will reflect your watering consistency.
8. After a couple of weeks, label the plants as being either NPK or PK. Then pull the plants up and clean off the roots under running water.
9. Take scientific note of the nodule abundance and size. (Make this a very accurate measurement!)
    - One way to do this is to select an average inch of root from each plant and actually count the number of nodules from each. Next, to compare the sizes cut all of the nodules off and weight them. The difference in weight will reflect the difference in size.
10. Cut up a root nodule and crush it. Place a tiny amount of it on a microscope slide. Next place one large drop of water on the slide with a small drop of methylene blue dye. Place a cover slip over the slide and observe it with a 40x objective under a microscope.

11. Try to draw a picture of what you see. Next to the drawing describe the action that you see in 2 or more sentences. Refer to your drawing while you describe the action.

# APPENDIX E-2

# SOIL AGGREGATES AND BACTERIA ABUNDANCE LAB

# Lab - Soil Aggregates and Bacteria Abundance

Purpose: The purpose of this lab is to clearly show that there is a great abundance of bacteria in soil aggregates. Briefly, we will be doing this by making different dilutions of a crushed aggregate soil sample and streaking each dilute sample on to a Petri dish which will grow bacteria. In addition, this lab should show the difference in bacterial abundance among several soil types. These are from a forest, grass field, farm field, and softball infield. Groups will have to collaborate so that we can be sure that all soils will be represented equally for good results.

We will do this work by gathering 10 g of soil from different sources and mixing the soil and 100 ml of water. Because there are only 10 g of soil and 100 ml of water, we could say that this is a 10% mixture. That is there is 10 grams of soil to every 100 ml of water. Next we will begin to dilute that 10% down to 0.0195%. We will do this by pouring half of the 100 ml of water and soil into another beaker. Next we will add 50 ml of pure water to that second beaker. This beaker now has only five parts soil to every 100 ml of water and so it is a 5% solution. We will continue to dilute on until you have a solution which is only 0.0195% soil and 99.9805% water.

Procedure:

1. Gather two 200ml beakers and label by soil types.
2. Weight out 10g. of each soil sample and place them in the corresponding beakers.
3. Add distilled water to each beaker until they are filled to the 100 ml level.
4. Mix both well and pour ½ into a second empty beaker.
5. Add 50ml. of water to this beaker.
6. Mix well and pour ½ into a third empty beaker.
7. Add 50ml. of water to this beaker.
8. Mix well and pour ½ into a fourth empty beaker.
9. Add 50ml. of water to this beaker.
10. Mix well and pour ½ into a fifth empty beaker.
11. Add 50ml. of water to this beaker.
12. Continue this until you have a 0.0195% solution
13. Pipet out one drop of water from each solution and place those onto the agar of several Petri dishes.
    a. Do this as smoothly and carefully as possible so that the only bacteria that get into the Petri dish come from the dilute water solutions.
14. Label the Petri dishes with the corresponding percentage of water that was placed into it.
15. Wrap the outside of each Petri dish with the paraffin that you have been given.
16. Allow these to incubate for two days.
17. Observe the Petri plates and record your observations.
18. When your work in the lab is finished, clean up your work area, and find a seat and begin to work on your lab report.

APPENDIX E-3

SOILS AS ELECTRICAL SYSTEM LAB

# Lab - Soils as Electrical Systems

Different soils have a different ability to hold onto the nutrients that it comes in contact with. Of this ability is known as its cation exchange capacity. Although these words seem large, the concept is quite easy. Clay particles and organic molecules in the soil have a net negative charge. By contrast, many soil nutrients are positively charged. As a result, the more clay molecules and organics that a soil has the better its ability is to hold onto the nutrients that it comes into contact with. In this lab, we will simply are observed the fact that good rich soils have a lot of negatively charged particles while poor soils have negatively charged particles.

Procedure:

1. Gather the necessary material.
    a. 60 g or 1/4 cup of the soil that your group is responsible for.
    b. 600 ml beaker
    c. 6 volt lantern battery
    d. two pieces of 12 gauge, plastic insulated, multiple stranded, twisted copper wire of about 20 in. in length
2. Place 60 g of the soil in the 600 ml glass beaker.
3. Add 500 ml of tap water to the above container with soil.
4. Stir or shake the container for several minutes until the soil is completely mixed with the water.
5. On each and of the electric lawyers, removed the insulation and strip back that insulation to expose the bare wire for about 2 in. at the ends of the wires.
6. Connect one end of each wire to the terminals of the battery and screw the terminal tight to fix the wire to the terminal.
7. Place each of the other ends of the electric lawyers in the clay suspension about 5 cm below the top of the water line in the beaker. Make sure the bare ends of the two wires are spaced about 5 cm apart from each other and do not touch each other. Mark which of the two wires is connected to the positive end of the battery and which is connected to the negative end of the battery.
8. Leave the wire electrodes in the clay slurry for about 10 to 15 minutes and then pull them out to see what happened.
9. Answer the following questions.
    a. Which electrode do you think will have attracted the clay to accumulate on the bare wire?
    b. What general principle is being observed here?
    c. What should be true of soil that has many negatively charged particles?

Graveel, Dr. John G. (September 5, 2004) ) Demonstrations in Soil Science
http://www.agry.purdue.edu/courses/agry255/brochure/brochure.html

# APPENDIX E-4

# CHEMICAL MOVEMENT IN SOILS LAB

## Lab - CHEMICAL MOVEMENT IN SOILS

Soils can do an excellent job of adsorbing many chemicals that are added to the surface or incorporated into the soil. However, not all chemicals are retained by the soil. Some chemicals move with the rain water that passes through the soil and thus, can contaminate ground water.

As an example, when nitrate ($NO_3$) is added to the soil in fertilizers, or through wastes from septic systems or land disposal of manure it has the potential to move through the soil if not intercepted by plant roots or denitrified (returned to the air) by bacteria. If high concentrations reach the ground water, it can present a health hazard. Problems of nitrate movement into ground water are most serious in regions of sandy soils with shallow water tables in rainy seasons or when irrigation is used. Current evidence indicates that $NO_3$ is sometimes found in wells that are shallow and close to animal feeding lots, fertilizer dealerships, or home septic systems.

Why does nitrate ($NO_3$) move in soil and ammonium ($NH_{4+}$), another form of nitrogen in soil, not move. Let's conduct an experiment using a blue dye (methylene blue) which has a positive charge like ammonium and a reddish-orange dye (eosine red) that has a negative charge like nitrate.

Materials and Methods:

This demonstration uses colored organic dyes (one positively charged and the other negatively charged) to illustrate what happens when water soluble chemicals of different charge are placed in soil.

1. Get two funnels that will hold at least 10ml of soil + some dye.
2. Place a small part of a cotton ball at the bottom of both funnel cups.
3. Fill the funnels with exactly 10 ml. of your soils.
4. Place the funnel above/on a 250ml Erlenmeyer flask which will be used to collect the water that filters through the soil.
5. In the first column of soil pour 20 ml of methylene blue dye solution (0.2g/liter), it has a positive charge like ammonium, $NH_{4+}$.
6. Into the second column pour 20 ml of another dilute dye solution, it has a negative charge like $NO_{3-}$.
7. When the second column has dyed water moving through, record how many ml it took for the dye to begin coming through. Into that same 1st funnel, now make a third soil column. This time pour a mixed solution of the methylene blue and the other dilute dye solution.

Questions:

1. Does the blue or red solution come through the soil into the containers below?
2. Can you explain why the red dye moves through the soil and the blue dye is retained by the soil?

Graveel, Dr. John G. (September 5, 2004) Demonstrations in Soil Science
http://www.agry.purdue.edu/courses/agry255/brochure/brochure.html

# APPENDIX E-5

## USING A COMPOUND LIGHT MICROSCOPE LAB

(Permission for publication has been granted from Prentice Hall)

# LABORATORY SKILLS 5

## *Using a Compound Light Microscope*

### Pre-lab Discussion

Many objects are too small to be seen by the eye alone. They can be seen, however, with the use of an instrument that magnifies, or visually enlarges, the object. One such instrument, which is of great importance to biologists and other scientists, is the compound light microscope. A compound light microscope consists of a light source or mirror that illuminates the object to be observed, an objective lens that magnifies the image of the object, and an eyepiece (ocular lens) that further magnifies the image of the object and projects it into the viewer's eye.

Objects, or specimens, to be observed under a microscope are generally prepared in one of two ways. Prepared or permanent slides are made to last a long time. They are usually purchased from biological supply houses. Temporary or wet mount slides are made to last only a short time-usually one laboratory period.

The microscope is an expensive precision instrument that requires special care and handling. In this investigation, you will learn the parts of a compound light microscope, the functions of those parts, and the proper use and care of the microscope. You will also learn the technique of preparing wet-mount slides.

### Problem

What is the proper use of a compound light microscope?

Materials *(per group)*

Compound light microscope
Prepared glass slide
Lens paper
Soft cloth (or cheesecloth)
Newspaper
Glass slide Coverslip
Dissecting needle
Medicine dropper
Scissors

### Safety!

Put on a laboratory apron if one is available. Always handle the microscope with extreme care. You are responsible for its proper care and use. Use caution when handling glass slides as they can break easily and cut you. Never use direct sunlight as a light source for a compound light microscope. The sunlight reflection off the mirror up through the microscope could damage your eye. Be careful when handling sharp instruments. Observe proper laboratory procedures when using electrical equipment. Note all safety alert symbols next to the steps in the Procedure and review the meanings of each symbol by referring to the symbol guide on page 10.

**Procedure**

**Part A. Care of the Compound Light Microscope; Parts of the Compound Light Microscope**

1. Figure 1 shows the proper way to carry a microscope. Always carry the microscope with both hands. Grasp the arm of the microscope with one hand and place your other hand under the base. Always hold the microscope in an upright position so that the eyepiece cannot fall out. Take a microscope and place it on your worktable or desk at least 10 cm from the edge. Position the microscope with the arm facing you.

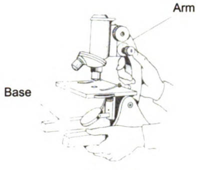



**Figure 1**

2. Study the labeled drawings of the microscopes in Figure 2. Identify the following parts on your microscope: eyepiece, arm, coarse adjustment, fine adjustment, revolving nosepiece, lowpower objective, high-power obje<:tive, stage, stage clips, stage opening, diaphragm, light source (mirror or lamp), and base. Review the function of each part of the microscope in Figure 2. Do not *proceed* with this investigation until you can identify all the parts of your microscope and describe the function of each part. Note: ***Tell your teacher at once if you find any parts of the microscope missing or damaged.***

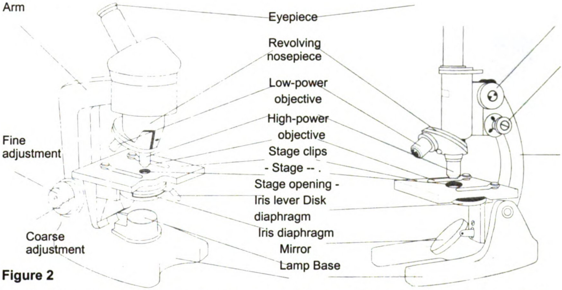



**Figure 2**

3. Notice the numbers etched on the objectives and on the eyepiece. Each number is followed by an "X" that means "times." For example, the low-power objective may have the number "lOX" on its side, as shown in Figure 3. That objective magnifies an object 10 times its normal size. Record the magnifications of your microscope in the Data Table. The total magnification of a microscope is calculated by multiplying the magnification of the objective by the magnification of the eyepiece. For example:

| magnification of low-power objective | x | magnification of eyepiece | = | total magnification |
|---|---|---|---|---|

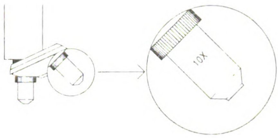



Figure 3

4. Before you use the microscope, clean the lenses of the objectives and eyepiece with lens paper. Note: *To avoid scratching the lenses, never clean or wipe them with anything other than lens paper. Use a new piece of lens paper on each lens you clean. Never touch a lens with your finger. The oils on your skin may attract dust or lint that could scratch the lens.*
5. Use a soft cloth or a piece of cheesecloth to wipe the stage and the mirror or light.

Part B. Use of a Compound Light Microscope

1. Look at the microscope from the side as shown in Figure 4. Locate the coarse adjustment knob which moves the objectives up and down. Practice moving the coarse adjustment knob to see how it moves its objectives with each turn.
2. Turn the coarse adjustment so that the low-power objective is positioned about 3 cm from the stage. Locate the revolving nosepiece. Turn the nosepiece until you hear the high-power objective click into position. See Figure 5. When an objective clicks into position, it is in the proper alignment for light to pass from the light source through the objective into the viewer's eye. Now turn the nosepiece until the low-power objective clicks back into position. Note: *Always look at the microscope from the side when moving an objective so that the microscope does not hit or damage the slide.*

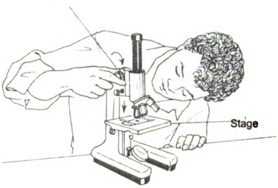



Figure 4

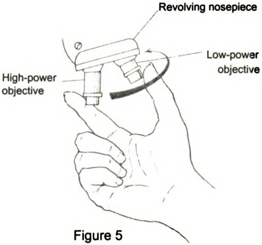



Figure 5

3. If your microscope has an electric light source, plug in the cord and turn on the light. If your microscope has a mirror, turn the mirror toward a light source such as a desk lamp or window. CAUTION: *Never use the sun as a direct source of light.* Look through the eyepiece. Adjust the diaphragm to permit sufficient light to enter the microscope. The white circle of light you see is the field of view. If your microscope has a mirror, move the mirror until the field of view is evenly illuminated.

4. Place a prepared slide on the stage so that it is centered over the stage opening. Use the stage clips to hold the slide in position. Turn the low-power objective into place. Look at the microscope from the side and turn the coarse adjustment so that the low-power objective is as close as possible to the stage without touching it.

5.. Look through the eyepiece and turn the coarse adjustment to move the low-power objective away from the stage until the object comes into focus. To avoid eyestrain, keep both eyes open while looking through a microscope. CAUTION: *To avoid moving the objective into the slide, never lower the objective toward the stage while looking through the eyepiece.*

6. Turn the fine adjustment to bring the object into sharp focus. You may wish to move the diaphragm to adjust the amount of light so that you can see the object more clearly. In the appropriate place in Observations, draw what you see through the microscope. Note the magnification.

7. Look at the microscope from the side and rotate the nosepiece until the high-power objective clicks into position. Look through the eyepiece. Turn the fine adjustment to bring the object on the slide into focus. CAUTION: *Never use the coarse adjustment when focusing the high-power objective lens. This could break your slide or damage the lens.* In the appropriate place in Observations, draw what you see through the microscope. Note the magnification.

8. Remove the slide. Move the low-power objective into position.

**Part C. Preparing a Wet Mount**

1. Use a pair of scissors to cut a letter "e" from a piece of newspaper. Cut out the smallest letter "e" you can find. Position the "e" on the center of a clean glass slide.

2. Use a medicine dropper to place one drop of water on the cut piece of newspaper. See Figure 6.

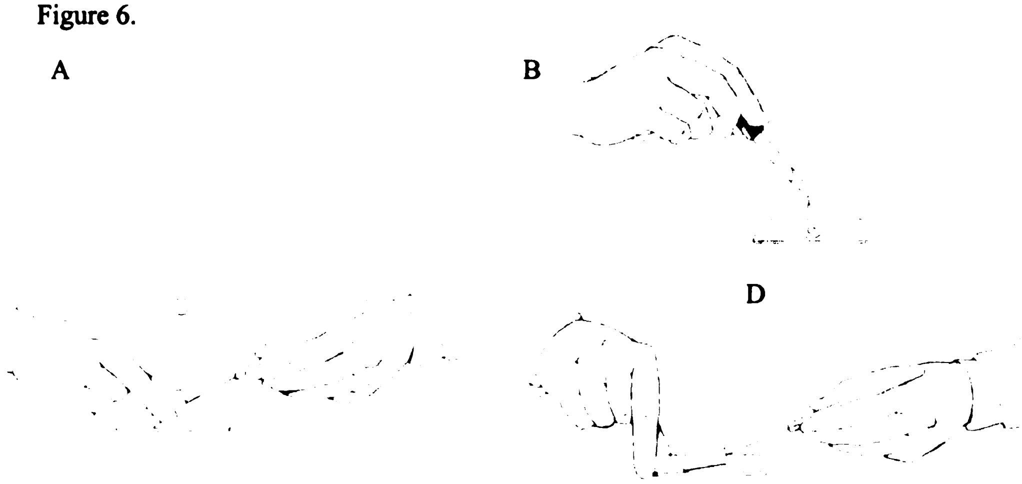



**Figure 6**

3. Hold a clean coverslip in your fingers as shown in Figure 6. Make sure the bottom edge of the coverslip is in the drop of water. Use a dissecting needle to slowly lower the coverslip onto the wet newspaper. Slowly lowering the coverslip prevents air bubbles from being trapped between the slide and the coverslip. The type of slide you have just made is called a wet mount. Practice the technique of making a wet mount until you can do so without trapping air bubbles on the slide.

4. Center the wet mount of the letter "e" on the stage with the "e" in its normal upright position. Note: *Make sure the bottom of the slide is dry before you place it on the stage.* Turn the low power objective into position and bring the letter "e" into focus. In the appropriate place in Observations, draw the letter "e" as seen through the microscope. Note the magnification.

5. Turn the high-power objective into position and bring the letter "e" into focus. In the appropriate place in Observations, draw the letter "e" as seen through the microscope. Note the magnification.

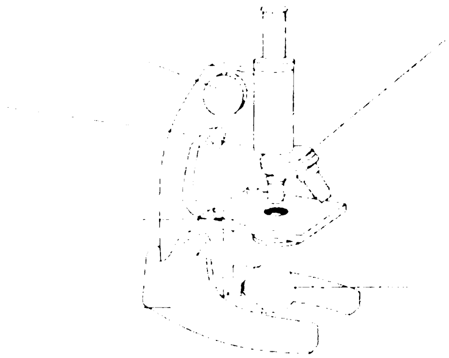
6. Rotate the nosepiece until the low-power objective clicks back into position and bring the letter "e" into focus. While looking through the eyepiece, move the slide to the left. Notice the way the letter seems to move. Now move the slide to the right. Again, notice the way the letter seems to move. Move the slide up and observe the direction the letter moves. Move the slide down and observe the direction the letter moves.

7. Take apart the wet mount. Clean the slide and coverslip with soap and water. Carefully dry the slide and coverslip with paper towels and return them to their boxes.

8. Rotate the low-power objective into position and use the coarse adjustment to place it as close to the stage as possible without touching. Carefully pick up the microscope and return it to its storage area.

## Observations

1. Label the parts of the microscope shown below.



2. Fill in the magnification of each objective and the eyepiece of your microscope. To determine the total magnification, multiply the magnification of each objective by the magnification of the eyepiece.

Data Table

| Objective | Magnification of Objective | Magnification of Eyepiece | Total Magnification |
|---|---|---|---|
| Low power | | | |
| High power | | | |
| Other | | | |

3. Make a detailed drawing of the object on your prepared slide as seen under low power and high power.

Low-power magnification

High-power magnification

4. Make a detailed drawing of the letter "e" as seen under low power and high power.

Low-power magnification

High-power magnification

## Analysis and Conclusions

1. Why do you place one hand under the base of the microscope as you carry it?

2. What kind of light source do you have on your microscope?

3. How is the image of an object seen through the high-power objective different from the image seen through the low-power objective?

4. How does the letter "e" as seen through the microscope differ from the way an "e" normally appears?

5. When you move the slide to the left, in what direction does the image appear to move?

6. When you move the slide up, in what direction does the image appear to move?

## Critical Thinking and Application

1. Explain why a specimen to be viewed under the microscope must be thin.

2. Why should a glass slide and a coverslip be held by their edges?

3. Why should you use a piece of lens paper only once?

4. Why is it a good idea to place your microscope at least 10 cm from the edge of the table?

5. Suppose you were observing an organism through the microscope and noticed that it moved toward the bottom of the slide and then it moved to the right. What does this tell you about

   the actual movement of the organism?

**Going Further**

1. Obtain some common objects, such as a piece of cotton, a piece of nylon, a small piece of a
   color photograph from a magazine, and so on. View each object under the low-power and high power objectives of the microscope. Make a drawing for each object. Describe the appearance of the objects when viewed under a microscope. How did each object differ from the way you see it with the unaided eye?
2. Use an appropriate resource to investigate the development of the microscope and the advancements that have been made in microscope technology. Write a report or make an oral presentation as directed by your teacher.

APPENDIX E-6

EARTHWORM POPULATION DENSITY LAB

# Lab – Earthworm Population Density

In this lab we will be going outside to dig several holes. After we have dug the holes we will count the number of earthworms in the dirt of each.

Procedure:

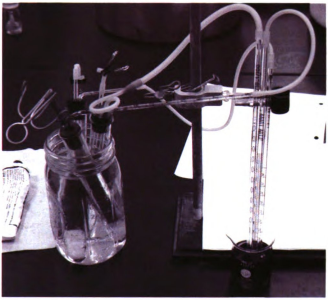
1. Go with your group to the assigned flag.
2. Start digging around the flag to a depth of about 1.5 feet.
3. Take out enough dirt so that your hole is 1 meter in diameter and 1.5 feet deep.
4. Toss all of the dirt on the tarp that has been provided.
5. Sift through the dirt and find your worms.
6. Place your worms in the bucket that is provided.
7. The group that finds the most worms will be awarded an appropriate prize at the end of the day.
8. Record your group's data along with the data of the rest of the class on the white board in my room.
9. Make a table and a graph that accurately represents the data of the whole class.
10. Answer the following questions:
    a. What do earthworms eat?
    b. How do they benefit the soil community? (What is their niche)
    c. Why was the greatest number of worms found in the ecosystem where they were?
    d. Why were there so few worms in the ecosystems that proved to have so few of them?
    e. Approximately how many earthworms would you expect to find at your house if you were to do the same project there?

# APPENDIX E-7

# SOIL TYPE AND BIOLOGICAL ACTIVITY LAB

# Lab - Soil Type and Biological Activity Lab

Purpose:
In this lab we intend to prove to ourselves that the bacteria and protists in the soil are working to break down the organic matter in the soil. We will show this by measuring the amount of oxygen that is being taken up by the microorganisms. The theory is that more oxygen is required all on those groups of microorganisms that are doing more work. Again, similar to the last lab, we will be comparing good soil and pour soil for microbial activity. We will measure the amount of oxygen and being used by sealing the bacteria in a chamber known as a respirometer. The chamber is similar to the one on the right in which the CO2 being given off by the bacteria will be combined with a substance behind the cotton. As the amount of oxygen in the chamber gets depleted, it will create a vacuum. This vacuum will suck up blue dye from a small beaker. Those soil samples with the greatest amount of bacteria will be the ones that use up the most oxygen, create the greatest vacuum, and as a result, suck up the most dye.



Procedure:
1. Gather your materials and bring them to your workstation.
    a. 1 long and 1 short rubber hose
    b. one two-holed stopper
    c. one test tube
    d. one 1/10ml pipet
    e. one ring stand with a clamp
    f. one 600ml beaker with room temperature water
    g. two short glass tubes
    h. one cotton ball
    i. enough sodium hydroxide or potassium hydroxide to fill about a half inch of the bottom of your test tube
    j. 30 grams of the soil sample assigned to you
    k. two hose clamps

2. Assemble the various parts so that your end result is similar to the one shown in the picture.
    a. Be very careful while pushing the glass tubes into the two-holed stoppers. The glass can break. It is best to wet the glass and push it into the stopper with a twisting motion.
3. Ask your teacher to double-check your final set-up.
4. We will leave these in-place overnight and return tomorrow to check out how much dye has been taken up as result of the vacuum created by the bacteria.
5. As a group make a prediction about which soil type will yield the greatest amount of bacterial activity and support your ideas. Do this as a group on one piece of paper with both of your names on it and hand that it to Mr. VanOverloop.
6. Cleanup your work area and go find a seat where you can begin work on your lab report. Also, make sure you are prepared to take a five question quiz tomorrow on the idea of this lab and its set up.

Follow-up questions:

1. Which sites had the highest and lowest microbial activity?
2. What site characteristics area associated with high and low levels of microbial activity?
3. Do human activities such as fertilization influence the level of bacteria activity?
4. How might the presence of microbes enhance plant growth? How might the plants be harmed by an absence of microbial activity?
5. How does your initial ranking of the soil match up with the activity?

APPENDIX E-8

AGGREGATES AND SOIL MANAGEMENT LAB

# Lab - Aggregates and Soil Management

Purpose: Soil aggregates, an important component of soil structure, consists of individual soil particles bound together by organic and inorganic compounds. Organic compounds which stabilize aggregates becoming trapped in their interior where decomposition is suppressed. This action benefits the entire ecosystem by removing some carbon dioxide that had been in the atmosphere and trapped sit in the soil. Additionally, soil aggregation reduces erosion, increases soil porosity, and may indirectly increased plant growth. Aggregation is known to vary considerably among different soil types as a result of the quantity and quality of carbon inputs, but earthworm abundance, plowing frequency, and plant species affects are also important.

In this exercise we will compare aggregation of soils from a farm field, grass field, and forest. A common method for testing aggregation is to see and soil through meshes of different sizes. We will use aggregates remaining on a 4 mm sieve as an indicator of total soil aggregation.

Procedure:

1. The way out 300 g of each soil and to weigh boats.
2. Place a 4 mm sieve onto a stainless steel bowl.
3. Poor the soil from the way boat evenly around the surface of the sieve and agitate the sieve gently.
4. Gently transfer the aggregates to another weigh boat. Weigh the aggregates and determine the percentage that it constitutes of the original soil sample.
5. Do this again you seem to other types of soil.
6. Record your results on the Whiteboard in front of the class.
7. Write down all of the information that the class gathered and create a graph that represents this data accurately.

APPENDIX E-9

SOIL MICROBES DECOMPOSITION LAB

## Soil Microbes Decomposition Lab

### Purpose

To understand that millions of microorganisms live in a handful of soil and these microorganisms, some too small to see with the naked eye, eat organic matter such as grass clippings, fallen plant leaves, and algae. In doing so, they reduce dead organic matter on Earth's surface and release nutrients from the decomposing organic matter for living plants to use.

### Materials and Tools

- 2 Handfuls of grass clippings
- 1 cup of potting soil
- 2 zip-closing plastic bags
- A sharp pencil
- A teaspoon

### Preparation

- Go out to a freshly mowed yard and gather grass clippings.
- Purchase zip-closing plastic bags.
- Obtain a teaspoon and a sharp pencil

### What to Do and How to Do It

1. Place one handful of grass clippings in each of two plastic bags.

2. In one bag, add a cup of fresh potting soil and mix well. In the other, leave the clippings as they are. Seal both bags.

3. With a pencil, carefully poke 5-10 air holes in each side of each plastic bag. Be careful not to poke yourself.

4. Place the bags in a dark place. Once each week, open the bags and add a teaspoon of water.

5. After one week open the bags and look inside. Look closely at the grass. Aside from being dirty in the soil bag, does the grass in either bag look like it has changed from when you placed it in the bag initially?

Write down your observations. Close the bags and put them back into a dark place.

6. After one more week, open the bags and look closely again at the grass in each bag. Compare what you see. Write down your observations. Close the bags and put them back into a dark place.

7. Continue to observe the bags for the next few weeks. Write down your observations and explain what you think is happening to the grass, and what is going on in the soil.

Class investigation- What has happened to the grass that was initially placed in the soil? What happened to the grass without soil? Over time, what is occurring to the grass in the soil? What is occurring to grass that has no soil? What factor does air, water, and temperature play in the decomposition process? If the air, water, and temperature levels are low what do you think will happen or wont happen to the grass, soil, and microorganisms living in the soil?

http://soil.gsfc.nasa.gov/activ_98/microact.htm

APPENDIX E-10

SEED GERMINATION AND GROWTH LAB

# Lab - Seed Germination and Growth Experiments

**Synopsis**

This is a long-term experiment (8-12 weeks) in which you will plant seeds and watch germination and early growth. The ideas is to decide for yourselves the variable(s) you want to test against an appropriate control. You will be provided with certain basic materials, *e.g.,* plastic seedling starter pots, potting soil, and a light table, but are otherwise responsible for designing the experiment, gathering the data, and presenting their results. The *experimental process* is the important lesson here; the actual results are less important than how they were obtained.

**Objectives**

The primary objectives of this exercise are related to experimental design. It is intended to help you develop the abilities to do scientific inquiry.

- ask questions that can be answered through scientific investigation;
- design and conduct a scientific investigation;
- use appropriate tools and techniques to gather, analyze, and interpret data;
- use mathematics in scientific inquiry; and
- communicate scientific procedures and explanations.

In addition, after completing this exercise, you should be able to describe the ways that biotic and abiotic factors can affect seedling development and plant growth.

You will be given several days to consider the experiment you wish to pursue. Each of you will be in a group of two and must do your own experiment.

- 'Watering' with different substances like orange juice, tomato juice, beer, etc. Warning—this can get pretty stinky over time.
- Using different colors of light by covering plants with colored cellophane.
- Light versus dark.
- Different temperatures (some seeds set to germinate in a refrigerator).
- Using different soils.
- Using different soil additives.
- Hydroponics.
- Playing music to the plants. You have to do this at lunch in a separate room, so other plants won't 'overhear' it.
- One student rigged up a battery and subjected her plants to electric shocks.

# APPENDIX F

# STUDENT ASSENT FORM

Student Assent Letter
Re: Collection of Data for Master's Thesis
Thesis Title: Incorporating an Agricultural Emphasis in Ecological Education
August 20, 2005

Dear student,

The following letter is a form letter necessary for the completion of my graduate work at MSU. It asks for permission to use your grades on quizzes, tests, and homework in a study that I will be doing during the 1st 6-week period of the school year.

For the past three years, I have been enrolled as a graduate student in Michigan State University's Department of Science and Mathematics Education (DSME). I have chosen to do my thesis work on teaching about the science of farms while I teach ecology. The idea is to teach my ecology unit making several references to farming and to do several labs that show both ecological and agricultural (farming) principles. In doing so, I hope to lead you to appreciate the farming community that exists all around you and equip you to be good managers of the lawns and gardens that you will own in the future.

In order to complete the thesis work, I need to examine information that is generated by you, such as pre and post-tests, quizzes, lab questions, written responses, surveys, and interviews about agricultural ecosystems. I will organize the information in graphs and charts and present these to a board at MSU. The data that are generated will remain confidential. Your privacy will be a big concern. I will not allow anyone at MSU to know whose work is whose. I will be taking pictures of you doing some of my labs and those pictures will also not have any names attached.

Participation in this study is strictly voluntary. You may choose to not participate at all. If you don't want me to use your grades then you will still have to do all of the work but I will not use your grades in my thesis presentation.

Please complete the attached form and return it to me by September 10, 2005 so that I can have adequate data for the study. If you have any questions about my work this coming semester, I encourage you to contact me at jonvo@altelco.net or at my home phone (249-0552) or school (453-5048.) Questions about the work can also be directed to Dr. Merle Heidemann at DSME 118, N. Kedzie, Michigan State University, East Lansing, MI 48824 or by her phone (517-432-2152 , ext.107) or by her 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 Vaselenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517)355-2180, fax: (517)432-4503, email ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Thank you,

Jon VanOverloop

# Student Assent Form

Name ________________________________________

Please check all that apply:

Data:

_____ I give Mr. VanOverloop permission to use data generated from my work in this class. All data shall remain confidential.

_____ I do not wish to have my work used in this thesis project.

Images:

_____ I give Mr. VanOverloop permission to use pictures of me in his thesis project. My name will not be attached to any picture.

_____ I do not wish to have my image used at any time during this thesis project.

____________________________________ ______________

Student Signature (Date)

APPENDIX G

PARENT CONCENT FORM

Parental Consent Letter
Re: Collection of Data for Master's Thesis
Thesis Title: Incorporating an Agricultural Emphasis in Ecological Education

August 20, 2005

Dear parent,

The following letter is a form letter necessary for the completion of my graduate work at MSU. It asks for permission to use your child's grades on quizzes, tests, and homework in a study that I will be doing during the 1st 6-week period of the school year.

For the past three years, I have been enrolled as a graduate student in Michigan State University's Department of Science and Mathematics Education (DSME). I have chosen to do my thesis work on teaching about the science of farms in my ecology unit. The idea is to teach my ecology unit making several references to farming and to do several labs that show both ecological and agricultural (farming) principles. In doing so, I hope to lead your child to appreciate the farming community that exists all around West Michigan and equip them to be good managers of the lawns and gardens that they will own in the future.

In order to complete the thesis work, I need to examine information that is generated by them, such as pre and post-tests, quizzes, lab questions, written responses, surveys, and interviews about agricultural ecosystems. I will organize the information in graphs and charts and present these to a board at MSU. The data that are generated will remain confidential. Your child's privacy will be of utmost concern. I will not allow anyone at MSU to know whose work is whose. I will be taking pictures of your children as they do some of my labs and those pictures will also not have any names attached.

Participation in this study is strictly voluntary. You may choose to not have your child participate at all. If you don't want me to use their grades then they will still have to do all of the work but I will not use their grades in my thesis presentation.

Please complete the attached form and return it to me by September 10, 2005 so that I can have adequate data for the study. If you have any questions about my work this coming semester, I encourage you to contact me at jonvo@altelco.net or at my home phone (249-0552) or school (453-5048.) Questions about the work can also be directed to Dr. Merle Heidemann at DSME 118, N. Kedzie, Michigan State University, East Lansing, MI 48824 or by her phone (517-432-2152 , ext.107) or by her 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 Vaselenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517)355-2180, fax: (517)432-4503, email ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Thank you,

Jon VanOverloop

# Parent Consent Form

Name of Child: ______________________________________

Please check all that apply:

Data:

_____ I give Mr. VanOverloop permission to use data generated from my child's work in this class. All data shall remain confidential.

_____ I do not wish to have my child's work used in this thesis project.

Images:

_____ I give Mr. VanOverloop permission to use pictures of my child in his thesis project. My child's name will not be attached to any picture.

_____ I do not wish to have any image of my child used at any time during this thesis project.

______________________________ ______________

Parent Signature (Date)

GENERAL REFERENCES

Andres, Dale W. and Juergenson, Elwood M. (1966) Selected Lessons for Teaching Agricultural Science The Interstate Printers and publishers, Inc. Danville, Illinois, 339 pages

Bonner, Jose. (Oct 2004) The Biology of Food The Science Teacher 71, 8

Borsari, Bruno. (Feb 2001) Sustainable agriculture: Its time has come - A Discussion on the Burgeoning Change in Agricultural Education Journal of College Science Teaching 30, 5; Education Module. pg. 336

Brian Parr (2004) INQUIRY-BASED INSTRUCTION IN SECONDARY AGRICULTURAL EDUCATION:PROBLEM-SOLVING – AN OLD FRIEND REVISITED Journal of Agricultural Education Volume 45, Number 4, pp 106-117

Chiappetta, Eugene L; April D Adams (Feb 2004) Inquiry-based instruction The Science Teacher 71, 2; pg. 46

Clark, Raymond M. (July 1967) Source Units for Plant Science Bureau of Educational Services. College of Education, MSU, East Lansing, MI, 49 pages

Crowther, David T; (Sep/Oct 1999) Cooperating with constructivism Journal of College Science Teaching 29, 1; pg. 17

Cuddeford, Vijay . (Fall 2003) When organics go mainstream Alternatives Journal Vol.29, Iss. 4 pg. 14

De Quattro, Jim. (Sep 1996) Full circle--and then some Agricultural Research. Vol.44, Iss. 9; pg. 12

Drawbaugh, Charles C and Hull, William L (1971) Agricultural Education: Approaches to Learning and Teaching Charles E Merrill Publishing Company, Columbus Ohio

Falvey, Lindsay (Nov 1997) Negative Impact of Food Production Australian Science Teachers Journal Vol.43, Iss. 4; pg. 7

Faniran A, and Areola, (1978) O Essentials of Soil Study Heinemann Educational Books Ltd, London, Nairobi, 278 pages

Faust, Robert M. (Nov 2004) Integrated Pest Management Programs Strive To Solve Agricultural Problems Agricultural Research 52, 11

Grow, Peggy L; Plucker, Jonathan A (Dec 2003) Good Problems to Have The Science Teacher; 70, 9

Jofili, Zelia; Geraldo Ana; Watts, Mike (May 1999) A course for critical constructivism through action research: A case study from biology. Research in Science & Technological Education.Vol.17, Iss. 1; pg. 5

Johnson, Roger T; David W Johnson (Jan 2000) How can we put cooperative learning into practice? The Science Teacher 67, 1; pg. 39

Kennedy, Ann C; Smith, Karen L; Neff, Raymond L (Feb 1995) Soil searching The Science Teacher 62, 2; pg. 34

L.H. Newcomb et al. (2004) Methods of Teaching Agriculture (3rd Ed.) Pearson Prentice Hall, Upper Saddle River, New Jersey 07458, 390 pages

Lurquin, Paul; (2002) High Tech Harvest Westview press. Boulder Colorado, USA, 218 pgs

Peat, Mary; Taylor, Charlotte; Fernandez Anne. (Jun 2002) From informational technology in biology teaching to inspirational technology: Where have we come from and where are we going? Australian Science Teachers Journal. Vol.48, Iss. 2; pg. 6

Pimentel, David et.al. (Jul 2005) Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems Bioscience Vol.55, Iss. 7; pg. 573

Rehorek, Susan J (Sep 2004) INQUIRY-BASED TEACHING: An Example of Descriptive Science in Action The American Biology Teacher Vol. 66, Iss. 7; p. 493

Rollins, Timothy J; Scanlon, Dennis C; (Fall 1991) THE COGNITIVE, PERCEPTUAL, AND INSTRUCTIONALPREFERENCES OF AGRICULTURAL EDUCATION STUDENTS Journal of Agricultural Education , pp. 48-54

Saunders, Walter L (Mar 1992) The Constructivist Perspective: Implications and Teaching Strategies for Science School Science and Mathematics 92, 3; pg. 136

Senft, Dennis (Apr 1992) Turn 'Em on to Science, Turn 'Em into Scientists! Agricultural Research 40, 4; pg. 24

Slavin, R. F. (1980) "Cooperative Learning." Review of Educational Research, , 50(2), 315-342

Spence, Larry (Oct 2004) The Usual Doesn't Work: Why We Need Problem-Based Learning Libraries and the Academy Vol.4, Iss. 4; pg. 485

Sternadel, Lisa (Apr 2004) INQUIRY AND DEVELOPING INTERPRETATIONS FROM EVIDENCE The Science Teacher 71, 4; pg. 38

Stock, Adah (Mar 2005) Doing Good Science in Middle School: A Practical Guide to Inquiry-Based Instruction Science Scope 28, 6; pg. 64

Tessier, Jack T (Sep 2004) Ecological Problem-Based Learning: AN ENVIRONMENTAL CONSULTING TASK The American Biology Teacher Vol.66, Iss. 7; pg. 477

Troeh, Frederick R. (2005) Soils and Soil Fertility 6th Ed. Blackwell Publishing, 2121 State Avenue, Ames, Iowa 50014, USA., pages 1-126

Volkmann, Mark J; Abell, Sandra K (Sep 2003) Rethinking laboratories The Science Teacher 70, 6; pg. 38

Woodward, Lawrence (Summer 2002) The scientific basis of organic farming ISR. Interdisciplinary Science Reviews Vol.27, Iss. 2; pg. 114

Yuretich, Richard F (Dec 2003/Jan 2004) Encouraging critical thinking Journal of College Science Teaching 33, 3 pg. 40

## SITED REFERENCES

"A Look at Michigan Agriculture" 5-6-06 USDA Agriculture in the Classroom webpage http://www.agclassroom.org/kids/stats/michigan.pdf

Barrick, Kirby R (Winter, 1989) Agricultural Education: Building Upon our Roots Journal of Agricultural Education pp.24-29

Bricker, Garland Armor (1915) The Teaching of Agriculture in the High School The MacMillan Company, Norwood Press, Norwood Mass., USA, 202 pages

Colburn, Alan (Sep/Oct 2000) Constructivism: Science Education's "Grand Unifying Theory" The Clearing House Vol.74 Iss.1 pg.9

Cornell University (June 5, 2006) The Land-Grant Colleges http://www.cals.cornell.edu/cals/about/overview/land-grant.cfm

Darling-Hammond, L., & Falk, B(1997, November). Using standards and assessments to support student learning. PhiDelta Kappan, 79(3), 190-199.

Davis, Barbara Gross (1993) Tools for Teaching Jossey-Bass Publishers: San Francisco

Graveel, Dr. John G. (September 5, 2004) Demonstrations in Soil Science http://www.agry.purdue.edu/courses/agry255/brochure/brochure.html

Hammer, D (1997) Inquiry learning and discovery teaching. Cognition and Instruction U 15(4): 485-529

Herreid, Clyde Freeman (Winter 2005) Because Wisdom Can't Be Told: Using Case Studies to Teach Science Peer Review Vol.7, Iss. 2; pg. 30, 2 pgs

Hsiao, Jy Wana Daphne Lin CSCL Theories http://www.edb.utexas.edu/csclstudent/Dhsiao/theories.html#construct Accessed 7-21-05

Kendler, Barry S; Grove, Patricia A; (May 2004) Problem-Based Learning in the Biology Curriculum. The American Biology Teacher Vol.66 Iss. 5 pg. 348

Lewis, Anne *C* (May 2003) Agriculture Program Changes Tech Directions Vol.62 Iss.10 pg. 4

Lord, Thomas R. (Jan 2001) 101 reasons for using cooperative learning in biology teaching The American Biology Teacher Vol.63 Iss. 1 pg 30

Luxmoore, R. J. (1994) Soil Science Education: Philosophy and Perspectives Soil Science Society of America Madison, WI, USA, 176 pages

Mark, Kelly E. (May 1990) Dirt-Cheap Soil Studies The Science Teacher 57, 5; pg. 70

McCracken, J.D. (1983) A profession in need of academicians. The Journal of the American Association of Teacher Educators in Agriculture 24(l), 2-12.

Michigan Teacher Network (August 15, 2005) Ecology Benchmarks http://mtn.merit.edu/mcf/SCI.III.5.HS.html

Miller, Steve (Dec 1989) These Students Track Disappearing Soybean Gene Agricultural Research 37, 12

NSW Department of Primary Industries (August 2002) Cation exchange capacity Accessed on (June 7, 2006) http://www.agric.nsw.gov.au/reader/soil-types-structure/ss393-cation-exchange.htm

Nye, Reuben L. (1921) A Century of Progress in Agricultural Education, A Thesis Michigan Agricultural College, 47 pages

Owens, R. F.; Hester, J. L.; & Teale, W. H. (2002, April) Where do you want to go today? Inquiry based learning and technology. Reading Teacher 55(7)

Phillips, Katherin A. Germann, Paul J. (Sep 2002) The inquiry "I": A tool for learning scientific inquiry The American Biology Teacher Vol.64 Iss. 7 pg 512

Papez, Jacqueline (June 7, 2006) Soil Aggregate Formation: determining the timeline for aggregate formation using a glacial chronosequence http://ibscore.dbs.umt.edu/journal/Articles_all/2001/Papez.htm

Pratt, Sandra (Apr 2003) Cooperative Learning Strategies The Science Teacher 70, 4; pg 25

"Seed Germination" (August 12, 2005) http://www.biology.duke.edu/cibl/exercises/seed_germination.doc

Sewell, Audrey . (Dec 2002) Constructivism and student misconceptions: Why every teacher needs to know about them Australian Science Teachers Journal Vol.48 Iss. 4 pg. 24

Shinn, G.C., & Cheek, J.G. (1981). Agricultural teacher education functions can be delivered more effectively through a department of agricultural and extension education. The Journal of the American Association of Teacher Educators in Agriculture, 22(2), 308, 63.

"Soil Microbes" (September 8, 2005) http://soil.gsfc.nasa.gov/activ_98/microact.htm

"Soil Science Education Homepage" (September 8, 2005) http://soil.gsfc.nasa.gov/index.html

Stanley, W.O., Smith, B.O., Benne, K.D., & Anderson, A.W. (1956) Social Foundations of Education. New York: Dryden Press.

Zimdahl, Robert L. (2000) Teaching Agricultural Ethics Journal of Agricultural and Environmental Ethic 13, 3-4 pg. 229