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FIELDWORK AS AN EFFECTIVE MEANS OF THEACHING ECOLOGY TO SECONDARY STUDENTS

By

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ABSTRACT

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Science curriculum in ecology often lacks authentic investigations with real world applications. Inquiries are frequently conducted in the classroom, out of the context of the scientific community. Students sometimes view science a list of terms and objectives to be learned for a test for the purpose of earning points and passing a class.

The purpose of teaching this unit is threefold; 1) to teach students how to do authentic scientific inquiry by giving them opportunities to do hands-on investigations with real world applications; 2) to use the outdoor resources available on the campus of Fowlerville High School to develop an ecology unit that teaches the state mandated benchmarks to produce ecologically and scientifically literate students; 3) to give students a sense of place by familiarizing them with their local ecology.

Students took a pretest and a post-test on fundamental topics in ecology. The results of these assessments indicated that students improved their understanding of fundamental ecological concepts. Anecdotal observations from investigations conducted by the students suggest that they also experienced and increased awareness of the scientific process.

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After three years of doing tissue culture and cancer research at Michigan State University, I realized a growing discontent with my professional life and a need to do something different. My dissatisfaction stemmed from the fact that the research I was doing wasn't my own and that while I was generating important data for the fight against cancer, I wasn't seeing an immediate impact on those people afflicted with the disease. Further adding to my restlessness was that this particular research project did not afford me the opportunity to pursue other interests and it did not allow for much ownership of the research.

A friend suggested that I combine several of my interests and my science education by becoming a high school life science teacher. After all, I still loved science. I just didn't care for the job. This move would allow me to use my science education, to pursue the interests I was missing, to have a very large degree of autonomy in my job, and to have a very immediate impact on the target group. So I enrolled in a teacher education program and became a student again.

Meanwhile, I took another research position at Barros Research Institute. There were many benefits to this position. I was working with a brilliant scientist, Dr. Barney Rosenberg, looking for a kinder, gentler cure for cancer than the current best treatments at the time. He was just as concerned about teaching his employees how to do "good science" as he was the completion of the project. It provided me with the financial means and time necessary to get my teacher certification. There was an additional bonus that came from working in what I call "grassroots science" that I hadn't counted on. I learned how to do "true scientific inquiry" and to really understand the scientific process. I became aware of the creativity and malleability in the scientific process, and I came to realize that science was in the service of mankind versus mankind being in the service of science as I once thought. This was probably due to the fact that Dr. Rosenberg used his talent at doing research to solve social problems. He could see that it was a tool to better us all and that the power of the science came from the individuals performing it. I did not realize the value of the lessons and skills I had learned until I actually began teaching. In fact, to this day I believe it was this experience in research and real life application of scientific method that earned me my teaching position at Fowlerville High school.

Upon making the transition from scientist to science teacher I became disappointed and discouraged at the lack of understanding of the scientific process demonstrated by high school students as a whole. I found that they could memorize the steps of the scientific method and that they could recite the definitions to the science related terms. Yet, they had no idea of how to carry out "authentic" scientific investigations. How could this be? After all, when do you actually learn how to do science? 7^{th} grade? 8^{th} grade? When do you learn to inquire like a scientist? The kids have the curiosity, but not the process. I think because I had lived the scientific process, I didn't realize that it was difficult skill to master and that scientific inquiry involves a type of thinking that is not inherent in anyone, especially 15 and 16 year olds in an isolated classroom.

I learned how to do good science toward the end of my undergraduate career when I had to do an independent research project and thesis and more so in the workplace after college. I think it was a result of several factors. First, the scientists I worked with and for were real scientists and themselves masters at problem solving. Secondly, the work they were doing was real and important and they knew that. It was not an exercise executed out of context in an isolated classroom devoid of any real world application, as it so often seems to be in current high school curricula.

Elaborating further, I thought to myself, what is it about the current way my students are being taught that is causing this discrepancy between knowledge and ability? As I considered this and observed my own teaching methods, I realized that I was mistaking activity for achievement. In most every laboratory investigation students were asked to perform, there I was standing over them with a clear-cut answer. I would quickly guide the students to the desired answers and conclusions using a cookbook procedure, which I provided for them, all in the course of one class period. This was nothing like the science I had done in the real world.

I had to construct my own procedures to test a hypothesis that we as a research group had formed, or at least evaluate established procedures to determine if they would be appropriate. When we had trouble or got results that we couldn't explain, there was no teacher there to tell us what it was suppose to mean. We had to draw our own conclusions, modify our procedures, or simply repeat the experiment. This is not something you typically see in the high school classroom or at least not what I was doing. What would I have to do differently to get my students to think critically and to be able to do authentic scientific inquiry? This question brings me to my first study objective: to teach students how to do scientific inquiry by giving them hands on opportunities to do investigations with real world applications, and to identify elements of scientific inquiry that are missing in my own teaching methods.

At Fowlerville High School there are three instructors that teach the required Biology I course. We all use "Biology: The Dynamics of Life" published by Glencoe/McGraw-Hill, 1995 as our textbook. We have aligned our curriculum in most respects with the science framework benchmark established by the State of Michigan in the document, Michigan Curriculum Framework Science Benchmarks (2000) and we all cover pretty much the same units during the same semesters. The only deviation in order of chapters is a product of the fact that we must all share the same equipment and resources and cannot teach the same units at the same time. I understand this and so I wasn't alarmed when we skipped over the chapters concerned with ecology and environmental issues.
It was only as we came to the conclusion of the school year when time was short and resources were in even shorter supply that I realized those objectives and corresponding chapters were only being taught if there was time and in a superficial fashion. In fact, the unit seemed to consist of a bunch of terms strung together in lecture fashion with routine and uninteresting laboratory

investigations. Furthermore, the labs in no way provoked critical thinking or the authentic scientific inquiry that I had noticed was missing from my student's education. The labs did not require the students to leave the classroom to use the natural resources available around Fowlerville High Schools Campus. I found this unacceptable for two reasons (1) We have a variety of natural resources around the high school that would lend themselves well to fieldwork, such as an old field that was turned over five or six years ago, a pine stand, a man made pond, and a deciduous forest; (2) The routine laboratory investigations that were in use at the time may teach a desired concept but seem contrived and do not foster the problem solving skills that I had learned dong my own research and that I felt the students needed. With this in mind, I arrived at study objective #2: Use the outdoor resources available on the campus of Fowlerville High School to develop an ecology unit that teaches the state prescribed benchmarks and produce an ecologically and scientifically literate student with heightened environmental awareness. There is a considerable amount of literature available, which suggests that field instruction is a valid and possibly better means of instruction than the traditional approach depending upon the concepts being taught. Disinger(1984) summarizes several different studies about the effects of field instruction in school settings. In each case, a group of high school students was divided into groups. One group incorporated fieldwork into their curriculum. While, the other did not and received instruction on the same concepts in a very traditional manner without leaving the classroom. Greater improvements were shown in both affective and cognitive domains within the fieldwork-based group. Additionally it was shown that recall and retention of facts and skills improve as well.

The third study objective is a by-product resulting from observations made while working on objective #2. It is to give students a sense of place by familiarizing them with their local ecology. It seems they may care more about the science they do if they can attribute immediate and personal importance to it. I thought that they would be more likely to demonstrate an increase in ownership and stewardship if they were more familiar with the surroundings in which the research took place.

RATIONALE FOR STUDY OBJECTIVES

"Students in all grades and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conduction investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanation, constructing and analyzing alternative explanations and communicating scientific arguments" (NSES; National Research Council, 1996 as cited in Eric Clearinghouse for Science Mathematics, and Environmental Education2001) In short, students need to experience science directly through hands on investigations in which they use their methods to test ideas they have about their world. I think that these direst investigation skills have been lost for several reasons but predominantly because information gathering has changed.

Real scientists are gathering information through experimentation as they have always done. However, this information is immediately available to students in quantities and at speeds unlike we've seen before in history. Students are losing the scientific context and process in which the information was collected. They have not had to gather the information for themselves as scientists once did. My observations are that students often lack the ability to inquire and problem solve effectively. They believe that information available on the Internet is inherently valid because it is on the Internet. Students, by and large, do not have the means for accessing validity or applicability of this information because they have had no experience in the process by which the information was produced.

Another reason for revising the ecology unit was to increase student participation and engagement. The original unit was taught very traditionally. It was lecture oriented with the teacher talking to or at students intermingling cookbook activities. Homework, typically worksheets, was assigned as a means of practice and assessment. Sometimes this is necessary. The problem is that when this becomes the norm my students lost interest and the less polite ones would even act out, displaying disruptive behavior decreasing the potential for learning. "Truancy and disruptive behavior have been identified as the main manifestations of disaffection [with schools, lessons, and curriculum]. Early research literature tends to suggest that disaffected pupils exhibit deviant behavior and they require special treatment ..." (Battersby, 1999) The focus of the labs was to provide an activity, which might have a learning benefit versus a well-considered investigation, which are often messy and time consuming that increases concept learning and mastery of the scientific process. Quite frankly, the traditional methods bored me sometime too. Where was the science? I feel it is my job not only to deliver reliable information but also, to give the students opportunities to learn how to gather information for themselves. Liskowski (1987) stated that employing an " involvement oriented way of teaching will increase interest and motivation of the students" and that "teachers can improve student interest by involvement in real life situations using real environmental issues facing local communities". With this in mind, I planned to replace some of the teacher-centered discussions in which students passively listened with student-oriented activities and inquiry based investigations. My goal was to engage the students in experiences that related to their world and required them to be actively involved.

The table below shows the contrast between selected characteristics of a traditional schooling and key characteristics of participatory, or hands-on learning (Barab and Hay, 2000) as expected to accomplish.

Traditional Schooling	Participatory Science Learning
1. Learners listen about the doings of others to receive a grade.	1. Learners do domain-related practices to address domain-related dilemmas.
2. Learning occurs at the pages of	2. Learning is participatory

textbooks and mouths of teachers.	and occur “at the elbows” of more knowledge-able others including teachers, scientists and peers.
3. The textbook and teachers ”own” the problems which have classroom, but not real-world applications.	3. Practices and outcomes are authentic and owned by the learn er and the community of practice, in response to real-world needs.

“Over the last century we have seen formal [teacher centered] schooling emerge as the predominant means of educating the young. One of the most common features of relegating education to schools is that skills and knowledge have become abstracted from their uses in the real world.” (Barab and Hay, 2000) That is, knowledge and skills are being learned out of context and therefore, students only value them in the situation in which they were learned. Students are unable to appreciate the skills, as they would apply to the community that actually uses those skills. What happens in the classroom has real world connections for the students and this practice minimizes the importance and relevance of the skills. Telling a student about something is no longer enough, and may never really have been, to positively affect learning. “Telling children how scientists how to do science does not necessarily lead to far-reaching changes in how children do science; indeed, it cannot, as long as the school curriculum is based on verbally expressed knowledge” (Papert, 1991, as cited in Barab and Hay 2000) Knowledge and skills must be taught in an authentic and active environment where the learners are doing meaningful scientific investigations. " . . . in many classrooms experiential learning or "hands on" is starting to replace or supplement traditional "chalk talks". Through experiments, simulations, debates, and other participatory activities, students discover concepts on their own. Experiential learning has been shown to increase retention, motivate students to learn, and encourage group cooperation." Braus & Woods (1993)

Finally, I think that students are losing contact with and no longer have knowledge of the world immediately around them. While out on a nature walk in our deciduous woodlot I pointed out several very common trees and wildflowers native to Michigan. I asked students to name them. None of them could. These plants were not rare or unusual and I could hardly remember a time when I couldn't identify these organisms. I also remember that I did not come by this knowledge in a formal education setting. It made me wonder what was different about my educational experiences, either formal or informal, that accounted for this observation.

Secondarily, an underlying motivation for getting students out into their local environment to give them a sense of place is this. I believe that the transient nature of our society and urbanization of our rural areas has resulted in a loss of connectedness to the land. We live on smaller and smaller sections of the land and move from city to city following jobs. Our daily routine is often house→car→office→ and back again. Recreation time is spent differently than it was a generation ago. Youth of today are frequently found in front of the TV or computer, or watching a movie, in the shopping mall, or taking part in organized sports. They simply don't go into the woods, river, and field, whatever the local environment may be anymore. It is not a matter of survival as it once was. "When man settled into villages and townships he was no longer dependent on [nature]. He had removed himself from intimate contact with nature and from the necessity for remaining in contact with her." (Smith, Steck, & Surrette, 1974) The informal education gained from immersing ourselves in nature has been lost. Cherif (1992) states that, "Teachers should concentrate more on fieldwork, both observing and investigating an ecosystem to develop an accurate understanding and appreciation of the environment and the human role in ecological process and environmental management."

Another observation I've made while growing up in the area and even in the twelve years that I've been teaching is that family farms are disappearing. We don't gather, hunt, or grow our own food any longer. It is now left up to large corporations and that too represents a loss of connectedness to the land. Historically, agricultural societies have understood natural cycles and relationships in an ecosystem because they were immersed in it daily and their lives depended on it. The relevance of this is that we have lost the awareness of how to use the land properly so that future generations have it to use too. "More people argue that students around the world-especially in urban areas-are losing touch with the natural world. In many places, outdoor experiences are not a regular part of instruction. Instead of occurring throughout a students schooling, outdoor experiences are often limited to a few outings in primary grades. Getting student out into the environment on a regular basis is part of a comprehensive environmental education program." Braus & Woods (1993) So it seems that this problem is not just a matter of what is happening outside our formal education but within it as well.

LITERATURE REVIEW: A COMPARISON OF ECOLOGICAL AND ENVIRONMENTAL EDUCATION

When I began this project my objective was clear and singular, to develop teaching methods that would allow me to make use of the natural resources on the campus of Fowlerville High School to teach fundamental ecological concepts. After all, many of the articles that I have read said that experience is the best teacher. Golley (1998) is very matter of fact stating, "Environmental literacy begins with experience of the environment" and that, "experience is the trigger for environmental literacy." While these statements confirmed what I already knew based on my own experiences as both student and teacher, the articles in which they were found raised questions in my mind about the relationship between ecology, environmental education, and environmental literacy, and a multitude of other terms and disciplines that were found in the literature such as conservation education, outdoor education, environmental science, and nature study to name a few.

Therefore, my first task in this comparison and contrast between ecology and environmental education was to clarify the terms. Are they synonymous or do they have distinctly different meanings? I felt these terms needed investigation because I needed to be clear on just what I was teaching if I intended to teach it clearly. As it turns out, there are important differences and this research was a worthwhile endeavor. "A continuing dilemma for those concerned with environmental education lies in the matter of definition. . . It is at least interesting, and may be productive, to assemble a representative selection of definitions for the purpose of comparing and contrasting them." Disinger (1998)

Ecology can be defined as the study of ecosystems, the interactions between the living and nonliving components in a given geographical area. The teaching of pure ecology is very academic and there is little room for social comment or application of personal attitudes. Environmental education is much broader in scope and knowledge of fundamental ecological concepts is a part of it. "Environmental education is a process that leads to responsible individual and group action. Environmental education should enhance critical thinking, problem solving and effective decision making skills . . . Environmental education should engage individuals as well as enable them to weigh various environmental issues to make an informed and responsible decisions. (Federal Register, Oct 16, 1992, p. 47516) One other distinction that helped me was to understand how the subject of environmental science differs from environmental education. According to Allaby (1996) "Environmentalists and environmental science are distinct. The former is a popular movement with political, social, and philosophical implications. The latter provides a means for obtaining precise information about the environment."

This definition of environmental education is the product of many years of deliberation and consideration by scientists, philosophers, and academics defining and refining various terms and parts into a collective whole. The antecedents of environmental education are nature study, conservation education, and outdoor education. While the root of current environmental education and literacy lie here, these studies may or may not have involved hard science at all. In the most basic sense, these terms seemed to mean simply moving students outside for inspiration and motivation in most any subject matter. In short this means, "The use of resources outside the classroom for educational purposes". (Swan 1975 as cited by Disinger 1998)

Nature study is the earliest forerunner of environmental education. This movement began in the late 1800's when Wilbur Jackman published Nature Study for the Common Schools. He called for taking students outdoors and into the environment for the purpose studying the whole environment. He suggested an integrated approach to learning about nature instead of dissecting and isolating factors of the environment as seem to be the trend in the classroom at the time. This book provided rationale for incorporating ecological concepts into the science curriculum. (McComas 1992)

Conservation education followed Nature Study in the early 1900's. This perspective seemed to convey an awareness of natural resources in the United States and a need to protect them. According to C. Roth (1978) this movement coined the phrases "wise use" and "natural resource management". It is easy to see the roots of environmental education taking hold with these ideas.

The distinguishing characteristics of outdoor education, which seemed to replace conservation education, were that it applied to almost any subject matter and unlike its predecessors, must take place outside the classroom. It has been closely identified with John Dewey's philosophy of "learning by doing". I think it was best summarized by L.B. Sharp (1943) in saying "that which can best be taught inside the schoolrooms should there be taught, and that which can best be learned through experience dealing directly with native materials and life situations outside the school should there be learned."

For as long as mankind has existed, I believe that there has been awareness that humans use the Earth's resources. Recently, in the last century or so, the awareness has become more a sense of concern. I think with each passing war or armed conflict we have become more aware of how we use the Earth. It is a result of arguments over resources such as oil, waterways, and land that we consider valuable and that each country needs to support its growing population. Also, after each war there is always a period of remediation and restoration where we become intimately aware of the effects that human activities have on the land. We also understand that there are limited resource and that we all want them.

Within the last thirty years or so even the tone of concern in the literature has been replaced by a dire sense of urgency and what I call a "must do" attitude. "Buttons, decals, and bumper stickers appeared proclaiming in iridescent colors, Ecology Now. It is important and instructive to find out what elements have lead to this general feeling of urgency. We appear to have crossed a threshold of some sort. The deterioration of the environment has reached a level where it has become immediately apparent to everyone" (Grahame, Steck, & Surette, 1974) How do we continue to use the Earth's resources and survive? How do we undo the damage that we have done? We read about oil spills, ground water contamination, and deforestation and habitat destruction on a daily basis. For those that are in tune with or educated about the environment understand that things must change. "It is essential that we all become aware of the potential danger, not in a casual and superficial way but with a real understanding of why the crisis is upon us" (Grahame, Steck, & Surette, 1974) The question is what must change and once that is established, how do we as educators go about affecting that change?

I believe environmental education has risen out of necessity and fear and in an attempt to find answers to these questions and more. As opinions and attitudes have evolved so has environmental education guidelines, curricula, and teaching strategies. The publication of "Silent Spring" by Rachel Carson in the early sixties may well have been the origin of the modern movement in environmental science. She wrote using only ecological concepts -food chain, trophic levels, bioamplification, etc. However, in the end the book takes a very political tone and so, in my mind modern environmental education was borne. "Nonetheless, by the last days of the1960's a body of informed opinion had developed that was sufficient to constitute the basis for the ecological [environmental] movement. Between the Santa Barbara Oil Spill in the spring of 1969 and Earth Day in the spring of 1970, the environmental question was placed on the agenda of American Politics. Ecology was promptly declared by many observers to be the issue for he 1970's." (Grahame, Steck, & Surette, 1974) The remainder of this literature review is an attempt to analyze and understand those aspects of environmental education listed above from global and local perspectives.

Goals, Principles, and Objectives of Environmental Education

The specific goals and principles of environmental education will vary from country to country. However, generally speaking they are universal and agreed upon. They were established at the Tbilisi Conference in 1977 and published in The Tbilisi Declaration. They are as follows:

1. To foster clear awareness of, and concern about, economic, social, political, and ecological interdependence in urban and rural areas,
2. To provide every person with an opportunity to acquire knowledge, values, attitudes, commitment, and skills to protect and improve the environment,
3. To create new patterns of behavior of individuals, groups, and society a whole towards the environment.

The objectives of environmental science have been presented in a variety of articles and readings. Here they are listed as they appear in the Tbilisi Declaration (1977). The same five objectives have stood the test of time and are also stressed by Braus and Wood in Environmental Education in the Schools: Creating a program that Works (1994)

1. Awareness: which helps social groups and individuals acquire an awareness of and to be sensitive to the total environment.
2. Knowledge: which helps social groups and individuals gain a variety of experiences and a basic understanding of the environment and its associated problems.

3. Attitudes: which help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.
4. Skills: to help social groups and individuals acquire skills for identifying and solving environmental problems.
5. Participation: which provide social groups and individuals with an opportunity to be actively involved at all levels in working towards resolution of environmental problems.

Guiding Principles and What Environmental Education Should Do

Due to the lengthy nature of this section of the Tbilisi Declaration, I have paraphrased the guiding principle of environmental education when possible.

1. Consider the environment in its totality natural and built, technological and social.
2. Be a continuous lifelong process.
3. Be interdisciplinary in its approach.
4. Examine major environmental issues from local, regional, national, and international.
5. Focus on current and potential environmental situations while taking into account historical perspectives.
6. Promote the value and necessity of local and international cooperation in prevention and solutions.
7. Consider environmental plans for growth and development.

8. Enable learners to have a role in their learning experiences and provide opportunities for making decisions and accepting consequences.
9. Relate environmental sensitivity, knowledge, and problem solving to all ages.
10. Help learners to discover the symptoms and causes of environmental problems.
11. Emphasize the development of critical thinking skills.
12. Utilize diverse learning environments and a wide variety of educational approaches to teach . . . with emphasis on first hand experiences.

On an international level it appears that there is marginal success at implementing environmental education programs in K-12 schools. Industrial nations are doing better than developing countries in implementing comprehensive environmental education programs. "Today there is a large gap between the level of the use of EE in the curricula on the industrialized countries on the one hand, and in developing countries on the other." (Muyanda-Mutebi & Yiga-Matovu, 1993) According to the African Social and Environmental Studies Program (1993) the greatest constraints of environmental education being felt in developing countries are:

1. Lacks of official recognition - Globally less than a quarter of the nations have effectively implemented Environmental Education strategies in their school curricula. Most of the world's developing countries are among the remaining three quarters that have not implemented environmental education programs.

2. Lack of Funds – this problem is persistent in all countries and presents a major hurdle to the implementation of environmental education strategies. There is usually no special allocation of funds and so purchasing special material and performing the necessary fieldwork are difficult.
3. Lack of Infrastructure and resources - There is a lack of personnel, communication, and physical resources to sustain the development of an environmental education program. Things like textbooks, teaching materials, and student work packets are not available.

Environmental Education in the United States

There has been a great deal of progress made in the United States since the passage of two very important environmental documents, the United Nations Educational, Scientific and Cultural Organization-United Nations Environment Programme, 1976 and the Tbilisi Declaration in 1978. Since this time, every state in the nation has incorporated environmental education into formal public education to some extent or another. Until the mid 1990's the extent of the progress was unknown. At that time, Kirk, Wilke, and Ruskey conducted a survey identifying the extent to which each of the fifty states had achieved the 16 components of a comprehensive environmental education program as established by Ruskey and Wilke. It is interesting to note that 11 states had master plans and 13 states were developing master plans for environmental education. Only 12 states had established by-laws requiring incorporation of environmental education into existing science curriculum. Of the 50 states, 15 had in place and 17 states were developing coordinated statewide teacher in-service programs. Only 3 states require any sort of environmental education training for pre-service teachers. Twenty-four states had provided adequate funding for environmental education programs and funding for the future looked optimistic. But, as of yet, no state in the USA had in place all 16 components of a comprehensive environmental education program. The point of reviewing these statistics is to point out that while we have made progress, there is still a long way to go.

Environmental Education in Michigan

Globally speaking the goals of environmental education is clear but daunting. I think that they are out of reach for most secondary schools and high school biology teachers. In order to achieve the objectives enumerated in the Tbilisi Declaration schools would have to devote an enormous amount of time to environmental education and find a substantial amount of additional resources to support the class. Whether environmental education is taught as interdisciplinary course or in a multidisciplinary, infused fashion one thing is clear. Budget considerations will factor into the implementation process. A highly sophisticated course that requires a great deal of lab equipment and field work is likely to be out of reach financially for public schools. The multidisciplinary approach to implementation and support of an environmental program will also be costly but is more likely to be successful because the cost is spread over multiple departments, curricula, and grade levels. (Hungerford and Peyton, 1986 as cited by Volk) The reality of the situation for many high schools is that implementing a comprehensive environmental education program is not possible at this time due to budget limitations. So let's examine what is possible using the current curriculum and recommended by local agencies.

The following is from Michigan Curriculum Framework: Science Content Benchmarks published in the summer of 2000. It lists the objectives, key concepts and real world context for learning goals. The benchmarks are an effort to standardize science education in Michigan and ensure a thorough and uniform education for all students from school district to school district. It seems that while there are some strands that are devoted to environmental education, the major emphasis is on teaching of ecological concepts. Those specific benchmarks are listed below.

1. Describe common ecological relationships between and among species and their environments.

Real World Context – Animals that live in packs or herds and plant colonies such as –wolves, bison, lilies and other bulb plants, various forms of algae.

2. Explain how energy flows through familiar ecosystems.

Real World Context – Energy Pyramids for food webs in various ecosystems.

3. Describe general factors regulating the population size of an ecosystem.

Real World Context – Common factors that influence relationships, such as weather, disease, predation, migration.

4. Describe the responses of an ecosystem to events that caused it to change.

Real World Context – Climax forests comprised of maple-beech or conifers, effects of urban sprawl or clear cutting of forests, effects of catastrophic changes such as the eruption of Mt. St. Helens.

5. Describe how carbon and soil nutrients cycle through selected ecosystems.

Real World Context –Movement of food materials through various food webs, including decomposition.

6. Explain the effects of agriculture and urban development on selected ecosystems.

Real World Context – Common factors that influence ecosystems, such as pollution of ecosystems from fertilizer, insecticide, and other chemicals.

There are very few benchmarks or curriculum specified for environmental education as a separate field of study in the state of Michigan. Benchmarks and concepts that do relate to environmental education are infused into various sections of the current science benchmarks. I find it interesting and disturbing to analyze the benchmarks in light of the push for environmental education programs at the secondary level. There is only one benchmark in the current framework devoted entirely to environmental education. Others may have an environmental education spin hidden in them but remain ecology concepts. This makes me wonder if it is really my job as a biology instructor to teach environmental education. It requires me to focus on social and cultural issues, politics, attitudes and sensitivities. As a scientist, have I received adequate training in that arena to be an effective teacher?

As I look back at my own preparation for teaching, I can say that my science education in my major and minor areas was exceptional. The same can be said f\the teacher certification program I attended in order to become a science teacher. It is clear that if I were to become an environmental education teacher I would have to prepare differently. The education given to traditional biology teachers would be only one part of the program. Teachers would need additional training in topics such as issue analysis, values clarification, politics, and philosophy of environmental education. It will be interesting to see how national and local governments adjust their curriculum requirements to remediate. Will new requirements be added to the current standards for certification as a science teacher or will there be entirely separate criteria specified for environmental education teachers?

Assuming that a teacher has had the proper preparation to be skilled in the instruction of environmental education, what exactly will take place in the classroom? What exactly is the ideal K-12 curriculum? "The notion of curriculum orientation is an interesting one with the most basic curriculum taxonomy containing three distinct types: ideal, intended, and received. (Cuban, 1992) It is important to know what the objectives are for the students, how you will accomplish those objectives and finally how you will evaluate how well you did at conveying those objectives. Sometimes what we teach isn't always what the student learns. The ideal curriculum is what students are provided through classroom experiences, discussions, investigations, and goals held by the teacher. This would usually relate to the curriculum benchmarks established and mandated by each state. The received curriculum is what the students actually learned or experienced for themselves, the information, attitudes, experiences, and perceptions that they actually take away from the lessons. (McComas, 2002)

I think that in order for Environmental Education to have the intended impact on our students and our future that it must have its own benchmarks and curriculum separate from the Biology and Life Science class that high schools offer. That is not the norm in most districts. According to Disinger (1987) "Infusion of environmental topic into other curricular areas was noted as a prevalent mechanism of inclusion in secondary schools". Ninety percent or more of the teachers he surveyed infusion as common practice and that it most always happened in biology class.

Governor Granholm and the Michigan Department of Education approach the teaching of Environmental Education topics in a similar manner. In an article published on the Sate of Michigan web site, and similarly in the August 2005 issue of Woods-N-Water News, "States Recognize the Value of Environmental Education" by Tom Carney. Granholm has earmarked one million dollars of the Clean Michigan Initiative funds to a three-year project developing and evaluation an environmental education for middle schools. The curriculum includes five topics: Air Quality, Ecosystems, Energy and Resources, Individuals Impact on the Land, and Water Quality. The program is reported to support the current benchmarks for science education in the state of Michigan. In addition, 3000 middle school educators will be trained and given ample support to implement this program into their current science curriculum during the 2005-2006 school year.

While the new environmental education goals are being infused into current curricula, environmental educators must have training specific to environmental education. It appears that environmental education preparation for teachers is applied like a bandage, fixing what's wounded. There does not seem to be any specific degree requirements in environmental education for teacher certification. Although, there are a great number of environmental studies and environmental science degree programs available at colleges and universities across the nation for individuals entering different fields like engineering, government, corporate and non-profit fields. This doesn't make sense. We need to teach environmental education but lack the specific training. "There is no traditional grammar or secondary school subject that focuses on the environment and relatively few school districts off a specific environmental course. However, many states mandate teaching about the environment . . ." "relatively few colleges or universities provide special environmental education courses for pre service teachers. In the future, more will be expected from all K-12 teachers in the area of environmental education." (Peterson's Guide 1993)

H.R. Hungerford and R.B. Peyton have very specific ideas about what preparation is necessary for a K-12 environmental education teacher. (1986)

1. Focus on and reflect the multifaceted and interdisciplinary nature of the environment. In doing so teachers should be provided with opportunities to

acquire and apply knowledge and attitudes important in environmental education. At the very minimum, this preparation should include:

a. Basic training in ecology
b. Field and/or laboratory experiences in environmental science.
c. Knowledge of environmental issues and problems of resource Management.
d. Competencies in environmental problem identification, issue analysis, Issue investigation and evaluation and citizenship action.
e. Opportunities to develop value-clarification skills and knowledge of roles of human values in environmental issues.

2. Provide instruction and experience with multidisciplinary curriculum as well as instructional activities and methods similar to those they might use in their own classrooms.

3. Provide instruction on philosophy and goals of environmental education and the nature of interdisciplinary and multidisciplinary environmental education curricula.

4. Provide specific training-particularly at the elementary level-in basic general education skills.

5. Provide opportunities for teachers to develop skills identifying, inventorying, and evaluating local resources for use in environmental education.

In order to teach about the environment an important consideration a teacher must make is how to breakdown the topic into sub-groups. Just how do you divide the topic of the environment? – Living vs. nonliving? That approach is good if life" is your central consideration, which is probably true if you are a biologist at heart. Perhaps you would split the topic into natural vs. built or manmade if human activities are your central consideration. This approach would suit you better if you were a social scientist at heart. Either way, it begs the question, what is the role of the teacher in an environmental education classroom?

According to John Hug (1998) an environmental educator "is not the mediator, trade off specialist or negotiator, but a developer of skills and an information analyst who prepares people who will participate in environmental decision making." He goes on to say that environmental educators are free to hold their own opinions about environmental issues but when teaching must remain neutral and must not be "propagandists for their own personal interests." The role that a teacher takes in an environmental education classroom hinges on a variety of matters for example, the curriculum being used, the materials available for teaching, the benchmarks that are mandated for the particular state in which the teacher works. It seems that the teaching about the environment can be seen on a spectrum with one end representing the pure ecologists and the other end representing the pure environmental educators. On the ecology end of the spectrum you'd see descriptors listed like: ecological concepts, knowledge, local, quantitative data analysis, outcomes based, organized, teacher driven and compartmentalized. At the opposite end under environmental education you'd find words like awareness, empowered citizenry, global, unstructured, moral and ethical considerations, multidisciplinary, integrated, and environmental action project. A teacher must consider his or her skills, interests, professional responsibilities, resources, and motivation to locate their place along the spectrum before beginning to teach EE. (Shoenfeld, 1969)

A comparison of environmental problem solving approaches, by John Ramsey (1994) of four of the most influential environmental educators of our time, Robottom, Hammond, Stapp, and Hungerford provide insight into what they feel the teacher's role should be in an environmental education classroom. In all four instances it is presumed that high school students have a basic understanding of ecological concepts. In fact, according to D.C Engleson (1993) by the time students get to high school ecology foundations should already have been laid and in grades 10 – 12 are an area minor emphasis. Robottom believes that the teacher should work jointly with the students collaborating on original research projects and organize educational experiences so that students have opportunities to engage in problem solving and inquiry activities. Hammond suggests that the role of the teacher is as a mentor and coach. He implies that direct, teacher centered instruction is necessary but says it should be reserved for significant skills. Stapp thinks that the teacher should be a facilitator, a source of information, and a coordinator of educational activities and opportunities. Hungerford would like the teacher to be much more directly involved by leading discussions and providing structured skill development using established curricular models. Teachers would primarily use direct and traditional instruction for skill development, but allow for small group and collaborative learning.

Regardless of how teachers incorporate environmental education into their curricula or what role they chose to take in their classrooms, they will need to evaluate the effectiveness of their efforts. If educators are specifying and mandating learning objectives in environmental education, then they measure the success of their students at accomplishing these objectives. Because environmental education is a multidisciplinary subject evaluating student success can be challenging and the tools used for assessments can take many forms.

How do you evaluate changes in attitude and awareness about the environment or an increase in problem solving skills? The affective nature of these objectives requires the use of nontraditional assessment tools. A traditional test would be useful to measure the accumulation of knowledge or increase in cognition about fundamental ideas in ecology, which is important for environmental education. However, the experts like Stapp and Hungerford recommend alternative assessments, which, are not necessarily new but have not been commonly applied to the sciences until recently.

Stapp (as cited in Bardwell et al, 1994) suggests the use of student reflection and self-assessment in the form of journals and peer review to evaluate achievement of objectives. Hungerford looks for competency in skills by employing teacher developed skill tests. Students are also responsible for developing an investigation plan about an environmental issue. Students sign a contract with the teacher on the plan and then the teacher uses the contract to evaluate student progress. Students prepare final oral and written reports about their investigations and issues for presentation to the class and teacher. These are not the only tools that can be used to evaluate outcomes in environmental education though. Marcinkowski (1989) explains many more alternative assessments to a traditional test such as: manipulative tasks and investigations, writing assessments, oral discourse, exhibitions, portfolios, and concept mapping. The point is that there are a great number of assessment tools available to environmental education teachers. Any of them alone or in combination is sufficient and appropriate to use.

This literature review proved to be quite informative and brings to light several interesting and significant differences between ecological education and environmental education with respect to their respective goals, implementation, and evaluation. While the goal of ecological educations' goal is primarily increasing knowledge base in the cognitive domain, environmental education is targeted at a learners' affective domain. This definition of environmental science emphasizes that point, "Environmental Education is aimed at producing a citizenry that is *knowledgeable* concerning the biophysical environment and its associated problems, *aware* of how to help solve those problems, and *motivated* to work towards their resolution" (Stapp, et al., 1969)

Ecological education has been implemented in K-12 curricula throughout the United States with relative ease and success. It think this is due in part, to the fact that it is a single discipline, the curriculum is well defined, there are plenty of resources available, and that student achievement if fairly easy to evaluate by objective means. This is not the case for environmental education. It is multidisciplinary in nature and the curriculum is still evolving. Every bit of information I have read says that a comprehensive environmental education program will be cost prohibitive to implement because is does span multiple topics and involve a huge number of students and staff. In my own experience the greatest difficulties with implementation come form:

1. Lack of financial resources
2. Availability of time
3. Accessibility to resources
4. Lack of appropriate teacher training

Finally, student achievement is much more difficult to evaluate in environmental education because of its affective nature. In fact, measuring success requires some pretty creative tools in comparison to those typically used ecological education.

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IMPLEMENTATION

DEMOGRAPHICS

Fowlerville is a rapidly changing village located in central, Lower Michigan between Detroit and Lansing. Within the last 20 years it has changed from a small, rural, predominantly agricultural community to a manufacturing and industry based town. Many of the large family farms that used to exist have disappeared and given way to subdivisions. Although you will still see a family owned IGA and a granary and feed warehouse as you pass the main four corners of town.

Fowlerville is nestled in western Livingston County. Neighboring school districts are Howell, Hartland, and Brighton. Livingston County is the fastest growing county in Michigan and one of the fastest growing in the United States. We are seeing a great influx of families from Lansing and Detroit, as it is centrally located between the two cities on the I-96 corridor. This contributes to a somewhat transient population and a large number of families living in rental type communities. The NCA accredited district spans 116 square miles with a population of 15,000 individuals. From the years 1997-2003 enrollment increased 10.2%, from 2866 to 3188 students.

Students must pass three credits of science to graduate from Fowlerville. Typically 9th graders will take Earth Science/Physical Science and10th graders will take Biology I. The third year of science is an elective and so students may choose from a variety of courses based on their needs and interests. All but a few sophomores take Biology I and therefore we have seven or eight section of it. I am responsible for three of those sections which are usually composed of 24 -28 students of varying talents. Within the classes there is great economic diversity but little or no ethnic diversity.

METHODOLOGY

The unit designed for the study of the environment originally included only one chapter from the textbook, "Biology: The Dynamic of Life" published by Glencoe/McGraw-Hill, 1995. The unit was entitled Principles of Ecology. Since then the environmental unit has increased in scope to include three chapters in the textbook: Chapter 3 – Principles of Ecology, Chapter 4 – Community Distribution, and Chapter 5 – Population Biology. Figure 1 is an outline of the Principles in Ecology unit showing individual chapter and topics of the textbook along with the corresponding objectives and student activities. I have included copies of student activities and assignments that I feel are unique to this unit and promote the development and use of authentic inquiry skills. Figure 2 is a similar outline showing the topics and corresponding activities that have been added since the original Principles in Ecology Unit.

TABLE 1: PRINCIPLES OF ECOLOGY UNIT OUTLINE

Section	Topic	Activity/Assignment (with Appendix reference)
Organisms and Their Environment	1. Biotic and abiotic factors. 2. Levels of biological organization 3. Niche and Habitat	Pretest/Post-test(A1) Objectives (A2) Vocabulary Terms Nature Walk – Outside Ecology (A3)
How Organisms Interact	1. Types of symbiotic relationships 2. Ecological pyramids and Nutrient cycles	Transparency – Food Webs Guided Reading Notes (A4) Relationships in a Community Worksheet Grassland Community Food Web Worksheet Transparency – Biological Pyramids Transparency - Carbon and Nitrogen Cycles "Mineral Nutrition of Lemna (A5) Model Your Own Ecosystem Using "Eco-columns Vocabulary Quiz Chapter review Post-test evaluation.

Pretest/Post-test Evaluation: Principles in Ecology (A): The goal of the pretest is to see what the student already knows and what they don't. I use it to establish a baseline or point from which to start the unit. It also serves as a tool by which I can measure student achievement because it makes up a portion of my post-test evaluation. Assessment should measure mastery of ecological objectives and nothing else like the students ability to follow instructions or grammar. I give it and show the results to the students and save it for later to compare with post-test results. Students enjoy seeing their improvement.

Objectives: This is a list of goals. I determined the goals to include based on what is mandated in the Michigan Curriculum Science Benchmarks. This gives students an idea of daily activities and expectations for learning. Also, it helps to organize the students and teacher.

Vocabulary Terms: The students must read through the unit content and define the terms listed. Then, often as a warm up I will ask them to use vocabulary lists and practice them with a nearby partner. Students seem to like the vocabulary assignments because they are not difficult to accomplish and are "easy points". What concerns me is the level of engagement that the students experience. They can complete the assignment without ever really thinking about the terms they are defining. I question the effectiveness of vocabulary assignments but have not had the opportunity to measure. However, understanding vocabulary is critical to success in science.

Guiding Reading Notes (B): The goal of this activity is to get students to read critically and gather information independently. If students do their preliminary work, then I do not have to lecture as much and can move to activities that engage the students and reinforce concepts. I do go over notes to give examples of and clarify concepts that I know students typically struggle with and give them an opportunity to ask questions. Often these types of notes serve as a reference for future labs and activities. Students learn very quickly that putting effort into these will pay off later. So, the quality of the responses seen in these types of assignments usually increases throughout the year. Students would not be expected to complete these in one day. They are broken into sections to correspond to the objectives being covered the next day. I try to make the guided reading notes an inquiry type of assignment. There are questions embedded in them that they must answer and diagrams that they must create based on the information and examples given in the textbook, and their own experiences.

Transparency 3 – Food Web: Allows me to assess whether students understand basics and gives practice with comprehension and expression of fundamental ideas. Low point value given. Completion is necessary for full points and questions are discussed in class so that answers can be modified for full point value. This motivates students to pay attention to discussions and correct mistakes.

Nature Walk – "Outside Ecology" (C): In this activity students are split into groups of three to four individuals. We take a 25 – 30 minute walk through an "old field" which and then into a deciduous forest. I point out various organisms and ask students what they know about them. Students are free to ask questions about the organisms and to handle them if it is appropriate. The assignment is that the students must decide the niche, habitat, and trophic level of each organism and incorporate them into a food web consisting of eleven organisms. They must also describe various biotic and abiotic factors in the area and answer other questions about the woodlot. Groups must use information about the organisms they observed to complete the Nature Study Guide. Not all groups will be identical.

The students enjoy this activity and perform quite well on it usually. The hands-on nature of it engages the students and motivates them to find out more about the organisms they observed. They will often go back to the woodlot on their own and investigate more.

Relationships in a Community Worksheet: Used in place of, or in addition to the previous assignment. It is useful for general biology because it requires less reading and writing which is extremely difficult for some students. It allows them to work with the concepts and be successful but actively without getting bogged down in the physical process of writing.

Grassland Food Web Worksheet: The goal is to get students to assimilate concepts related to vocabulary. The types of question have changed from earlier assignments. These questions require more detailed answers and explanations. Also, students are asked to "predict" the results of human activity and construct or synthesize new ideas. So, I am trying to guide them to the higher levels of Bloom's taxonomy.

Transparency 4 – Biological Pyramids: Biological pyramids are new to students. They are provided with an example of each type of pyramid: energy, numbers, and biomass. I make a point of trying to connect biological pyramids with food chains/webs. By the time we reach concept, I have returned their nature walk assignments. Then the students use the information they collected to construct their own biological pyramids. Students seem to comprehend the pyramids of energy and numbers, but have difficulty with biomass.

Transparency 5 – Carbon Cycle and Nitrogen Cycle: I have found that students are already somewhat familiar with biogeochemical cycles as a result of the ninth grade Earth science curriculum. I review biogeochemical cycles giving them examples that relate more directly to biology and to specific local ecology. Food web and trophic levels continues to be reinforced. By now, students are expected to know those concepts. This serves as another chance to assess their progress.

Mineral Nutrition of Lemna (Duckweed) (A5): was developed at MSU during the summer of 2000. Specific objectives of lab are listed. Because we are looking at different levels of NO_3 and PO_4, it ties in nicely to biogeochemical cycles and the effects of human activity on them. Analysis questions provoke students to apply scientific knowledge outside of ecology such as: scientific method and attitudes about environmental issues. A data set is included so that a teacher can have a valid set of results to use in anyway they see fit. This lab is fairly easy, reliable and cost effective. This lab can be used or modified in a variety of ways. The students find it challenging to isolate the duckweed required for the investigation. We try to a source locally so that they can collect it themselves. This gives them an idea if its natural habitat and frame of reference for the lab. I will make this more or less open-ended depending on the level of the class that is performing the lab. I try to serve only as a guide in my Biology I classes and suggest to the students that they confer with their lab group when questions come up.

Model Your Own Ecosystem - Eco-column: I did not develop this activity, but I have implemented it in my classroom. I have not included a copy of the original but procedure but recommend strongly that you get a copy of the book, Bottle Biology: An Idea Book for Exploring the World Using Soda Bottles and Other Recyclable Materials. This project ties in all objectives for the Principles of Ecology unit. The instructions and diagrams are clear decreasing the students' anxiety about a big project. Students are required to use what they have learned about feeding relationships, interactions, energy flow, and nutrient cycling to create their own mini ecosystems in 2-liter bottles. They must determine the types and numbers of organisms that they include in their eco-columns and provide justification for it. They must design and construct eco-columns so that it is appropriate for their biotic components by providing the right abiotic components. Once the eco-column is completed students are required to use a variety of scientific process skills. They observe their eco-columns at least two times a week for three to four weeks. Observations are recorded and at the end of the time frame given, they answer questions about their eco-columns. They are also required to observe their classmates' eco-columns and compare and contrast them with their own.

Guidelines for a variety of different eco-columns are provided. This is very open-ended and allows students to be creative while using scientific process. This is a great inquiry based learning activity and students learn a great deal from this activity. Because this activity requires three to four weeks of observation, I set it up at the end of the basic ecology unit and let it run through the next unit, Community Distribution and Population Dynamics. It has great relevance and can be used to learn reinforce concepts in that unit.

Vocabulary Quiz: Formal assessment of understanding of vocabulary terms which serves as a progress check for the students

Review: One last look at objectives, terms, and concepts. Give students a final look at expectations and a chance to sample possible test questions. I make this structures and teacher guided.

Post-test Evaluation – Principles in Ecology: Post-test evaluation of achievement. It is the same as the pretest and scores are compared to pre-test scores to determine improvement and to isolate concepts that require remediation. Also, can be used to modify lessons and teaching methods, especially for students with special needs and learning styles.

TABLE 2: COMMUNITY DISRIBUTION AND POPULATION DYNAMICS UNIT OUTLINE

Section	Objectives	Activities with Appendix Reference
Homeostasis in Communities	1. Explain how limiting factors and ranges of tolerance affect distribution of organisms. 2. Sequence the stages of succession in different communities.	Unit Pretest/post-test (A6) Chapter Objectives (A7) Observing Soil Bacteria Using Winogradsky Columns(A8)
Biomes	1. Compare and contrast the euphotic and aphotoic zones of ocean biomes. 2. Identify major limiting factors affecting the distribution of terrestrial biomes. 3. Distinguish among the terrestrial biomes.	Calculating Soil Organic Matter Using Soil Ignition (9) Water Quality Testing(A10) Continue to observe and analyze Eco-columns Eco-Columns Observations and Questions Worksheet (A11)
Population Dynamics	1. Compare and contrast exponential and linear population growth. 2. Relate the repro-ductive strategies of different populations of organisms to models of population growth. 3. Predict the effects of environmental factors on population growth.	Investigation already in use serve this section.

When teaching these topics I followed a similar pattern of pre-test, post-test, group work, discussion, and in class inquiry based activities as I did when teaching the Principles of Ecology Unit. The lab investigations implemented in this unit were: Calculating Soil Organic Matter Using Soil Ignition, Observing Soil Bacterial Using a Winogradsky Column, and Water Quality Testing. All of these activities reinforce the concepts of ranges of tolerance, succession and the relationship between biotic and abiotic components of an ecosystem. Students collected all samples for these labs locally, which get them back outside observing and collecting data in their environment. Ultimately, I would like students to collect data one year to the next so they can see the on-going dynamic nature of science. Although, I am unable to report formal data from these chapters, I have given anecdotal observations and descriptions of the lab investigations and injury-based activities. I have included the pre and post-tests and chapter objectives so that the goals of this unit are clear.

Observing Soil Bacteria Using Winogradsky Columns (A8): Soil bacteria can fill many roles in the environment from producer, to decomposer, to nitrogen fixer, to parasite. However, since bacteria are small, students tend to underestimate their importance in the ecosystem and fail to understand their niche. In this lab students construct Winogradsky Columns, which they use to observe many different types of bacteria. Concepts discussed in this lab are: decomposition, succession, niche, chemosynthesis, photosynthesis, nitrogen fixation, and bacterial structure and classification.

This lab requires the students to be very active. They must build the column themselves and then observe over the course of three or four weeks. They take ownership of and become very protective of their Winogradsky Columns, almost like they were pets. They get particularly excited when the colored bacteria become visible and become very animated and curious when the sulfur bacteria start producing the rotten egg smell. This sparks a great deal of discussion and comparison within and between lab groups.

Calculating Organic Matter Using Soil Ignition (A9): Decomposing organic material in the soil allows many nutrients to be available that in turn influence the plant, animal, and microorganisms populations in the soil. In this investigation, students determine the amount of organic material in soil samples collected from various locations on the campus of Fowlerville High School or at their homes. Once they have determined the amount of organic matter present in the soil, they compare the various forms of life that are present there. Concepts reinforced by discussion resulting from this lab are succession, nutrient cycling, tolerance limits, decomposition, and biomes.

Students become engaged in this lab easily because they are allowed to choose which soil they will use and to go outdoors to collect the samples. They are surprised to see the differences in organic material in the soil and how that affects the living things in the area. They become especially excited about this activity after the fact when they realize the connections it has to the previous unit, Principles in Ecology, and that they can use the information learned there to explain results from this lab.

Water Quality Testing (A10): Water samples were collected from three different sources on and around the campus of Fowlerville High School. The samples were from a pond, a stream, and an aquatic eco-column constructed by a student. Students worked in groups using Hacht Kits to determine the levels of dissolved oxygen, nitrates, total solids, pH, turbidity, and the biological oxygen demand of the samples. The students analyzed results and tried to explain differences between the water sources. Students were given a reading assignment in Water Quality Monitoring, a book by William Stapp, to provide information and resources so that they could attempt to find meaning in their results.

Initially students have a difficult time with this lab. The procedures for the individual tests are a little confusing and the newness of the materials causes frustration. However, because the students must repeat their particular test on multiple samples, they develop comfort and competency with their skill. I see a sense of satisfaction evolve in students as we conduct this investigation and I see a great deal of mentoring between more and less proficient students.

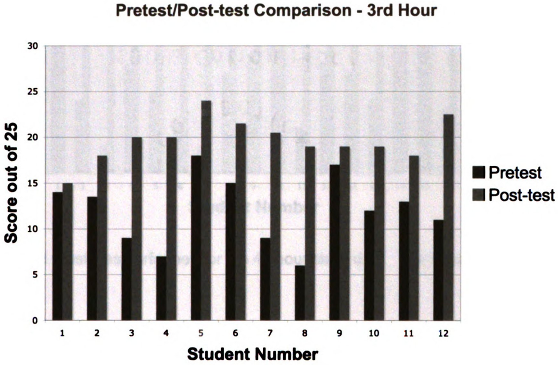
One aspect of this lab that I really like is not all students get to do all of the tests. This is because of budget constraints within the school district. Therefore, students must rely on other groups to determine some of their test results for them and then share information. I think this gives them a realistic view of the collaboration that goes on in a real science laboratory and an understanding of how data is generated and analyzed in a group.

Eco-column Observations and Questions Worksheet A11: This activity it the wrap up activity and brings closure to the unit. Students must apply all of the concepts they've mastered in order to be successful. They work collaboratively to get the best answers they can and reveal that they really understand the material.

RESULTS

The data formally presented here represents data from only one school year. It is one set of pre-test and post-test scores for the unit entitled Principles of Ecology from the year 2001.

Figure 1: Student Pretest/Post-test Comparison Graph – 3rd Hour



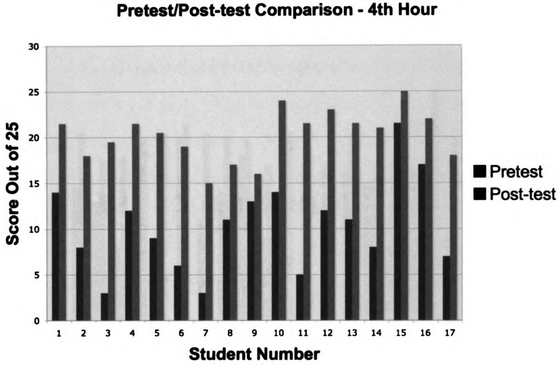
A paired t-test was performed for the 3rd hour class data. The results are as follows:

t = -7.10

Degrees of freedom = 11

The probability of this result, assuming the null hypothesis, is 0.00.

Figure 2: Student Pretest/Post-test Comparison Graph – 4th Hour



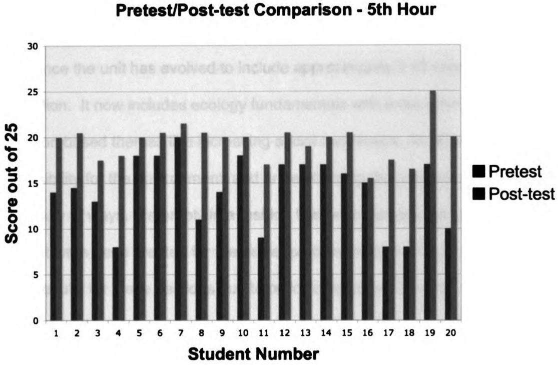
A paired t-test was performed for the 4th hour class data. The results are as follows:

T = -10.4

Degrees of freedom = 16

The probability of this result, assuming the null hypothesis, is 0.00.

Figure 3: Student Pretest/Post-test Comparison Graph – 5th Hour



A paired t-test was performed for the 5th hour class data. The results are as follows:

T = -6.10

Degrees of freedom – 19

The probability of this result, assuming the null hypothesis, is 0.00

CONCLUSIONS

This data set represents the first attempt at modifying my curriculum to address the objectives discussed in the introduction portion of this thesis. In the years since the unit has evolved to include approximately 2 i/2 chapters worth of information. It now includes ecology fundamentals with more Environmental Education based themes like increasing social awareness, developing a responsibility for the environment, and understanding that resources can be used in a variety of ways, preferably in a fashion that promotes sustainability. Pre and post-test have been created for the newer portions of the unit but I cannot report formal results for these sections due to policy constrains. However, I can comment on them informally and have included the student materials in the appendix so that the evolution of my unit over the last several years can be seen.

The average improvement for all three classes was 43.6%, which indicate that to some extent students are learning ecology concepts and that this style of teaching is effective. I am concerned about the validity of the data with respect to what it actually represents. Was the improvement a reflection of the fact that the pre and post-test were the same and the students felt more comfortable with it the second time around or did they truly learn the concepts? I suspect that both play a part in the results. Although, I did not discuss the questions or answers to the pre-test after it was given. The only input was the information and activities discussed in the implementation section and shown in the appendix.

Since then, I have altered the pre and post-tests to be more objective. Certain portions have been modified to a Scan-tron format so that the answers are either correct or incorrect and are scored by a machine. There are still questions that are subjective and are included to show changes in attitude and awareness. These questions are short answer and essay style and require the students to write. As a result, student with poor reading or writing skills may score lower on this portion but I think that relative improvement will still be indicated. I also use other tools now to evaluate the more affective, attitudinal aspects of the unit. Often times this takes place informally as a "warm-up" question on the board at the beginning of class or as reflection questions given at the end of class. More formally, student responses to analysis questions included in the investigations can be used to monitor progress.

Some students did not use complete sentences on the short answer section of the tests. Because this expectation was clearly indicated in the instructions, points were deducted if this didn't take place. Obviously this is a test of instruction following skills and not scientific knowledge and may have affected my results in ways that I had not intended.

When asked, students indicated that they sometimes could not answer the question because they were unsure of what the question was asking. In future years I instructed the students to circle the terms that they did not recognize in the pre-test. The terms frequently circles were in #2 – "symbiotic relationship" and in question #3 – "niche".

It was also possible that students are not motivated to perform well on pre-tests because they are pre-tests. Most students understand that pre-tests scores do not count toward their grade like a post-test does. I try to counter act that by assigning a small point value to the pretest that is given if the students make a reasonable effort. I determine that using two criteria. First, did they take the time to read the entire test? Second, did they circle the terms they were unfamiliar with in the short answer section of the test?

My final observations are as follows:

1. Students are more interested and engaged in an active, investigation-oriented classroom.

2. Students perform the investigations better and have an increased understanding of the scientific process after experiencing this type of unit as demonstrated by designing experiments in future units.

3. Students did become more aware of their local ecology as a result of this unit. On subsequent nature walks students were able to identify various organisms that they couldn't previously. They also reported back to me on occasion of activities that they had engaged in since the unit that immersed them in their environment.

4. The campus at Fowlerville High school does provide many resources and opportunities for fieldwork but I have more difficulty making use of them than I thought. Factors such as weather, class behavior, time of day the class is offered, portability of equipment, mobility of students can vary from year to year and make an entirely fieldwork based unit unlikely. I will still take my students outside and approach this unit with fieldwork opportunities whenever possible and appropriate for the learning objective. However, I have learned that some

concepts can be taught in the lab just as well or better than outside and that sometimes going outside distracts from the learning.

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APPENDIX A

STUDENT HANDOUTS

Pretest/Post-test A1 | **Name:**
Unit 1: Principles of Ecology | **Date:**

Instructions – Read the following paragraph carefully. Then, respond to the questions below in complete sentences. Please do your very best. However, if you do not know an answer, simply skip the question.

Milkweed, pictured in figure 3-1 is a plant found in pastures and along roadsides in eastern and central North America. It gets its name from the milky, white sap that oozes when the plant is injured. Milkweed flowers June through July and if fertilized, large seedpods form that will open in the fall. The following observations were taken from a scientist's field study of the milkweed plant from spring through fall.

In the summer, the sugary nectar made by the milkweed's flower attracts bees, butterflies, moths, and a variety of smaller insects that carry pollen away when they leave. Milkweed nectar seems to be the main source of nutrition for several species of small moths, ants, mosquitoes, and flies. Monarch butterflies, which visit in large numbers, lay their eggs on the plants. The caterpillars feed on the leaves when they hatch. As fall approaches, milkweed bugs begin to attack the developing seeds and milkweed beetles eat the leaves.

Aphids, which suck the milkweed sap, are found throughout the year. Crab spiders do not feed on the plant itself, but on most of the insects that visit the plant. In two to three weeks while the milkweed are in bloom, successful adult female crab spiders may increase ten times in mass before laying their eggs on the inner surface of the leaves. Some of the species of flies and wasps that come to the plant feed on these eggs. Harvestmen spiders also called "daddy longlegs" recover and feed on the remains left by predators.

1. Based on the scientist's observations, formulate two possible hypotheses about the effect of the crab spiders on the survival of the milkweed plant.

2. How would you describe the symbiotic relationship between the aphids and the milkweed?

3. What is the niche of the harvestmen spiders?

4. Based on the scientist's observations, what is one food chain that begins with the milkweed?

5. How would you characterize the interaction between the milkweed and the organisms that visit or live on the plant?

Instructions – Using figure 3-2, in the space at the left, write the letter of the word or phase that best completes the statement or answers the question.

_____6. Suppose that 10,000 units of energy are available to the grasses, what is the total amount of energy lost by the ___time it reaches the coyote?

a. 9 units b. 90 units c. 990 units d. 9990 units

_____7. As matter and energy move from grasses to coyote, the amount of available energy _____ and population size _____.

a. decrease, increases
b. increases, decreases
c. decreases, increases or decreases
d. increases or decreases, remains the same.

_____8. The relationship between the cats and mice could best be described as ____.

a. predator-prey
b. scavenger-carrion
c. parasite-host
d. autotroph-heterotroph

_____9. The coyotes would be considered _____.

a. herbivores
b. third-order consumers
c. second-order consumers
d. decomposers

_____10. Energy flows from _____.

a. coyotes to grasses
b. cats to mice
c. mice to cats
d. coyotes to cats

Figure 3-1

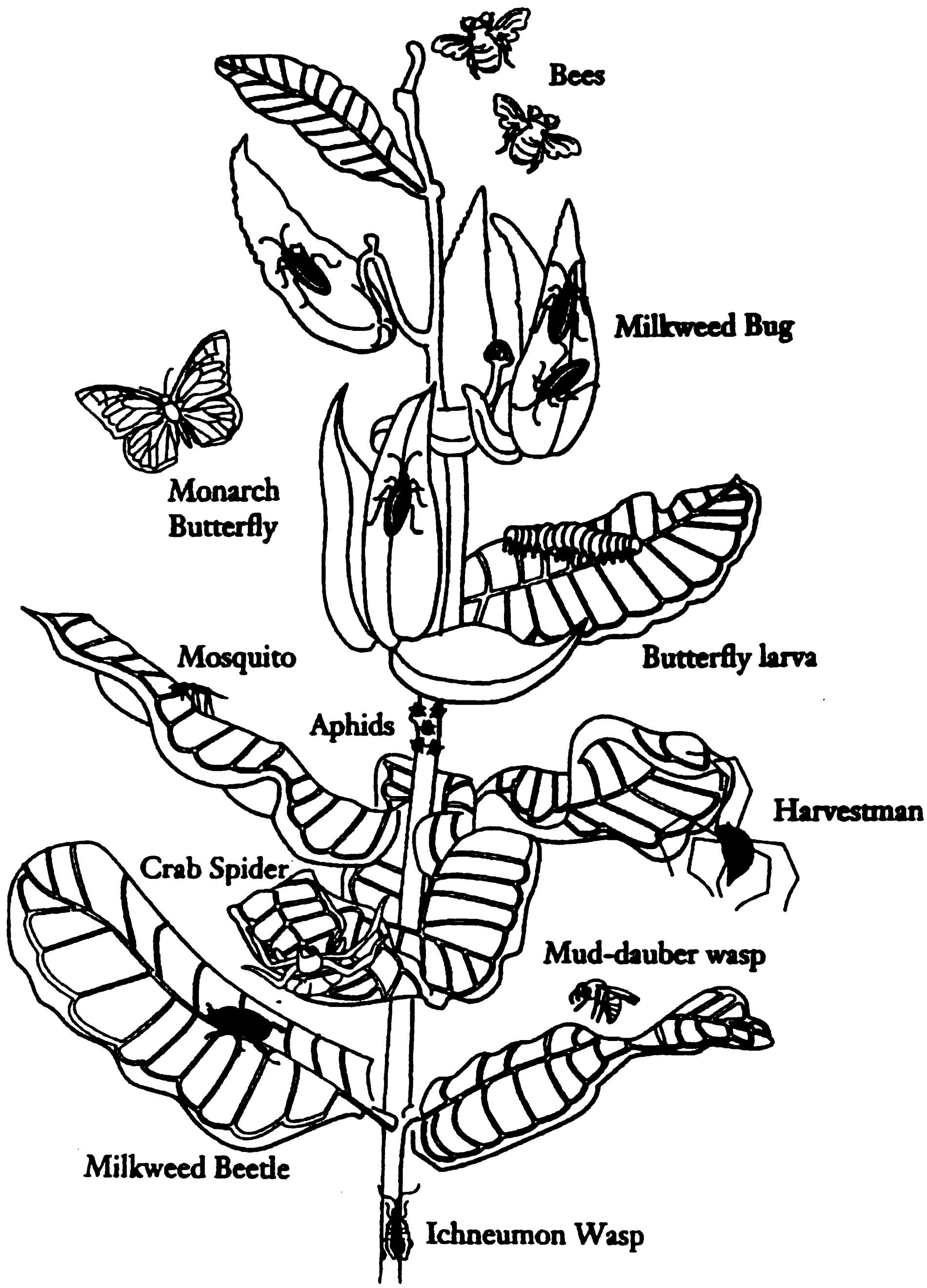


Figure 3-2

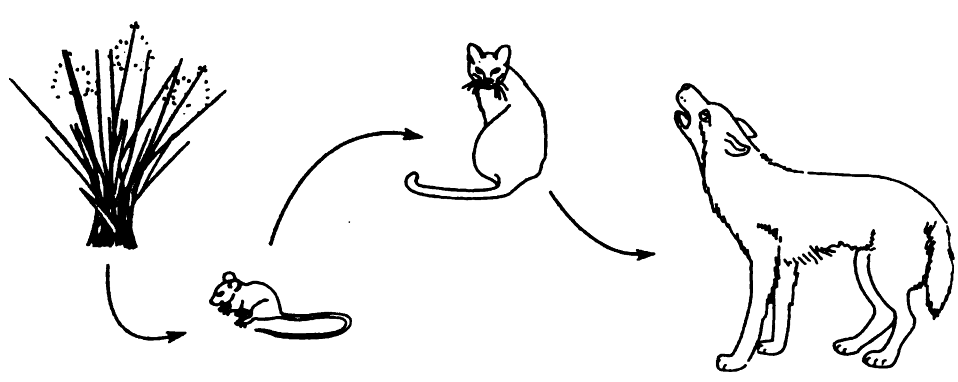


Figure 3-1

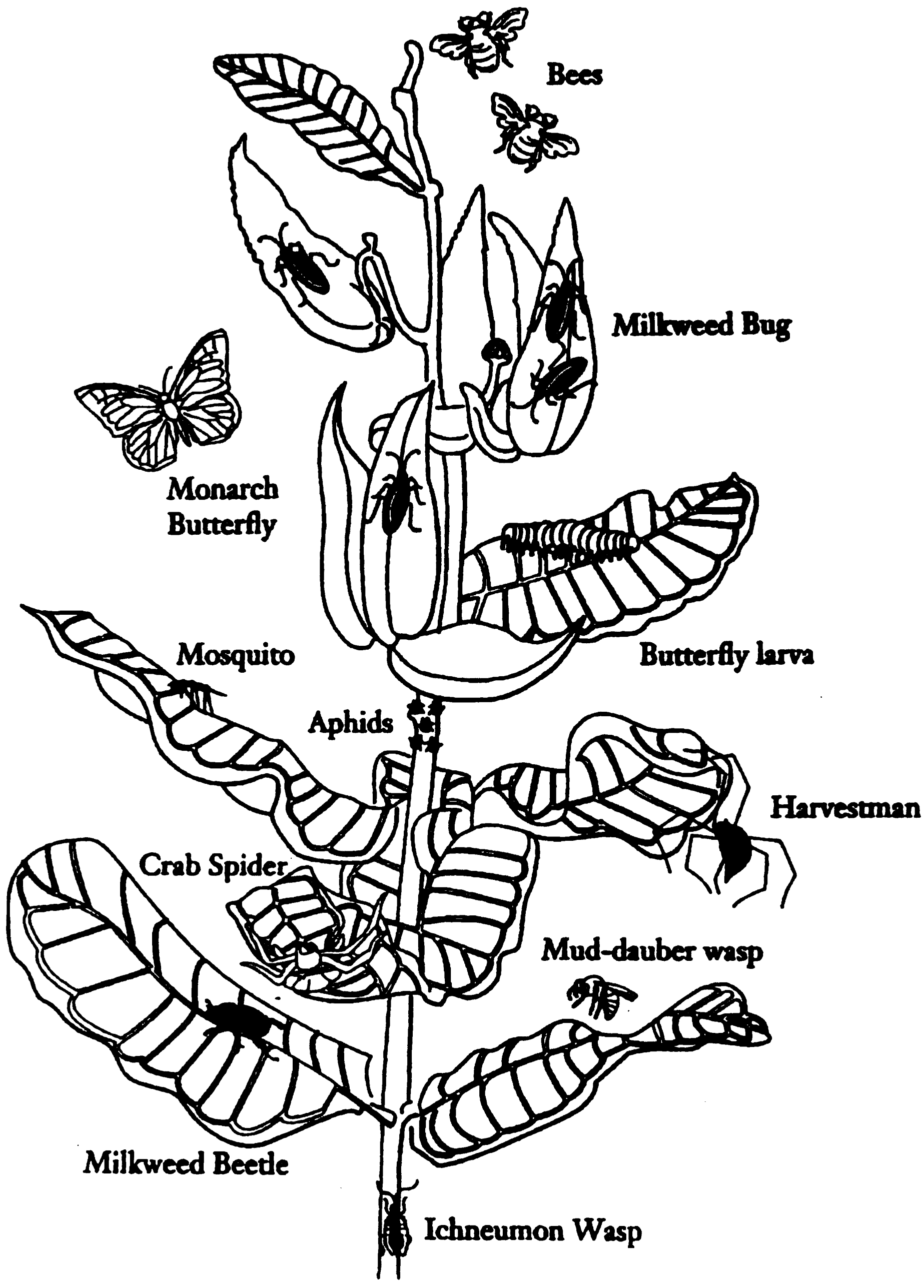
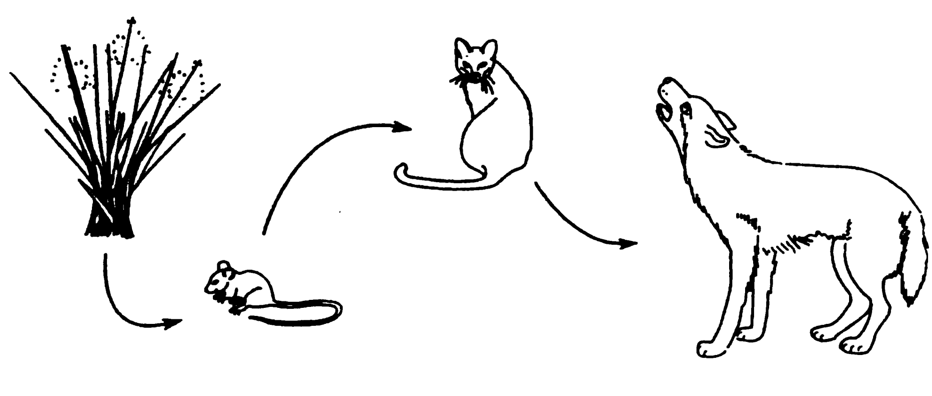


Figure 3-2



Objectives A2
Unit 1: Principles of Ecology

1. Distinguish between biotic and abioitc factors in the environment.
2. Compare the different levels of biological organization used in ecology.
3. Explain the difference between habitat and niche.
4. Compare and contrast the different types of symbiotic relationships.
5. Explain the relationships between energy and matter as shown by ecological pyramids.
6. Compare and contrast the ways in which nitrogen, carbon, and water cycle through the biotic and abiotic parts of the environment.

Nature Walk – Outside Ecology A3
Observations and Analysis Questions

1. List three biotic factors that are found in the woods.

2. List three abiotic factors found in the woods.

3. Find two organisms and describe each organism's niche.

4. What are the habitats of the organisms listed above?

5. _______________ is a relationship between two organisms in which one benefits and the other remains unaffected. Find and describe on e example.

6. _______________ is a relationship between two organisms in which both organisms benefit from the relationship. Findand describe one example.

7. _______________ is a relationship between two organisms in which one organism benefits and one is harmed. Find one example and describe it.

8. List three producers that are found in the woods.

9. List three first-order consumers that you observed.

10. List three second order consumers that you observed.

11. List two decomposers that are found in the woods.

12. Diagram a food web using all eleven organisms that you listed above.

Principles of Ecology A4
Guided reading Notes

I. 3.1 Organisms and Their Environment

A. Ecology – the study of interactions of organisms with their physical environment and with each other.

1. Biotic Factors – all the living organisms that inhabit an environment.
   - ➢ Biosphere – the zones of air land and water at the surface of the Earth occupied by living things.
     - Aquatic - water
     - Terrestrial – land
2. Abiotic Factors – the nonliving parts of the environment
   - Air temperature
   - Air currents
   - Soil
   - Moisture
   - Elevation
   - Slope

B. Levels of Organization – The Hierarchy of Life

Organism – anything that exhibits all of the "attributes" of life.

➢ Species – a group of interbreeding individuals that can produce fertile offspring. (They are reproductively isolated from others.

Population – a group s of organisms of one species living in the same place at the same time that interbreeds.

➢ Individuals with in a population compete for resources.

How do organisms with in a population reduce competition?
- Spread out – increase range.
- Have different food requirements between juveniles and adults
  Example – fawns and does/bucks.
- Have different habitat requirements between juveniles and adults.
  Example – tadpoles and frogs.
  Dragonfly and larva.

Community – a collection of interacting populations.

➢ A change in one population will cause a change in the other populations.

Example –

Ecosystem – all the organisms in a community plus the associated abiotic factors with which they interact.

- Within an ecosystem, each organisms has a job or function called it's niche

  Niche = the role a species plays in a community.
  - Food
  - space
  - conditions needed for reproduction.

  Habitat = where an organism lives out its life.

  Example =

II. How Organisms Interact

A. Feeding Relationships

1. autotroph – organisms that use energy from the sun or energy stored in chemical compounds to manufacture their own food.
   Example =

   - Photoautotroph = organisms that use light as a source of energy for food productions. (photosynthesis)
     Example -
   - Chemoautotroph = organisms that use chemicals such as sulfur compounds, instead of light as an energy source for food production.
     Example -

2. Heterotroph = organisms that depend on autotrophs as a source of their nutrients.
   - Scavenger – animals that feed on carrion, refuse, and similar dead organisms.

   - Decomposer – Organisms that breakdown and absorb nutrients from dead organisms.

Hey, these two sound a lot alike. What's the difference?

B. Close Relationships

Symbiosis = "living together"

1. Commensalism = a relationship between two organisms in which one benefits and the other remains indifferent.

   - Example = Spanish moss in a cypress tree.

2. <u>Mutualism</u> = a relationship between two organisms in which both organisms benefit from the relationship.

   - Example = bacteria in the gut of termites.

3. <u>Parasitism</u> = a relationship between two individuals in which one organism benefits and one is harmed.

   - Example = a tick on a whitetail deer.

C. Matter and Energy Flow in Ecosystems

1. <u>Food chain</u> – a simple model of how matter and energy move throughout an ecosystem.

   algae → fish → heron

   - Arrows indicate the direction in which energy is transferred.
   - There are always 3 links but rarely more than 5.

   a. <u>Trophic Level</u> – "feeding level" or "feeding step".

      1) Autotrophs = producers

      - <u>Primary productivity</u> – the amount of organic material that photosynthetic organisms of an ecosystem can produce.

      2) first order consumer – herbivore

      3) second order consumer – carnivore

      4) detritivores – organisms that feed on dead and discarded organic matter; include large scavengers, smaller animals such as earthworms and some insects, as well as decomposers like fungi and bacteria.

         - Can function at any point in the food chain.

2. <u>Food Web</u> – a more complex diagram showing all possible feeding relationships in a community.

3. Ecological Pyramid – diagram showing the quantitative relationships between numbers of organisms, biomass, or energy flow between trophic levels in an ecosystem.

Pyramid of Energy – illustrates that energy decreases at each succeeding trophic level.

- The amount of energy transferred from one trophic level to the next is only about 10%. What happens to the other 90%?

Example -

FYI – 10 kg of grain are needed to build 1 kg of human tissue if we eat grain directly. However, 100 kg of grain is needed if a cow eats the grain first and then we eat the cow.

Take Home Lesson → eating "low on the food chain is energy wise and ecologically beneficial.

Pyramid of Numbers – based on population sizes of organisms in each trophic level.

Pyramid A

Pyramid B

Pyramid of Biomass – expresses the weight of living material at each trophic level.

- How do you suppose this is calculated?

4. Nutrient Cycling Maintains Homeostasis

   a. The Water Cycle

   b. The Carbon Cycle

   c. The Nitrogen Cycle

Mineral Nutrition of Lemna (Duckweed) A5

Purpose: (1) To determine the mineral requirements of duckweed.
(2) To relate growth rates of duckweed to abiotic factors present in the environment.
(3) To become aware of natural an artificial causes of eutrophication in wetland communities.

Materials:
200 ml pond water
clear plastic cups
forceps or inoculating loop
graduated cylinder
grow light or shop light
KNO3
fresh duckweed (3-4 lobes each)
phosphate buffer (See Cell and Molecular Notes for instructions)
plastic wrap

Procedure:
1. Collect Lemna (duckweed) and pond water from a local source.
2. Label plastic cups with desired treatments.
3. Use a graduated cylinder to measure 200 ml of pond water and pour into each cup.
4. Add the desired treatment. See table 1 or determine your own.
5. Count 10 Lemna consisting of 4 lobes each and transfer them to the cup using an inoculating loop. (it is least likely to damage the Lemna.)
6. Cover the cups lightly with clear plastic wrap, making sure it is not air tight, and place under the lights.
7. Observe the plants every 2 days for 8 days. **Count** the number of lobes and **note** their arrangement and color.
8. **Record** your data and graph the number of **living** lobes on each observation day.

Table 1

Cup #	Pond Water	Nitrate	Phosphate	Duckweed
1	200 ml	---	---	10 – 40 lobes
2	200 ml	.1 % (0.2g)	---	10 – 40 lobes
3	200 ml	.5% (1.0g)	---	10 – 40 lobes
4	180 ml	---	.01 molar	10 – 40 lobes
5	198 ml	---	.001 molar	10 – 40 lobes
6	198 ml	.1% (0.2g)	.01 molar	10 – 40 lobes

Results:

	Day 0	Day	Day	Day	Day
Cup #	Living Lobes	Living Lobes	Living Lobes	Living Lobes	Living Lobes
1					
2					
3					
4					
5					
6					

Analysis Questions:

1. Which cup served as the control and why?
2. What effect did adding nitrate have on the duckweed?
3. Did you see any additional effects on other organisms in the nitrate treatments?
4. Design an experiment that would test if the duckweed and the green algae are competing for minerals present in the water.
5. What effect did adding phosphate have?
6. Imagine that you are an ecologist and have the responsibility of managing a lake around which many beautiful and expensive homes have been built. The homeowners like having lush green lawns that grow right up to the shoreline and so they fertilize their lawns heavily. Predict what will happen to the lake over several years time. Describe the appearance of and biodiversity in the lake in 5 years.
7. There is a shallow pond located at the bottom of a hill, on top of which sits a dairy farm. Describe in detail what the pond would look like and the types of organisms it would support in mid-August. Explain why you responded the way you did.

Pretest/post-test A6 **Name:**
Unit 2: Part I - Community Distribution **Date:**

In the space at the left, write the word true if the statement is true. If the statement is false, change the underscored word to make it true. Write that word in the space provided.

____________________1. A pioneer community is a stable, mature community that undergoes little or no succession.
____________________2. Conditions that restrict the existence, population size, reproductive success or distribution organisms are called limiting factors.
____________________3. Succession is the replacement of one community by another as environmental condition change.
____________________4. The range of factors under which an organism functions and survives are called limiting factors.
____________________5. A large group of ecosystems characterized by the same type of dominant vegetation is called a community.

Instructions – Respond to the following questions using complete sentences. Please do your best. If you do not know an answer, simply skip the question.

6. Describe the sequence of events that might happen if a slab of rock slid off the side of a mountain in a temperate deciduous forest.

7. How can the success of one species cause the disappearance of another species?

8. What are the three major factors that determine which biome will be dominant in a terrestrial location?

9. Would a cleared area in a tropical rain forest make rich or poor farmland? Please explain.

Pretest/Post-test **Name:**
Unit 2: Part 2 – Population Dynamics **Date:**

Instructions – In the space at the left, write the letter of the term or phrase that best completes the statement or answers the question.

_____1. Organisms that employ a strategy of slow reproduction usually require an environment that _____.

a. is stable
b. fluctuates from year to year
c. has cold days
d. has 24 hour growing periods

_____2. Density-independent factors are limiting factors whose effects are ____.

a. confined to the habitat of the population.
b. determined by how much competition there is for resources.
c. not influenced by population densities.
d. determined by the difference between birth rate and death rate.

_____3. For a particular species, the carrying capacity is the maximum number of individuals that _____.

a. the species could reach in a given time period if all of the offspring survive and reproduce.
b. could be supported by the environment indefinitely.
c. are in their post reproductive years.
d. could be supported by the environment over a one-year period.

_____4. Population control factors whose effects increase, as the population gets larger are _____.

a. abiotic factors
b. density-independent factors
c. limiting factors
d. density-dependent factors

_____5. Unrestricted populations of organisms experience _____.

a. linear growth
b. exponential growth
c. fertility
d. slow growth

Instructions - Answer the following questions to the best of your ability. Use complete sentences and clear detailed responses. If you do not recognize a word in the question, please underline it.

6. How are the reproductive patterns of a population of mosquitoes and a population of white tailed-deer different?

7. Explain the concept of carrying capacity.

8. Hungary has the world's slowest population growth. Which age groups do you think make up the largest portion of the population in Hungary?

Objectives A7
Unit 2: Community Distribution and Population Ecology

1. Explain how limiting factors and ranges of tolerance affect the distribution of organisms.
2. Sequence the stages of succession in different communities.
3. Distinguish among terrestrial biomes by describing their climax communities.
4. Identify the major limiting factors affecting the distribution of terrestrial biomes.
5. Compare and contrast aphotic and euphotic zones of ocean biomes.
6. Compare and contrast exponential and linear population growth
7. Relate the reproductive strategies of different organisms to models of population growth.

Observing Soil Bacteria Using Winogradsky Columns A8

Introduction:

In many ways bacteria are the most successful organisms on Earth. The earliest known fossils are 3.5 billion year old bacteria, making them the oldest group of organisms. They existed for 2 billion years before any other living thing. Today, bacteria can be found living almost everywhere on the globe, even is some very hostile habitats. Bacteria occur in great abundance. One gram of rich soil can contain about 2.5 billion bacteria.

Most bacteria are one of three different shapes, **coccus**, **bacillus**, or **spirillium**. These bacteria can group together in different arrangements. Strepto means in a chain. Staphyo means in a cluster like grapes. Put the two parts together and you may hear some names you recognize.

Streptococcus pneumonia -> pneumonia
Staphylococcus aureua -> staph infections of the skin

All bacteria are **prokaryotes**, which means they have no nucleus or organelles that are covered by a membrane. They do have a "nucleoid region" and ribosomes. In addition, they have many unique coverings that protect them and allow them to adhere to surfaces or to each other for conjugation.

Autotrophic bacteria make their own food using simple molecules. Many autotrophic bacteria, such as freshwater **cyanobacteria** are **photosynthetic**. However, there is a different approach taken by some **autotrophic** bacteria. Instead of light, **chemosynthetic** bacteria are able to use the energy stored in sulfide, H_2S, to assemble carbon atoms into simple sugars. These bacteria live in soil or around volcanic vents on the ocean floor where no sunlight can reach.

Most bacteria cannot make their own food and are therefore **heterotrophs**. Many act as **decomposers**, feeding on dead animals, animal wastes, dead plants, fallen leaves, fruits and branches. Other types of heterotrophic bacteria are **parasites**. Parasitic bacteria are the cause of many diseases such as tetanus, tuberculosis, syphilis, and Lyme disease.

One unique group of bacteria called nitrogen-fixing bacteria is worthy of special mention. They are found in the soil, in aquatic ecosystems, and within the roots of some plant species. (Legumes -> peas, clover, beans) These bacteria live in **commensal relationship** with the plants. They convert atmospheric nitrogen (N_2) in to ammonia (NH_4), a form of nitrogen that plants can use. This process is called **nitrogen fixation**.

Since bacteria are so small, they are difficult to see. As a result we often underestimate their importance in an ecosystem and fail to understand their

niche. In this investigation we will construct Winogradsky Columns, which we will use to observe many different types of bacteria. Upon completing this lab you should be able to:

1. Explain the structure of a typical bacterium
2. Describe the niche of bacteria in an ecosystem
3. Explain the function of nitrogen fixing bacteria in the nitrogen cycle.
4. Relate the way a bacterium earns a living to its position in the Winogradsky Column.
5. Compare and contrast photosynthesis and chemosynthesis.
6. Discuss several abiotic factors that affect bacterial growth.
7. Describe the process of succession.

Materials: (per group of 2 – 3)

- 1 – 2 liter clear plastic bottle with 2 inches cut from the top of the bottle
- $CaSO_4$
- $CaCO_3$
- Miracle Grow or other general fertilizer
- Sucrose
- Shredded paper towel or newspaper
- Stirring rods
- Bucket, trowel, mud from shore of lake, stream, or pond
- Plastic wrap, varying colors
- Milk jug
- pH test strips

The Winogradsky Column is named after a Russian microbiologist, Sergei Winogradsky who first used the soil column to describe the growth of various microorganisms, particularly the photosynthetic, anaerobic bacteria. The column is really a contained ecosystem with anaerobic and aerobic regions that develops over a period of weeks and visually demonstrates the sulfur cycle. You will be able to see how the system changes over time and how different organisms interact with each other to facilitate geochemical cycling of sulfur.

Let's consider the players ... Put on your thinking caps! There's a lot of chemistry here!

a. **Obligate, chemosynthetic anaerobes** (*Desulfovibrio*) earns a living using organic compounds as a source of carbon and energy. This bacteria uses sulfate (SO_4^{2-}) instead of oxygen as an electron acceptor at the end of the electron transport chain. It can be detected easily in two ways: 1. H_2S gas is produced and smells like rotten eggs. 2. A black precipitate is formed (FeS).

b. **Anaerobic photosynthetic bacteria** (green sulfur, purple sulfur and purple non-sulfur bacteria) unlike plants, algae, and cyanobacteria that use H_2O to replace electrons lost by chlorophyll during photosynthesis and make O_2 as waste, these bacteria use a substance other than H_2O. The purple and green sulfur bacteria use H_2S or S to replace the lost electrons and produce SO_4^{2-} as a waste product.

c. **Aerobic sulfur using bacteria** (*Beggiatoa Thiobacillus*) these are bacteria that use sulfur compounds for energy and CO_2 as a source of carbon. They use H_2S and S and produce SO_4^{2-}. The SO_4^{2-} reacts with H + and produce sulfuric acid. This can cause the pH to drop to 1.0 creating very acidic conditions. Not many things can live here.

Procedure:

1. Collect enough mud to fill your bottle. Upon returning to the work area, remove the large pebbles, twigs, and leaves etc,....by hand. Collect pond water in a separate plastic container.
2. Mix in a teaspoon of $CaCO_3$ and a teaspoon of $CaSO_4$. (These will provide an immediate source of sulfate and carbon dioxide for the bacteria.) The mud should be the consistency of heavy cream. Fill to the height of about three inches.
3. Add a ½ inch layer of shredded paper towel. This will provide a long-term source of CO_2 and other organic material, as the anaerobic soil bacteria degrade the cellulose in the paper.
4. Continue to add mud until 2 inches from the top of the plastic bottle. Pack the column tightly, eliminating all air bubbles.
5. Add a water layer to the level of about 1 inch. Cover the column with plastic wrap. It is important that the column never dry out.
6. Incubate the column at room temperature under indirect sunlight or with artificial illumination. Within 3 – 6 weeks it will develop the characteristic appearance.
7. If you chose to test an abiotic factor such as addition of nitrogen (fertilizer), extra organic material (sucrose), or changing light color or absence of light altogether, "okay" your procedure with the instructor before beginning.
8. Observe regularly. Look for color changes, developing layers, smells, and test the pH of the water at the top. Be sure to compare your column with others.

At the bottom of the column, where it is anaerobic, you will observe black patches next to green and purple/bright red patches and green and purple bacteria. The purple and red patches are intense and vivid.

Towards the middle of the column where it is still anaerobic, the purple non-sulfur bacteria will grow. As you reach the top of the column oxygen content increases and conditions become aerobic. Here you will find obligate aerobic sulfur users such as Thiobacillus or Beggiatoa.

Results:

Use the table below to record weekly observations and changes in your column.

Date:	**general observations (smell, color, striations)**	**bacteria identified pH**
Day 0		
Week 1		
Week 2		
Week 3		

Calculating Soil Organic Matter Using Soil Ignition A9

Introduction:

One of the four major components of an ideal soil sample is the organic matter content. The quantity of organic matter compared to inorganic minerals, moisture, and air is only about 5% of the total for an ideal sample.

Decomposing organic material allows many necessary nutrients to be available that in turn will influence the plant, animal, and microorganism populations of the soil. Organic matter slows water runoff, absorbs moisture, and binds minerals that prevent erosion and reduce leeching.

Organic matter has a complex and varied chemical structure. It is made mostly of carbon, hydrogen, and oxygen. As a result of its chemical structure, heat can be used to remove it. The carbon and oxygen can be removed in the form of CO_2 gas and the hydrogen molecules can combine with oxygen to form water vapor and other gases. Inorganic materials will remain. This heating technique is called soil ignition.

The problem in this lab is to predict which soil sample has the higher organic matter content, a managed area or an unmanaged area or a cultivated field, or from a fencerow.

Hypothesis:

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

Materials:

Crucible tongs	ring stand
Clay triangle	burner
Balance	soil samples
Crucible lid	goggles **MUST BE WORN! NO EXCEPTIONS!**

Procedure:

1. Collect soil samples from designated locations and allow to air-dry overnight.
2. Weigh the crucible and lid to the nearest 0.1 g. Record this weight.
3. Fill the crucible with soil, cover, and reweigh. Record this weight.
4. Place the covered crucible on the clay triangle and the ring stand and heat. Heating is complete when no fumes are observed leaving the crucible and the soil sample appears uniform in grayish-black color.
5. Allow the crucible to cool for 5 minutes.

6. Reweigh the crucible and top along with the heated sample.

Data:

Develop a data table that will include the above measurements and show the calculations of percent organic matter.

The mass of the original sample minus the mass of the heated sample will equal the mass of organic matter.

____________ Mass of original sample

____________ Mass of heated sample

____________ Mass of organic matter

The mass of the organic matter divided by the total soil mass prior to heating X 100 will equal the percent organic matter.

$$\frac{\text{(Mass of organic matter)}}{\text{(Mass of total soil sample)}} \times 100 = \%\ \text{organic matter}$$

Conclusion:

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

Analysis:

Answer the following questions using complete sentences and well thought out responses.

1. According to your data, which soil sample contains the largest amount of organic matter?
2. Describe the area from which the soil samples were taken.
3. What chemicals are used in the area from which the soil samples were taken?
4. Suggest possible reasons for the differences between the soil samples.
5. Explain how using a mulching mower instead of bagging mower could help your lawn to grow better. Consider the carbon cycle as you think of your answer.

Water Quality Testing A10
Questions & Analysis

Name:
Date:

Watershed = the land area that drain rain and snowmelt to a river.

Instructions - Use the data table to record the values determined in class for the water quality tests. Then use this information and the information provided in the reading material* to answer the following questions. Read carefully and respond thoughtfully using your best writing skills.

*Page 18 – 59 in Field Manual for Water Quality Monitoring: An Environmental Education Program for School by Mark K. Mitchell and William B. Stapp.

DATA TABLE

	DO	NO_3	TS	pH	TURB	BOD
Pond						
Stream						
Eco-col						

DO

1. What is the source of dissolved oxygen in lakes and streams? Explain one way in which oxygen might become dissolved in a body of water.

2. Describe how human activities can impact the amount of dissolved oxygen in a body of water.

3. Give example of 2 organisms that require high oxygen levels and two organisms that can tolerate low levels of oxygen.

4. Which of the three water samples tested, the pond, the Red Cedar River, or the eco-column water had the highest percent saturation of oxygen. Explain why this is so.

pH

5. What is pH? Explain the pH scale.

6. What is acid precipitation? How does it compare to the pH values of natural bodies of water in the U.S?

7. What types of organisms have the greatest range of tolerance for pH? The narrowest?

8. pH values were determined for three different samples. Were any of them acidic? Explain why that might be.

BOD

9. What does BOD measure?

10. What are the main contributors to high biochemical oxygen demands in rivers?

11. What is *point* pollution? Give two examples.

12. What is *nonpoint* pollution? Give two examples

13. Explain what could happen to a river that has high BOD levels.

Temperature

14. Why is the temperature of a body of water important for water quality?

15. What is one way human activity can greatly impact the temperature of a stream?

Nitrates

16. What do living things use nitrogen for?

17. How do aquatic animals obtain the nitrogen they need?

18. Describe the three major sources of nitrogen introduced into the watershed by human activities.

Turbidity

19. What does turbidity measure?

20. What are some sources of turbidity?

21. Which water sample had the greatest turbidity? Does this make sense? Explain

Eco-Column Observations and Analysis Questions A11 Name:
Date:

Instructions – Observation should be made no less than twice a week. However, you are encouraged to do more. Observation must be made prior to starting class or at the end of class. Record your observations carefully in a data table that you have created. Notice as many things as you possible can like growth, death, condensation, decomposition, etc. Be sure to make careful observations. Many discussions will be based on these observations. After we have discussed your observations, answer the following questions using complete sentences when appropriate and always using well thought out answers.

1. What did you put inside our eco-column? Diagram your column and label the biotic and abiotic factors you put in each of the three levels of your column.

2. Illustrate the energy transfers taking place in your eco-column by drawing a food web of your eco-column.

3. What organisms filled the producer niche in you eco-column? Explain

4. What organisms filled the niche of herbivore in your eco-column? How do you know?

5. What organisms filled the niche of predator in our eco-column? What did you observe that led you to believe that?

6. What organisms filled the decomposer niche in your eco-column? Did you put them there? If not, how do you suppose they got there?

7. Is decomposition taking place in you column? What observation did you make that support our answer?

8. Consider a biome such as a rainforest, tall grass prairie, or desert. In your head, list some habitats that you might find in these biomes. What types of habitats can did you represent in your eco-column?

9. Explain and example of competition that you observed in your eco-column.

10. Define succession. Did you observe it in your eco-column? Explain.

11. How does water move through your eco-column? Draw the water cycle as it occurred in your eco-column.

APPENDIX B

UCRIHS APPROVAL

MICHIGAN STATE
UNIVERSITY

October 23, 2001

TO: Merle HEIDEMANN
118 North Kedzie Hall
MSU

RE: **IRB# 01-557** CATEGORY: EXEMPT 1-A, 1-C, 1-D

APPROVAL DATE: October 23, 2001

TITLE: FIELDWORK AS AN EFFECTIVE MEANS OF TEACHING ECOLOGY TO SECONDARY STUDENTS

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

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

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

Sincerely,

Ashir Kumar, M.D.
UCRIHS Chair

AK: br
cc: Kirstin Atlee
572 Lincoln Avenue
Lansing, MI 48910

OFFICE OF
RESEARCH AND GRADUATE STUDIES
University Committee on Research Involving Human Subjects
Michigan State University
246 Administration Building
East Lansing, Michigan
48824-1046
517/355-2180
FAX: 517/353-2976
Web: www.msu.edu/user/ucrihs
E-Mail: ucrihs@msu.edu

APPENDIX C

PARENT CONSTENT LETTER

October 12, 2001

Dear Parent and Students,

I have been working toward the completion of a Master's Degree through the Division of Science and Mathematics Education at Michigan State University for several years. I spent six weeks this past summer developing an Ecology unit that met the state mandated educational objectives and made use of the natural resources that exist on Fowlerville High School's campus. It will be implemented this spring and will take approximately four weeks to complete. The greatest change from what has been done will take approximately four weeks to complete. The greatest change from what has been done previously is that the laboratory investigations will be conducted primarily as fieldwork, getting the students outside, interacting with and understanding their natural environment.

In order to evaluate the effectiveness of my work, I will be collecting data from the students. The data will be in the form of pre- and posttests, lab activities, homework, journal entries and the use of technology in the classroom. The workload for the students will not change from previous years and the same assignments will be required of all students. However, I would like your permission to use the data mentioned above in my Master's thesis. Student names will never be associated with their work and confidentiality will be maintained to the maximum extent the law will allow. As mentioned, th purpose of collecting this information is to see if my efforts have made a positive impact on your child's education.

Please fill out the bottom portion of this letter and return it to me by November 15, 2001. There is no penalty or negative impact on your student's grade if you chose not to participate. Your child's data would simply be excluded. Your child will still be responsible for the same work as all other members of the class. I would simply be unable to collect data from his/her work for publication of the thesis.

Thank you for your time and consideration. If you have any questions please contact the building principal, Mr. Don Buggia at (517)223-6002 or me at (517)223-6073.

If you you have any questions or concerns related to your rights as a participant, please contact Dr. Ashir Kumar, Chair of the University Committee on Research Involving Human Subjects at (517)355-2180 or email: ucrihs@msu.edu.

Sincerely,

UCRIHS APPROVAL FOR
THIS project EXPIRES:

OCT 23 2002

SUBMIT RENEWAL APPLICATION
ONE MONTH PRIOR TO
ABOVE DATE TO CONTINUE

Ms. Kirstin Atlee
Biology Teacher
Fowlerville High School
