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The Entomologist As A Science Partner
And Curriculum Advisor:
The Earth School Model For Grades 6-8

presented by

Bethany Johnston Marshall

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Entomology

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Date 16 November, 1999

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THE ENTOMOLOGIST AS A SCIENCE PARTNER AND CURRICULUM ADVISOR: THE EARTH SCHOOL MODEL FOR GRADES 6-8

By

Bethany Johnston Marshall

A DISSERTATION

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

DOCTOR OF PHILOSOPHY

Department of Entomology

1999

ABSTRACT

THE ENTOMOLOGIST AS A SCIENCE PARTNER
AND CURRICULUM ADVISOR:
THE EARTH SCHOOL MODEL FOR GRADES 6-8

By

Bethany Johnston Marshall

The Earth School model for creation of partnerships between university scientists and public schools began with a traditional research project involving the study of macroinvertebrate recolonization of agriculturally based restored wetlands. From fieldwork designed to address hypotheses of community composition over time, protocols and equipment evolved for application in middle-school classrooms. In addition to classroom teachers guiding their students in replicating active scientific research, the inclusion of a science partner was key to the success of this model. To ensure that the classroom teachers were themselves comfortable as researchers, monthly staff development workshops were conducted as a component of the Earth School model.

The use of entomology as a unifying theme for educational scientific investigation lets the student explore virtually every other system in the biosphere. Because of the unparalleled survivability and adaptability of insects, we can find examples from all biomes, all time references and all disciplines. Over the course of long-term continuous exploration, learners become familiar with relationships and patterns evident in natural

situations. These same patterns of birth, growth and decay are much more vividly demonstrated in the field than in textbooks. Similarly, concrete examples of feeding relationships between organisms are plentiful in nearly any outdoor situation. The following model incorporates current research from multiple scientific disciplines but focuses on the many and varied research activities offered by the entomological community.

Teachers and students in a primarily urban setting made extensive use of the materials developed through the course of this model's development. Their feedback as the materials were integrated into an established curriculum allowed for the fine-tuning of activity development. A conversion template has evolved that gives teachers, curriculum directors, parents and other educators a simple mechanism for adapting the work of leading researchers into activities suitable for all age levels and all learning abilities.

As public schools rally to change the course of science education, they are met with a seemingly never-ending supply of materials promoted as hands-on learning. To the extent that the manipulation of tangible objects and materials supports identified outcome objectives, these materials fulfill their promise. Although there is merit in offering these types of kinesthetic experiences to reinforce theories and principles of science, this approach does not address the same goal as activities that promote 'doing science' through investigation and discovery using a process that includes observation, inquiry, design and collaboration. The active recruiting of and collaboration with science partners from universities offers public school teachers and their students an alternative for curriculum enrichment as the nation strives to reach literacy goals in the sciences.

To all the friends and family so essential to the completion of this project I extend a humble thank you. To my children, tomorrow's stewards, I wish for you rich blessings and the wisdom to honor our Earth.

We join with the Earth and with each other.

To bring new life to the land
To restore the waters
To refresh the air

We join with the Earth and with each other.

To renew the forests
To care for the plants
To protect the creatures

We join with the Earth and with each other.

To celebrate the seas
To rejoice in the sunlight
To sing the song of the stars

We join with the Earth and with each other.

To recreate the human community
To promote justice and peace
To remember our children

We join with the Earth and with each other.

We join together as many and diverse expressions
Of one loving mystery; for the healing of the
Earth and the renewal of all life.

U.N. Environmental Sabbath Program

ACKNOWLEDGEMENTS

The process of beginning, completing and surviving a doctoral program requires the support of a great many people. Chief among my supporters were the friends comprising my committee; Drs. Fred Stehr, Edward "Ned" Walker, Edward Grafius, Richard Merritt and Frances Ekern. For their attendance at long meetings and for reading, re-reading and often re-re-reading page after page of learning activities and philosophical meanderings, I am truly grateful.

Beyond the call of duty, Dr. Stuart Gage was an ever-present force in the creative aspects of program development for both teacher and student enrichment and development programs. He, along with my always supportive family, provided a critical check-system for those times when the push was too hard or the goal too ambiguous.

Dr. Vinston Birdin, Mr. Milton Patch and Mrs. Joyce Butler received and explored my work with open minds and open spirits. Thanks to them and to the many students who were honest enough to let me know they liked or didn't like my work.

For the use of their land I thank the Fick, Reed, Mashne, Holmes and Running families. A special thank you to Jim VosBurgh of the Lapeer Soil Conservation District for helping open doors with land owners and to Jim Hazleton for delivering my samples while my husband and I delivered our son.

Peace to you all and to our global family.

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LIST OF ABBREVIATIONS

AAAS	American Association for the Advancement of Science
ELI	Experiential Learning Initiative
GIS	Geographic Information System
GPA	Grade Point Average
GPS	Global Positioning System
IPM	Integrated Pest Management
SA	Science Alternative Program
SSP	Student/Scientist Partnership
NRC	National Research Council
NSES	National Science Education Standards

INTRODUCTION

The Earth School model has evolved from a basic foundation of Earth stewardship and the belief that answers to our most pressing problems are latent within the spirits and values of our children. The whole notion that we are killing the planet is so large and so difficult to process that most people have, at best, only an inkling of understanding. We may have some idea of the theories and hypotheses that surround key issues, but without first a basis in one's belief system and then an understanding of the science (Van Matre, 1990), we will be unable to do more than live as lightly as our individual comfort levels allow.

The students we teach today make tomorrow's decisions. To serve their futures and our own, we need to be very conscious in our dealings with even the youngest child. We have taken a 'hands-off' approach to ethics, values and the development of children's belief systems in the interest of a democratic education that doesn't cross controversial lines. My personal belief is that all education and especially Earth education must begin, follow through and end with a personal investment as the foundation. In addition to the very real potential of teachers sharing their values with their students through word and deed, authentic field and other nonformal experiences have been shown to have positive impact of the formation of environmental ethics in young people (Manzanal, 1999; Meredith, 1997; Orion, 1994). Teachers and other leaders must not be ashamed to reveal their values to others. Teaching is not a job but rather a responsibility that passes from one generation to the next (Nash, 1989). Where are children to gain perspective if not through our leadership? Some children will accept our words without blinking, some will reject them summarily, and others will consider and accept or reject our teachings now or later. To this end, the following model is offered. Within its framework is presented a program for increasing scientific literacy among in-service teachers, examples of programs that unite students with practicing scientists, and a curriculum guide for integration of Earth education into traditional and non-traditional science classes. Because the chapter readings are heavily dependent on actual classroom materials, these materials have been included in an appendix to this work.

Recommendations and suggestions are respectfully submitted. Every school has a culture based on the administrators in power, the teachers, the students, the community and the geographic location. Implementation would be very different in Barrow, Alaska than in Chicago. These works are intended to inspire creative thought and application rather than to impose a single method presented as the answer to environmental ignorance.

Our planet is clearly in danger. There are many problems needing our attention and many people who are willing to take aggressive stands for their beliefs. While some people are vigilantes for the environment, many more are quietly living the philosophy they would teach. From either position or from any of the gradations in-between, our knowledge as scientists comes with a responsibility to provide our successors with a higher environmental consciousness.

Chapter 1

ENVIRONMENTALLY RESPONSIBLE DECISION MAKING THROUGH SCIENTIFIC LITERACY

Scientific literacy in the developed world may very well be more critical than general knowledge in developing countries. Our exploitation of resources dwarfs the minimal impact of indigenous people around the world (Chiras, 1992). If we are to be viewed as world leaders and the guides in a global economy, we need to be able to make decisions that lead to sustainability in both economics and ecology. This begins with education of our young and those who teach them.

As a consequence of our failure to prepare the next generation to take their places at the heads of economic tables or to lead the world in environmentally responsible decision making, the problems reported generations ago still exist and have grown more severe (Ehrlich, 1990). Land management decisions have left a wake of desertification as an excess of 70 square miles of desert are formed each day in response to population pressures, burning, erosion and overgrazing (Chiras, 1992). Nutrient deficient soils grow nutritionally inferior products. More than 50 percent of the biologically rich wetlands in the conterminous United States have been lost to agriculture and urban development since the 1700's. Many of the remaining wetlands have been altered significantly from their former ecological functions (Mitsch, 1993). Fossil fuels support a questionably sustainable lifestyle of undervalued and inefficiently used energy (Naar, 1990; Chiras, 1992; Flavin, 1994). Greater than 1000 species will becoming extinct each year as a result of habitat destruction (Robbins, 1990). Evidence of global warming continues to mount (Naar, 1990; Flavin, 1996) despite controversy even within the scientific community (Schneider, 1990) as to the reality of the reports. Economic instability in environmentally critical corners of the globe has often left nature last in line for consideration (Renner, 1997).

Around the world species from every kingdom are being displaced as acre after acre of tropical and temperate forests are blindly leveled in the name of economic progress. Each day, trees are harvested for pulp and lumber while land is cleared and burned to make way for increased agricultural demands or for urban sprawl to accommodate the housing needs of a rapidly growing human population. The most apparent motivation for this assault on the planet is monetary gain. As with most things, a complete explanation is far more complicated.

The developed world has a missionary zeal for spreading technology wherever it perceives the need to be. This includes electric power, waterworks, dams, sewer systems, telephone lines and roads. These luxuries are considered necessities for providing the infrastructure needed to support a 'better way of life' that can include appropriate medical care and education for all the world's people. In the course of building the necessary utilities, vast debts are accumulated by developing countries (Chiras, 1992). As notes come due and interest accumulates on loans, these countries have no way of repaying their debts. Land must be used for cash crops rather than for growing food. Since the need for food remains, more people become dependent on international food distribution programs and more land must be converted for agriculture.

Through increased availability of medical care and internationally supported nutrition programs, life expectancy increases and birth rates climb as people become healthier and infant mortality decreases (Ehrlich, 1990). This, in turn, adds to the ever increasing population and augments the problems associated with poverty, hunger and diseases associated with hunger. More people require more housing and food. More housing means an increased need for building materials, which means more resources are used and more of the natural landscape is stripped to provide the resources. The increased need for food requires that still more land be converted for agriculture.

Many countries have nothing to export except their natural heritage. Exotic plants and animals are sold through the black-market (Chiras, 1992). Ancient forests are leveled for the beautiful wood they produce. The landscape is destroyed in mining operations and still, the debt for progress is barely chipped.

The World Bank and industrialized countries, including the United States, have been major forces (Sachs, 1993; Grumbine, 1992) in providing loans for countries seeking assistance for construction projects. In addition to financial investment, intellectual investment by the funding source is commonplace. Teams of experts draw up plans for rerouting natural waterways. Dams are constructed to provide power to generators that carry electricity to the villages. Downstream, water supplies are reduced, animals die and crops fail due to drought. Now we need to finance an irrigation system. More debt...sell more of the natural heritage...clear more land.

This scenario offers an extreme but not unrealistic picture of why tropical and temperate rainforests are being lost with such alarming speed. There are 'softer' or more direct explanations as well. Villagers need to burn vegetation for fuel to heat their houses. Land needs to be used to grow food for the animals that provide or become food. Exotic wood brings a good price. Of what importance is cutting down some trees and killing off a few bugs, birds and monkeys? Answers to this very sad question can come from social (IUCN, Inter-Commission Task Force on Indigenous Peoples, 1997), political (Gunderson, 1995; Rifkin, 1991), ecological, medical and spiritual (Nash, 1989) perspectives. The ecological perspective is very compelling and can provide a hub for all the others. Among the critical ecological issues at stake in discussions about the destruction of the tropical rainforest are biodiversity, energy flow and biogeochemical cycling.

Biodiversity in the tropical rainforests is so vast that it hasn't even been quantified. Estimates of the numbers of species vary widely. Some ecologists and systematists believe the number of species that will never be identified before becoming extinct will exceed the total of all extant species. Lost forever will be the genetic variability, phylogenetic links and interactions associated with these plants and animals (Forsyth, 1984; Mader, 1985).

Our knowledge about the natural world is imperfect. We theorize about possible relationships between plants and animals. We know plants have defenses against insects and insects have defenses against each other. Agents that can kill a human are part of natural cycles between plants and insects or between insects and other animals. We know this from our research with encephalitis, Lyme disease and malaria, among others. Somewhere in these successful and benign cycles rest answers to our questions about disease control. What chemical and physiological events allow hosts and vectors to remain unaffected by the pathogen? Can these same biological strategies be used to prevent disease among humans? How many cures for life threatening diseases will be lost with the loss of diversity? What diseases unknown and restricted to the confines of the rainforest community will be released upon the human population as we move into uncharted regions? Will we have eliminated the antidote just as the pathogen becomes widespread? Not knowing should be reason enough to stop and rethink our global perspective. Awareness is the first step.

Solutions rooted in change are complicated and carry certain political risks. The first step is accepting that ecological impact must be given at least equal consideration to economic priorities. Until the major political powers around the world make planetary health a priority, the current downward cycle is likely to continue. Partial solutions might include any or all of the following:

Stop funding projects that divert water flow.
Stop funding programs that promote monocultures.
Stop expanding fossil fuel dependent energy grids.
Invest in alternative energy.
Forgive or suspend interest generation on existing loans wherever possible.
Promote agri-forestry.
Teach sustainable agriculture.
Promote organic farming worldwide.
Reduce dependence on animal protein.
Establish international guidelines for global food production and distribution.
Eliminate subsidized Western agriculture and forestry.
Rebuild land through responsible planting.
Establish international regulations for pesticide use
Teach human biology and preach family planning.
Enforce trade laws regarding threatened and endangered species.

No single entry on the above list holds the answer to our environmental crisis. Taken in whole, they may form the beginning for recovery. Included among these is sustainable agriculture. While the concept of producing food without destroying land in the process is superficially black and white, sustainable agriculture has gotten mixed acceptance globally. There are those from deep ecology who view such programs as compromising the original goals of the 70's ecology movement (Sessions, 1995). Sustainable development and its companion, sustainable agriculture, represent economic positions that assume we have ownership of the Earth's resources and that these resources exist for our use. They are further rooted in a belief that we are able to determine the Earth's carrying capacity and that as long as we operate within this set of limits, all is well. Progress defined as 'having more' is our worldview. The perception that progress is acceptable and desirable as long as it is sustainable goes unchallenged. Sacrificing the feeling that comes with a love of nature and our connection with Earth can't possibly be progress.

Realistically, people must be fed. Hunger and those diseases secondary to hunger erode educational progress and make conversations about saving an endangered butterfly seem insignificant. To feed our growing population while minimizing the impact of agriculture on the planet, farming practices that use the Earth without using it up are gaining acceptance. Growers are discovering that short-term sacrifices of production are yielding excellent long-term results. Such practices include conservation tillage and cover crops to preserve soil and reduce erosion. Agriforestry combines trees with crops to the benefit of both. A return to indigenous plant species suited for their environments reduces the need for water beyond natural inputs. Integrated Pest Management (IPM) helps reduce the need for chemical intervention to reduce damage caused by insects.

Solutions to the destruction of rainforests, both tropical and temperate, are dependent on recognizing the resources of Earth as finite. Sustainable agriculture incorporates this reality into practice and amounts to the first few steps toward a philosophical shift.

Systemic change leads to permanent solutions. My personal commitment to change has a strong attachment to a central theme that the process of change requires a personal investment. We're willing to give this essential investment when we recognize that the outcome has a direct impact on us (Gunderson, 1995). To direct change, we must be committed to a belief and be steadfast in our determination. Grassroots organizations are making changes from the bottom up as their collective voices get larger and louder. Through the election of government officials with track records supporting environmentally responsible behavior, we influence change from the top down. Good ideas become good laws.

At the heart of all environmental realities is a set of values that allow us to make and live with our decisions. Some values have come from indoctrination, ignorance or wrong information. The experiences we have had and the educational opportunities we've been given shape other personal values (Manzanal, 1999). As a member of the scientific community, I feel that it is my responsibility to become an Earth advocate and to embrace the next generation as an elder and as a mentor. To make change happen from the inside out, live what you believe and those around you risk being swept under your influence.

Chapter 2

GUIDELINES FOR SCIENCE EDUCATION IN AMERICAN MIDDLE-SCHOOLS

Teachers have heard the call for hands-on teaching and are responding to the seemingly limitless supply of kits available in current supply catalogues. What appears to be missing from hands-on education is a careful analysis about the goals of individual learning activities. As long as students are touching materials and talking about a scientific principle or principles, the activity is considered hands-on learning. Does manipulating materials alone actually lead to inquiry, discovery or ultimately, comprehension and integration? Employing the traditional use of convergent thinking, a known outcome is carefully choreographed using step by-step instructions. These "cook-book" style activities often include questions leading the students to a specific "discovery" as they progress through the experiment and converge upon predicted results. These hands-on activities serve as effective examples of the principles, theories or facts but do not generally support inquiry-based learning.

Contrasted with this example of convergent thinking is an inquiry-based approach that is centered around divergent thought processes where even the teacher may not know where the lesson will take her learners. I recently had the pleasure of participating in a rather ambitious outing to the overflowing banks of a river in the Des Plaines watershed that flows through a region just west of Chicago. We were prepared to do traditional measurements of turbidity, pH and invertebrate community composition. As teachers and facilitators open to the widely divergent thought processes of young people, we soon abandoned the prescribed materials and shared in discovery as hundreds of snail shells became the focus of a statistics exercise. A few students were engaged in finding every possible kind of spider while another small group spent an inordinate amount of time methodically dissecting a partially decomposed turtle carcass. The experiences of that day were joyful, student-directed and provided deep impact on the learners. We are not seeking a single answer but rather moving closer to a range of new knowledge that provides insight into the topic. We now have data about the turbidity, pH and macroinvertebrate community of this area of the watershed but we also know a bit about snail populations, spider homes and turtle morphology.

Guidelines such as those outlined by the National Research Council or Project 2061 Benchmarks can be used to help teachers and curriculum developers break from the tradition of letting text book publishers and kit builders determine curriculum and look at new goals for scientific literacy. In developing these goals, students were considered respectfully as the next generation of decision-makers. Goals were developed to serve the needs of children who will need to be high functioning adults in a rapidly changing world.

Project 2061

Science for All Americans (1990) and the subsequently published, Benchmarks for Science Literacy (1993) were landmark publications of the American Association for the Advancement of Science (AAAS). Based on the collective research and collaboration of experts from math, science, engineering, technology and education, AAAS's Project

2061 established a set of benchmarks required for scientific literacy. The original Science for All Americans does not propose instructional methods or curriculum design for reaching the benchmarks, but rather establishes a baseline of knowledge for high school graduates. Contained within its fifteen chapters are recommendations for science literacy based on the nature of science, mathematics and technology, physical science, the environment and human beings as organisms. Additional chapters include historical perspectives, change, values, and ultimately, a direct call for reform. Integral to the work and included throughout are common sense reminders to teachers about living what we teach and recommendations for getting these changes airborne.

Included among the recommendations of Project 2061 is a call for the inclusion of academic and professional colleagues for in-service teachers. This includes not only those teaching in universities and colleges but also partners who are practicing professionals in all fields of science, engineering and technology.

Project 2061 calls on teachers to embrace responsibility for the component of educational reform within their control. Teachers are viewed as central to broad changes in education. As such, training for in-service and pre-service teachers is very much a part of the recommendations from Project 2061.

As a planned Phase II production of Project 2061, the overall conceptual frameworks from the chapters of Science for All Americans were carefully dissected and refined. The key concepts were restated as age-specific benchmarks for primary, upper elementary, middle school and high school students. The same twelve major divisions used in the original work were continued in Benchmarks. Among these chapters are specific treatments of the physical setting and the living environment. Chapter five deals with the living environment. Within its pages are six areas; diversity of life, heredity, cells, interdependence, evolution, and flow of matter and energy that serve as the foundation for understanding.

The benchmarks established within each division offer a framework for progressive knowledge and understanding. An example of the use of benchmarks includes those established for teaching lessons about diversity within the living Earth. Diversity benchmarks progress from Kindergartners looking for similarities and difference between plants and animals to high school students evaluating the validity of DNA-fingerprinting and DNA's role in speciation. The primary grades are viewed as an appropriate time to bring light to reality verses fiction in the anthropomorphic nature of many books written for children while older students progress through sorting, classification and morphology/physiology related to classification.

The final phases of the long-term reform program developed by AAAS through Project 2061 include a third work entitled, Designs for Science Literacy which addresses alternative curricula and a final published work, Blueprint for Reform, which considers the broader scope in which a curriculum must function. Together, these four publications form the AAAS Curriculum Design Education System.

National Research Council Standards

Similar to the work of AAAS, the National Research Council (NRC) published National Science Education Standards (1996) as a guide to improving science education nationwide. Included in its eight chapters are recommendations for content standards as well as standards for science teaching, professional development, learning assessment, program evaluation, and science education system standards that involve the school as part of a community. At the core of this work is an emphasis on teachers and teaching.

The National research Council's content standards are very similar to those of AAAS and similar to most local and state content standards. The eight categories of content standards include: unifying concepts and processes in science, science as inquiry, physical science, life science, Earth and space science, science and technology, science in personal and social perspectives, and history and nature of science. Within each category are specific recommendations for subject matter at three grade divisions: K-4, 5-8, and 9-12. Expanding on the Earth and space science standards, students in the K-4 grades would focus on properties of Earth materials, objects in the sky and changes in Earth and sky. As the knowledge base increases with age, 5th through 8th grade students would be expected to study the structure of the Earth system, Earth's history and Earth in the solar system. At the high school level, students explore energy in the Earth system, geochemical cycles, origin and evolution of the Earth system, and origin and evolution of the universe.

The standards for science teaching are based on five assumptions (p. 28).

- The vision of science education described by the standards requires changes throughout the entire system.
- What students learn is greatly influenced by how they are taught.
- The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned.
- Student understanding is actively constructed through individual and social processes.
- Actions of teachers are deeply influenced by their understanding of and relationships with students.

From these five assumptions are six standards for teachers (p. 30-51).

- Teachers of science plan an inquiry-based science program for their students.
- Teachers of science guide and facilitate learning.
- Teachers of science engage in ongoing assessment of their teaching and of students learning.
- Teachers of science design and manage learning environments that provide students with the time, space and resources needed for learning science.
- Teachers of science actively participate in the on-going planning and development of the school science program.

To complete the vision for both division content standards and for teaching standards, a professional development component is critical. The authors make an analogy about professional development for other professions and stress the importance of maintaining current information in a rapidly changing world. Included in the four professional development standards are requirements for; learning essential science content through the perspectives and methods of inquiry; integrating knowledge of science, science learning, pedagogy and students; building understanding and ability for lifelong learning; and the fourth standard which specifies that professional development programs for teachers of science must be coherent and integrated (p. 59-70).

All the standards listed for improving the quality of teaching and teacher development reflect a changing emphasis from traditional fragmented learning with the teacher as follower to a new paradigm emphasizing inquiry and the use of outside expertise with the teacher acting in a leadership role.

Although the *Standards* are often referred to as the "bible" by teachers and teacher trainers, these standards are not without criticism. While one of the stated premises of *Standards* is the equity-directed goal of "...excellence for all students regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science" (p. 2), Alberto Rodriguez (1997) describes the document as a "discourse of invisibility" (p. 19) in which the intended goals of the NRC are not only not addressed but compromised by "...not directly addressing the ethnic, socioeconomic, gender, and theoretical issues which afflict science education today" (p. 19). In a similarly negative perspective, Angelo Collins (1998) offers a discussion about three political aspects and four tensions involved in the development of the document.

Because the purpose of my mentioning guidelines, standards and benchmarks appropriate to the teaching of science is only to point out that various guides exist, I will not pursue the political or philosophical issues proposed by these authors. Suffice to say that no guide for content, training, or pedagogy is accepted by all in the dynamic field of science education.

State Science Guidelines, Illinois

The Proposed Illinois Learning Standards (PILS, adopted in 1997) were developed based on earlier Illinois guidelines, NRC's National Science Education Standards (NSES) and "various other state and national guides". In addition to the use of professionally developed guides for educational standards, including those for science, the state of Illinois considered the input from more than 28,000 Illinois citizens responding to a survey in their development process. Of the thirty goals identified in the PILS three are content-based science goals. (Illinois State Board of Education, 1997).

- Understand the processes of scientific inquiry and technology design to investigate questions, conduct experiments and solve problems.
- Understand the relationships among science, technology and society in historical and contemporary contexts.
- Understand the fundamental concepts, principles and interconnections of the life, physical and Earth/space sciences.

Within each goal are specific learning standards and sub-standards based on development from early elementary, late elementary, middle/junior high school, early high school and late high school. Of the three goals, State Goal 12 dealing with fundamental concepts is the most extensively developed. Comprising this goal are six learning standards and thirteen sub-standards.

Examples of learning standards associated with fundamental concept goals include the following.

- Know and apply concepts that explain how living things function, adapt and change.
- Know and apply concepts that describe how living things interact with each other and with their environment.
- Know and apply concepts that describe properties of matter and energy and the interactions between them.
- Know and apply concepts that describe force and motion and the principles that explain them.
- Know and apply concepts that describe the features and processes of the Earth and its resources.
- Know and apply concepts that explain the composition and structure of the universe and the Earth's place in it. (p. 34-37).

Each of the three sources discussed; *Benchmarks*, *Standards* and PILS have been designed to assist school districts, administrators, curriculum directors and teachers in the very large task of teaching science in the public schools. While each addresses specific content standards, only *Benchmarks* and *Standards* address more over-reaching goals for knowledge-based teacher development and methods skills. All of these guides promote fairness of education for all children but none address specific needs related to cultural, racial, socioeconomic or gender issues in their plans (*Blueprints* does openly acknowledge these issues as factors in fairness but offers no proposal for mitigation). It is assumed that fair education for all includes a common point of origin for all as they enter the educational system. Of the three documents or series, the AAAS series, (Science for All Americans, Benchmarks for Science Literacy, and Blueprints for Reform) provides the most comprehensive approach to science education but its use is cumbersome without intimate familiarity and a district wide systemic approach to implementation.

Chapter 3

TRAINING FOR IN-SERVICE TEACHERS, SCIENCE METHODS

The Science Alternatives Program in Bellwood School District 88

Two fundamental goals of the Science Alternatives program were to increase scientific literacy among teachers and to reduce the anxiety level of classroom teachers about their abilities to teach science. Working toward these goals, it was necessary to include teachers from all grade levels and from all backgrounds. Participating in the monthly workshops were art teachers, gym teachers and classroom teachers from grades K-5, and middle-school teachers from all subject areas. Language Arts, math and science teachers work as teams with sections of students in the regular school setting. Maintaining this existing collaborative effort meant having materials that would appeal to each team member.

While most elements of the activities were clearly intended to teach science to the teachers, cross-curricular extensions were included to help generate material ownership and to foster a sense of familiarity for science-shy teachers. Extension activities incorporated art experiences, writing exercises and current event analysis. Although a Language Arts teacher may not have been familiar with the ramifications of introduced exotic insect species, she could explore the topic as a current event and integrate the scientific vocabulary into class discussion as political or cultural issues. Through the use of science topics in language arts and social studies, students were provided with an opportunity to make an intellectual investment into their opinions about environmentally-charged realities. Similarly, an art experience could include a fabric collage illustrating a biome. Through the creation of such a collage, students are combining the aesthetic quality of the landscape mosaic and combination of landscape elements with the manipulation of concrete materials and consideration of related habitats.

The workshop materials were based on a combination of influences. Frequently, teachers were interested in materials they could use in upcoming units. If there were specific topics of interest, materials were developed for the next workshop. Occasionally, a workshop topic itself became the inspiration for additional materials. If informal formative assessment indicated that a particular activity didn't live up to its intended goal, there was always the possibility of redesigning it with the teachers' help and offering the revised edition at subsequent workshops. With a heavy emphasis on natural materials, availability was nearly always significant to the development of learning activities. Many materials were of a seasonal nature such as seeds or flowers while others were simply serendipitous finds. An example of the latter was the discovery of dozens of hawk pellets as the winter snows cleared.

The general framework for each workshop was fairly consistent and typically included; 60-second science demonstrations, experiments and activities, project ideas and instructions: guidelines for enhancing classroom atmosphere, reading lists and snippets from the news, vocabulary lists and resource sites, and variations and extensions. In addition to standard format materials for teacher use were special topics such as: classroom atmosphere, collections, research, science fairs, and values clarification.

Sixty-second science demonstrations were quick demonstrations that could be done at the beginning or end of class time. These may serve multiple purposes including introduction to a unit, brainteasers, fill-time at the end of a class or simply to get attention. Examples included simulating a lung with a plastic pop bottle and balloons. By cutting the bottom off a 2-liter bottle, covering this open bottom with a piece of cut balloon or rubber, and inserting an inverted balloon into the top, pressure changes are easily created by pulling on the flat rubber bottom. The result is partial inflation of the inverted balloon as the pressure changes. (Many students were seen demonstrating their "lungs" in the hallway after class).

Another popular 60-second science demonstration can be used to show sound waves. Cut both ends off a metal can. Cover one end with a piece of balloon or rubber so it is flat and relatively tight. Glue a small mirror to the rubber side and hum or talk into the open end. By shining a flashlight onto the mirror so that the reflection is received on a flat, white surface, one can see the effect of changing pitch as the reflected vibrations move.

Experiments and activities were rarely presented cook-book style. One exception was a unit on growing crystals. By providing a foundation with recipes pre-tested for success, the teachers were able to grow crystals and carefully consider the factors involved in the process of crystallization. Based on the questions asked by teachers, such as, '…what happens if…', it was evident that they were engaged. Their enthusiasm as they participated in show-and-tell with their products indicated that transfer into the classroom was imminent. Several teachers did, in fact, squeeze the unit into their lesson plans very quickly with positive results.

Several activities involved building models with a variety of materials from islands of sand and glue to landscape elements represented with grape tendrils and moss. Several of the island models became very artistic as teachers entered an impromptu competition for Best Island. At several points, teachers left the workshop to collect extra materials from their classrooms for use in the model building. Such landscape units were very conducive to model building, as was a project about erosion.

Experiments were more often discussed rather than completed. The idea throughout the workshop program was to build confidence and enthusiasm. When completion was a benefit to confidence building, experiments were completed. When a new perspective was all that would be required for a teacher to run with an idea, the teachers were provided with supplies, planning time and any assistance they required.

Classroom atmosphere was a minor component of the workshops. Teachers have a strong sense of ownership over their classrooms. As such, rather than offer specific topics directly addressing classroom atmosphere, enhancements such as materials design, display and arrangements were included in practice as elements of my presentations. This modeling proved effective as a non-invasive delivery strategy. Additionally, by teaching in their classrooms with children ranging from sixth through eighth grades, I was able to provide real-life demonstrations. This helped build their confidence in me as a partner and as a consultant much more quickly than an artificial laboratory situation could.

As a monthly feature created to integrate reading about science with thinking about and doing science, I reformatted current news from a science news server and provided short articles relative to the month's topic. These reading packages typically included thirty articles that could each be read in less than five minutes. For each group of articles, I provided questions in a worksheet that was duplication ready. These were especially popular with the language arts teachers and were frequently the first section they turned to at the beginning of each workshop.

The combination of activities, readings, discussions and demonstration was effective for staff-development workshops. As the foundation for a month's topic, the concrete learning experiences provided a good foundation for discussion and integration with existing curriculum and classroom materials. The opportunity to discuss events and collaborate with other teachers from across the curriculum helped create and maintain an atmosphere of cooperation and progress toward a unified goal. From the experiences enjoyed during the five-hour workshops teachers were enthusiastic about transferring their new knowledge into classroom activities promoting scientific literacy.

Chapter 4

EXPANDING OUR RESOURCES WITH STUDENT SCIENTIST PARTNERSHIPS

By middle school, most students have seen enough worksheets and 'chapter questions' to be thoroughly familiar with questions designed to elicit very specific answers. Multiple choice, true/false and short-answer are all typical forms of questions used to gauge the acquisition of knowledge. Students at this age often think that all questions have answers and that someone besides them already knows the answer. From this perspective, it follows that learning may be perceived as the digesting and memorizing of an unmanageable collection of facts. This can seem a very daunting task for a young child still trying to make sense of his or her world. Creative questioning and shared inquiry includes children in the discovery of knowledge and makes them partners in their own education rather than recipients. Student-scientist partnerships (SSPs) offer children a new perspective on learning. The emphasis is on exploration rather than evaluation.

Student-scientist partnerships provide a special opportunity for practicing scientists to share their intellectual investment with the students who represent the next generation of scientists and political decision-makers. It is this sharing of knowledge and acquisition of state-of–the-art technological expertise that benefits students, teachers and researchers alike as students graduate with more than textbook information. Damrosh

(1998, in Marks, 1999) goes so far as to argue that "circulation of knowledge may be more important than the generation of new knowledge" (p. 42) As such, many in the scientific community feel a personal sense of duty to make an effort to provide a far-reaching and potentially pivotal event in the lives of school children. No longer is the teacher the only source of adult academic interaction; scientists are becoming a presence in education through often rich and involved partnerships and relationships with individual students, class groups, school districts and global programs. Students are able to refine their images of stereotypical scientists by gaining personal access to people who are surprisingly like themselves. By blurring the line that separates 'them and us', careers not previously considered become new and exciting possibilities for the students (Kesselheim, 1998). Advanced studies in the sciences become more enticing and the study of math and science can become desirable for children of all backgrounds as they are given experiences that bring them within the professional and cultural communities of scientists (Richmond, 1998).

The university environment is rich with concrete materials, ideas and information. Through the creation of academic partnerships between universities and public schools scientists are available to provide specialization and depth of subject knowledge while the classroom teacher supports pedagogy needed for age-appropriate curriculum design. The often limited resources of schools and inadequate scientific training of teachers can be greatly expanded as professional contact, equipment and supplies are made available (Druger, 1998). Materials considered too specialized or too expensive for limited funding available to schools may be provided through loan programs included in the design of the partnership (Ebbers, 1999).

The Experiential Learning Initiative

In 1997 an academic partnership was established between public school District 88 located in Bellwood, Illinois and myself as a graduate student in Michigan State University's Department of Entomology. Under the umbrella of this student-scientist partnership (SSP), the Experiential Learning Initiative (ELI88) was designed to give urban students an opportunity to break from traditional educational methods and to practice scientific investigation in the field.

To fully appreciate the difficulties and opportunities inherent in this and other partnerships, a look at demographics is in order. District 88 is located approximately 10 miles west of Chicago along I-290 between I-94 and I-294. Approximately 5000 children from the villages of Stone Park, Bellwood and part of Hillside are served by the early childhood, elementary and Jr. High Schools of the district. District 88 serves a predominantly minority community. The racial mix is approximately 85% black, 12% Hispanic and 3% white and Asian combined.

This is an economically depressed area with the majority of employed adults working in the service industry. Approximately 85% of the students are eligible for school lunch assistance, and roughly 15-25% of the children live in court-appointed foster care. Nearly 80% of the children reside in single-parent or extended, multi-generational family settings (Birdin, 1999).

All commonly known gangs are represented in the community and provide strong challenges to law enforcement and social service agencies. D.A.R.E. and The Boys and Girls Clubs of America provide well-attended alternatives to street activities.

Within the physical structure of Thurgood Marshall Academy in District 88, 150 students in 6th, 7th and 8th grade classes are formally considered academy students. During its first year with academy status, only the 6th and 7th grade classes were 'academy classes'. Eighth grade was added the second year. Students attending Thurgood Marshall were selected from the school district's population based on test scores in math and science. As a public school, there are no additional expenses associated with the students' opportunity to attend academy classes designed around a central theme of math and science. As the academy program entered its second and third years, parents from around the district were actively lobbying to get their children admitted to Thurgood Marshall. Based on the success of the first group of students to graduate from the academy, the local high schools have indicated a strong position in support of the academy's ability to prepare students for entry into high school.

Students selected to participate in the first and second years of the ELI88 Project were all from the Thurgood Marshall Math and Science Academy. There were no additional test requirements for participation in ELI88 but the students selected all showed a high level of interest in science, were able to work cooperatively in groups, generally exhibited behavior conducive to success and were willing to commit to the project for a period of five months. Final selection was done by the ELI88 coach/teachers. It is important to note that Grade Point Average (GPA) was not among the selection criteria. Because ELI88 offered students an alternative educational experience, traditional measurement instruments would not necessarily provide an effective screen and could actually eliminate the most qualified candidates. This process resulted in the selection of 16 children from the two 6th grade and two 7th grade classes for the 1997 pilot program. Students understood that failure to complete assignments on time, lack of cooperation, or any disciplinary actions associated with school would result in removal from the program. Happily, none of the original students were removed from the program.

Over a period extending from December 1997 through May 1998, I met with the original sixteen students in monthly pull-out sessions during the regular school day. Most sessions lasted between 30-minutes and two hours. During these meetings, designed to facilitate a sense of cooperation and trust, skills needed for scientific investigation were practiced. Observation and inquiry were key to preparing students for the final field trips. During an early activity, students observed crickets for various lengths of time and recorded observed features, behaviors and interactions of the insects. These physical and behavioral observations provided a base from which students could begin to formulate questions and develop hypotheses. Physical features such as size, coloration and antenna length generated questions related to adaptability and survival in the wild. Behavior observations typically resulted in students wondering about competition, hierarchy and social interactions among the crickets.

The observation and inquiry practices developed during this and other early lessons helped prepare the students to approach a field experience at a local pond with a more finely honed perspective. Many of these students had never been to a natural environment nor used the outdoors as anything more than space. As such, it was important that they be given the tools necessary to reduce any anxiety associated with a field experience (Bunderson, 1997). This included the ability to quickly assess a situation, become situationally acclimated and actively engage in appropriate activities such as insect surveys or plant sampling. Several studies involving the use of ponds or streams as entry level experiences for school children have indicated that such activities serve a valuable function in science education and values formation (Stein, 1997; Teutsch; Friday 1997; O'Sullivan, 1999; Atha, 1999; Margolis, 1999; Mattingly, 1994; O'Neal, 1995).

During the first year's field experience, a heavily managed pond located a few miles from the school was chosen. Although not ideal biologically, the pond provided these urban students with many new experiences. Catch-and-release collection techniques were used for insects and one very large frog. The original intent had been for the students to collect, sort, identify and label insects collected at the site for the purpose of analyzing community composition. This goal was immediately abandoned when we realized that the students were simply not prepared well enough to provide reliable information. Instead, the students' heightened interest in the natural environment was allowed to flow and techniques involving the use of insect nets and traps were refined. This provided the students with concrete experiences in the techniques of insect collecting and allowed them to begin formalizing their observation and inquiry skills. The frequency and complexity of their questions increased dramatically over the period of two field trips.

The interests expressed by the ELI88 participants became the topics of their final posters. Some of the topics explored as a result of inspiration from the field trips included algae, insects, birds, animal homes and plants. Working in small teams or as individuals the students prepared posters to be presented during a campus visit to Michigan State University. Eleven of the sixteen students in the pilot program traveled by train to MSU for a three-day event hosted by the Department of Entomology. The students stayed in dorms, ate dorm food and enjoyed the MSU museum, the Michigan State Capitol, the 4-H Children's Garden and the Impression Five Children's Museum during their stay. They also presented their posters to the faculty and staff members attending the poster session. Although very nervous, the students were all extremely proud of their work and very excited to have an opportunity to talk with professional scientists

The second year of ELI88 was a time of rapid growth. The academy status of Thurgood Marshall was expanded to include 6th, 7th and 8th grade classes. This resulted in two classes of each grade level and enrollment of approximately 150 students. After the successful first year with the pilot group, all 6th, 7th and 8th grade students were included in the second year of ELI88. Because all 150 students were included, pull-out sessions with me as the science partner were no longer needed. Instead, I taught in the classroom two or three days each month September through April and maintained contact through e-mail between sessions.

From the beginning, students knew that only forty-five students would travel to MSU in the spring to present a poster about a topic they selected and investigated. It wasn't necessary to conduct an experiment, but rather an investigation in an area they found interesting. Toward this end, each month included learning activities that were non-traditional in context and delivery but that aided in the development of skills deemed necessary for success in science. Key to this investigation was the ability to conduct keen observations and to ask questions based on these observations.

The final two meetings with the ELI88 students took place in the Cook County Forest Preserve Des Plaines Watershed (Appendix C). The site selected was a flooded portion of the Des Plaines River only a few miles from the school district. Following a short orientation on site, the students formed small teams and began self-directed supervised explorations. Self-direction provided the students intellectual independence (Bencze, 1999) although some structure was provided by a list of items to be found during the trip. Included on the treasure hunt list were animal tracks, animal homes, examples of different kinds of insects, and similar natural items or organisms. The students quickly engaged in the treasure hunt. Within less than an hour, all students were focused on something of their own choosing found during the treasure hunt. The heavy floods had left an unexpected find of snails along the banks of the river. A group of three male students began collecting the shells and soon had more than one hundred specimens. They asked if they could do something with the shells for their project. Back at school, they washed, weighed and measured their samples. This became a very interesting investigation into statistics as these 7th and 8th grade students completed calculations by hand and with the use of Microsoft Excel's graphing functions. Their results were discussed and presented in the final poster session at MSU.

Another group was intrigued by all the animal tracks found along the river banks. Using plaster of Paris mixed on site, this group of students prepared plaster casts that were later identified and organized by theoretical food webs. Their samples provided a very nice display to support further research into the animal communities of woodland forests. The twin sisters conducting this project have declared veterinary medicine as their career choice.

In total, there were twenty-one posters completed covering topics ranging from spiders and aquatic insects, animal homes, plant pressing and identification to water quality analysis. All students choose their own topics and were assisted in reaching their goals for the project by their teachers and by me. The poster presentations were held at MSU for a second year with very positive results. The students participating in the program as well as their teachers and the staff and faculty of MSU were all very enthusiastic about the program. The students involved in the ELI88 project experienced success at many levels throughout the various stages of the ELI88 project. Most notable was the completion of their presentations before a panel of experts. The students enjoyed the experience and district officials have encouraged the continuation of the project for the next school year.

Student-scientist partnerships provide involvement with practicing scientists and can offer a valuable association with universities. Both sides should pursue such associations. The university gains an ideal forum for outreach while the students' experience of being junior researchers creates a non-traditional dynamic within traditional public school settings. Flexibility and personal contact are two of the cornerstones of these programs. Spontaneous consultations between the scientist and the junior researcher give the student a great deal more than just information about a science topic. The contact with a caring adult who is a science professional can go a long way toward helping students from many backgrounds understand science from a broader perspective and to consider what it means to work in the sciences. Additionally, research indicates that positive natural experiences like these contribute to an overall expansion of values associated with environmental ethics and leadership (League, 1997; Orion, 1994;

Meredith, 1997). The extent to which this student-scientist partnership will influence the lives of these students may never be known. We do intuitively know that whatever level of impact programs such as ELI88 have on young people, they have the potential to offer a contact of significance.

Chapter 5

CONVERTING PRIMARY RESEARCH TO MIDDLE-SCHOOL CURRICULUM

The 'pipeline' through which research findings are distributed is very small and restricted. Cooperative extension, university outreach activities, visual media including 'educational television' and print media including lay publications have been the traditional routes by which new and exciting information goes from the lab to the people. The path to public schools is even smaller. Converting current research into usable curriculum for children is the objective of this student-scientist partnership. The younger the students are, the more challenging it becomes to translate significant primary research into classroom-friendly materials. Determining the age at which children are able to understand the significance of natural events is often a difficult but critical element in applying scientific research to classroom materials and activities (Marks, 1999).

In this section we will establish a template or model that can be used to translate the most innovative, the most interesting and the newest topics in research into lessons that involve tomorrow's leaders in this very exciting discovery process.

As members of the scientific community, we have more access than others do to professional journals and fellow scientists. Editors and publishers look for research that is new and exciting or innovative in some way. Likewise, most scientists are fascinated by the questions that lead them to choose their research. By talking with colleagues and by reading professional journals we learn about what is leading edge. By reading contemporary lay publications, we get a sense of where the public's interest rests or where the media is focused. This is where we can find material for the new paradigm in science education. The general science of today was the current research at some time in history. Today's leading edge research will be the general science of tomorrow. If we teach science that includes current investigations, those investigations that are as of yet without firm grounding in theory or principle, we will bring up a generation of collaborative, thinking, questioning investigators. By teaching only what is included in textbooks or that which is "proven" we offer several injustices to our successors. First, we position ourselves as the embodiment of knowledge and challenge them to know all that we do. Second we offer activities in the name of 'hands-on' science when, in reality, these activities are not investigative but rather demonstrative of what is already known. Recent articles have offered guidance for selection of educationally appropriate "hands-on" activities (Moscovici, 1998; Jeffries, 1999) and promotion of inquiry-based learning (Roth, 1996; Hand, 1999; Edwards, 1999).

Bookstores and classrooms are filled with how-to books and recipes for science fair projects. Select your experiment from the menu, follow the directions exactly and the outcome is nearly assured. Many, if not most of these how-to books go one injustice further and explain the outcome and solve problems (divergent outcomes) with flow-charts. Any science fair in the country is filled with the products of these mock investigations. Certainly there is value to following a path to a known outcome but we need to stop accepting this as research or as investigative science.

In selecting materials for conversion to learning activities, individual interests and enthusiasm need to be valued. If a teacher or curriculum developer is not interested in the research then even a best effort will fall short. This is very much like the old saying about writing about what you know. When talking to colleagues or while looking thorough magazines and journals certain articles will grab your attention. Begin with these. The second consideration is the sophistication of equipment used in the research. Is the equipment readily available? Is there a way to build or adapt equipment to suit the need? Is there a simpler way to do an investigation that could parallel the professional work or is there a tangent that could be followed as a springboard to the research?

The question does not need to be the same as the research seeks to answer. It only needs to provide inspiration. Once you and/or your students have brainstormed a few questions of your own, the rest is easy and consistent with the scientific method. Ask the question, formulate a hypothesis, design an experiment, isolate or identify the variables and determine a method for data collection and organization. Not all investigations need to have results or data as an outcome. Observation may be needed, and is itself a valuable skill. From time spent in observation, more questions will likely be asked. Formal data collection isn't always needed. Formal procedures may prove one's intuitive sense but the lack of formal data does not disprove anything. It isn't necessary to quantify the joy of discovery. All that's really needed is eye contact to see the proof.

In our professional existence, we use what is already known to color our observations and shape our questions. A difference between adults and children is that, generally, adults know more things. They have more experience to draw from and have developed ideas about what works and what doesn't work. This advantage can be a disadvantage. In addition to not knowing what works, children don't know what doesn't work and feel freer to try the "impossible". While searching for answers using impossible methods children will come upon all sorts of wonderful things.

I recently read about French scientists who were doing research about friction in granular materials (Weiss, 1999). Since kids love sand, this one caught my interest. Without sophisticated rotating drums and humidity sensing devices, even the youngest students could add measures of water to sand in jars and roll them to see what happens. As the dry grains of sand flow freely and the moist sand sticks a bit longer we can then talk about the general science of friction, adhesion, surface tension and the physical properties of water that allow it to become a bridge between granular materials. All kids on the beach know the castle turns out better with moist sand than with dry sand.

In a similar publication, there was a brief article about communication in insects based on scent (Travis, 1999). By relating known smells to defined messages, students could easily communicate without looking at or talking to each other. Small spray bottles with diluted peppermint oil could be used to spray a "go sharpen your pencil message". The smell of lemon could mean, "line up at the east door" and garlic could signal "get out your lunch, it is time to eat". Playing with scents sets the stage to talk about non-verbal and non-visual communication in insects and other animals. Natural extensions could include chemistry, chemical properties, density and concentration and sensory receptor physiology. Again, we've been inspired by current research to explore the cutting edge and bridge with general science.

The steps to research conversion for curriculum can be summarized as follows:

a) Notice what sparks your interest (the same applies for students).

b) Decide if an identical, a parallel or a tangential investigation is most appropriate for your equipment availability, and your students' ages, abilities and time.

c) Determine whether a full investigation is needed or if an observation or demonstration activity is most appropriate.

d) Consider the possible sphere of support from general science. What theories, principles or patterns might be used to understand this conversion? Conversely, into what theories, principles or patterns might this investigation provide a segue?

e) Establish a working list of key vocabulary words to support discussion of the topic. Avoid the trap of relying on the use of vocabulary as a key to student comprehension. Some students may be very masterful with words but fail to understand the concept. Teachers need to listen carefully to explanations as students discuss the new concepts.

f) Gather materials as needed for your approach to the topic.

Sample Conversion – The Watershed Suite

The hydrologic cycle is at the heart of every ecosystem (Speidel, 1988). Vegetation is present or absent largely because of the presence or absence of water, the duration of the water and the quality of the water. Birds, insects and other animals are present in predictable measure based on the water regime and resulting vegetation. The water, vegetation and animals are the major factors in defining the community structure that, in turn, defines the ecosystem and biome (Johnson, 1997). Understanding the broad scale landscape patterns associated with regional watersheds and small, local aquatic systems provides generalized understanding of the natural world in general. Due to the large scale of the Great Lakes, circulation patterns are very similar to those expected in oceans (Canadian Hydrographic Service, Department of Fisheries and Oceans, 1999).

Additionally, the Great Lakes make up the largest source of freshwater in the world. Freshwater is becoming a premium commodity as ground and surface waters are sold, rivers diverted and aquifers depleted. There are potentially serious ecological and biospheric ramifications if water use issues in and around the Great Lakes are not dealt with in an intelligent, scholarly manner.

The Watershed Suite was created to offer students an experience that a landscape approach to aquatic ecosystems through the use of mapping and visualization strategies. In this suite of activities, background information about the Great Lakes provides the student with an overview of Great Lakes history, mapping with GIS and vector-based approaches, multi-factor two and three-dimensional graphing and, finally, circulation in the Great Lakes. The first learning activity in the Watershed Suite uses student data from GLOBE (Global Learning and Observations to Benefit the Environment) to demonstrate graphing with multiple factors and in three dimensions. Students begin with simple graphing of three significant biological factors. In this example, combinations of time, temperature and pH are used. The time sequence covers a short three-year period but has representative temperature and pH measurements from all seasons. By comparing different sorting priorities, students are asked to consider the relative nature of data sets and to become aware of the different representations and stories that can be told with identical data. This first activity is included in the Watershed Suite found in Appendix A. As a follow–up to single plane graphing, students are also asked to use Legos or other suitable materials to create 3-dimensional graphs that include time along the x-axis, pH along on y-axis and temperature on a built-up z-axis.

We are finding more opportunities to include visualizations in daily lives. From the meteorologist who flies us through a virtual storm to the physician who reads an MRI to the teenager in an arcade driving his super-speed race car through an obstacle course, we are becoming more dimensional and looking at our real worlds, virtual worlds and data sets from new perspectives. We see in 3-dimensions and are naturally better able to comprehend complex data when it can be presented the way we see. The Geographic Information System (GIS) has put an almost limitless supply of data and data combinations literally at our fingertips. By following the contours created as demographics, geography and resource distribution come together we are able to determine who is using what where. The learning activity described takes students a base graph and allows them to create their own dimensional show. With this as a background for further use of visualization strategies, the student is not only able to appreciate the complexity of such visualizations but also approach them more critically as she considers the selection of data, the priority with which the data is shown, and the strategies that can be used to 'change the story'. This is a very 'back-to-basics' approach to new age information easily taken for granted. By increasing awareness and by adding to a student's ability to conduct critical analysis, he may be less likely to accept information at first glance and put additional thought into his acceptance or rejection of evolving truths.

The second activity in the Watershed Suite (see Appendix A) uses the basic graphing knowledge gained in the previous activity and elsewhere to stress the creation of maps with the use of points, lines and polygons. Any feature found on a map can be represented with a point as in the case of a radio tower, a line that might show a highway, river or political boundary, or polygons for lakes, towns and preserve areas. A point can be further defined as a coordinate (x,y) on a grid. Pairing coordinates yields a line while grouping coordinates yields a polygon. This being the case, we can 'draw' on a grid simply by defining the coordinates.

The vector-based mapping activity stresses the use of points, lines and polygons while teaching data organization through grouping into classes and using color as a visualization tool. Data sets for temperature and depth in Lake Superior are organized by the student into classes. Each class is color coded and the associated color is applied to a grid map of Lake Superior based on the temperature or depth class represented at each of several data collection stations. To complete the activity, students must be able to determine class groupings that most efficiently represent the data, locate the research stations based on their coordinates and apply the appropriate class color symbol to the station. Once completed, visual patterns coincide with temperature and depth patterns.

With every weather report, students see maps that were created in a similar fashion. As with the previous visualization activity, this vector-based mapping activity goes back to the foundation of visualization with color and creates awareness for the complexity of the product and possible biases imposed by color assignment or class definition.

The next activity in the suite is also based on mapping, but this time we use a primitive layering to demonstrate data visualization with GIS layers. Students are given several transparencies and overhead markers to use in creating layers of themes from their watershed. Students are asked first to draw a map of their neighborhood including the school they attend. This in itself proved to be a worthwhile activity. The very routes traveled daily could often not be mapped without assistance. After completing the basic shape map, students created single-theme maps of lakes, ponds, ditches or other sources of water in their neighborhood. Additional themes included residential property, commercial property, recreation areas, and paved areas. The winning question was inevitably, "What order should I put these in?" Bingo!! GIS allows you to choose data you need and organize it into whatever type of sandwich you require. After each student had created several of the theme maps, they were asked to look at different combinations of information with and without the underlying shape map. They were further asked to consider some of the biological implications of the relative location of water and land and to discuss their thoughts.

Horizontal circulation was the theme in the final activity of the watershed suite. In this activity, students talked about different kinds of shadows. Light shadows from the sun or a lamp, solar and lunar eclipses, "snow shadows" cast as trees block the falling snow, and finally, wind shadows. Since even toddlers understand the concept of shadows being created as one factor is blocked by another, the cognitive transition to wind 'shadows' being created by landscape elements was elegantly simple.

After discussing shadows, students were given worksheets (Appendix A) and asked to position ½" square blocks in the spots marked on the worksheet. With the overhead lights off, students used flashlights to cast shadows across their blocks. Colored markers were used to outline the shadows cast from various directions around the worksheet. With the lights back on, the next task was for the students to predict wind shadows based on assigned wind headings.

As the students predicted the effect of wind over the landscape, other concepts relating to circulation were offered. This discussion and potential additional activities and extensions can include issues of density. Since fresh water is most dense at 4°C, the Great Lakes are dimictic, meaning they undergo vertical mixing twice each year. This fall and spring overturn impacts not only the biological community but also the distribution of nutrients and pollutants (Speidel, 1988). The predictable overturn of water in the Great Lakes is a critical contribution to vertical circulation as are pressure gradients and basin topography. By breaking circulation down into these digestible packets; wind shadows, horizontal circulation, vertical circulation and the effects of the Earth's rotation, students are more easily able to follow the patterns.

Sample Conversion – Landscape Visualization through Interpretive Modeling

The ability to learn a subject is often directly related to the appropriateness of the delivery model used to present the materials. In order to develop the most appropriate delivery vehicles for teaching complicated environmental processes, we need to be able to identify the student's existing level of understanding . The level of understanding a student brings to a lesson is likely to be based on a combination of fact, interpretation and confusion. Conclusions based on personal observations may or may not be correct and may or may not be complete (Gardner, 1993). For many students, a tree is a tree, mountains are mountains and a stream is likewise not seen as relating to the other elements in a landscape.

Pre- and post-testing has been added to much of the new material used in public schools, but even this attempt to qualify the learner's background is based on standard testing methods such as short-answer or multiple-choice questions. The following activities represent a multi-sensorial approach to teaching a landscape patterns unit and the relationship between patterns common to various biomes and associated biogeochemical processes.

The Mini-Mountains learning activity was created to facilitate the recognition of landscape patterns through the use of three-dimensional objects. (Refer to the complete learning activity in Appendix B). By recognizing basic patterns found in natural and humanmade environments, the student may gain a greater understanding of environmental processes and the relationships that exist between patterns and processes. Throughout this lesson's development, students from the Experiential Learning Initiative (ELI88) were encouraged to comment freely on the activities. Based on their input and the results of these initial activities, refinements were made in the choice of objects, selection of images and documentation appropriate for quantifying outcomes. It should be noted that this was not an experiment but rather a learning activity that shows potential diagnostic value for learning styles. Through this visualization activity, students were given concrete materials with which to consider landscape patterns.

Each student was given a large sheet of presentation paper marked into 1-inch squares, a set of Styrofoam objects, a marking pen, and a landscape photograph typical of a defined biome such as mountain, desert or prairie. Available objects included several different sizes of Styrofoam balls, cones, disks and rectangles. All materials are readily available from craft and office supply stores. The instructions were very simple. Use the objects to build a model of the landscape being viewed. There was no time limit and students could use as many of the objects as they wanted. Further, there were no restrictions on how the objects could be used. They might be flat, lying on their sides, stacked or piled into groups. After the students were satisfied that their models were complete, they traced around the bases of their objects with marking pens. Only after this step were students allowed to see what the other students had done in their interpretations. The results were quite surprising. The students themselves commented about how two people could see a scene so differently.

Many students wanted to do additional models after the first one and were allowed to do so using photographs of other landscapes. After several rounds of model building, students were talking among themselves about the relationships between <u>their</u> mountains and <u>their</u> trees and <u>their</u> rocks. While possession was not intended as part of the exercise, it was a nice add-on toward environmental awareness. It was interesting to hear students explaining to each other why a particular combination of elements made more sense than another combination would. Samples of the models have been included in Figures 5-1 through 5-8.

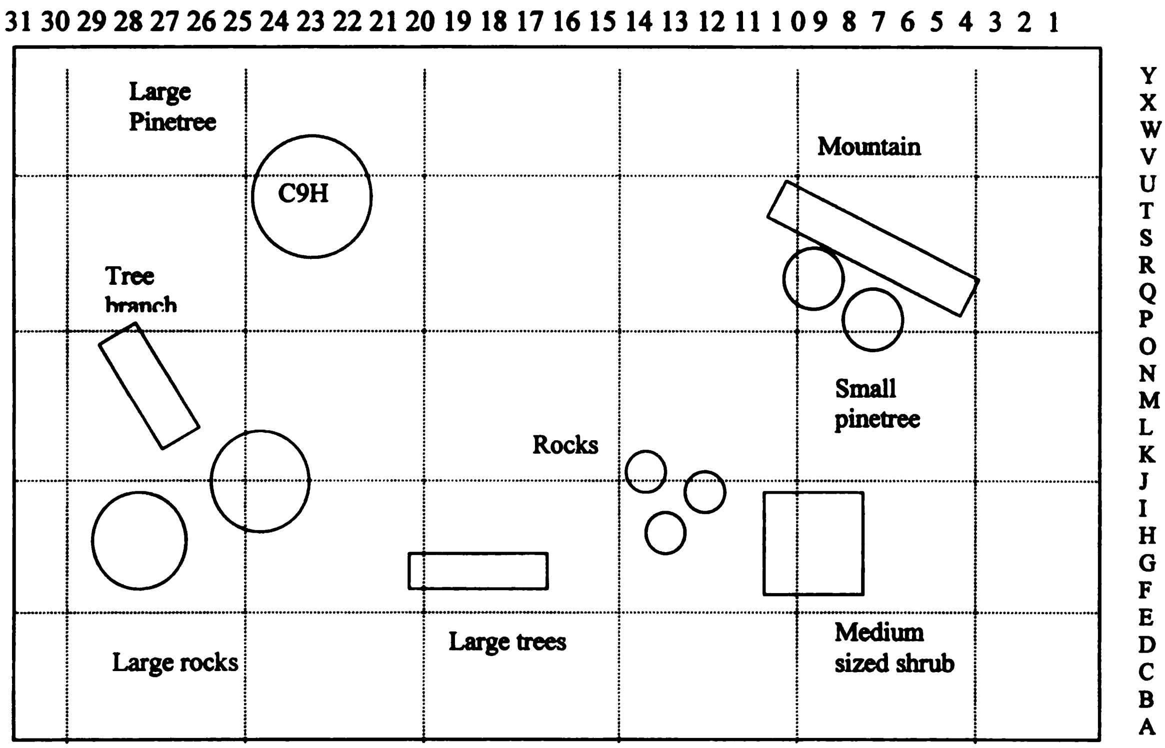

Figure 5-1. Interpretation of Mountain Scene (AF)

Figure 5-1 is one student's interpretation of a mountain scene. She used twelve of the available objects and included all of the shape classes. She used cones to represent pine trees, balls to represent rocks and squares in two positions to represent shrubs and trees. Also used as a large tree was the 12-inch tall block. The most interesting use of manipulatives in this example was the 8-inch diameter disk on its side to represent the mountain range. There was also a noticeable use of angles in her choice of object positions.

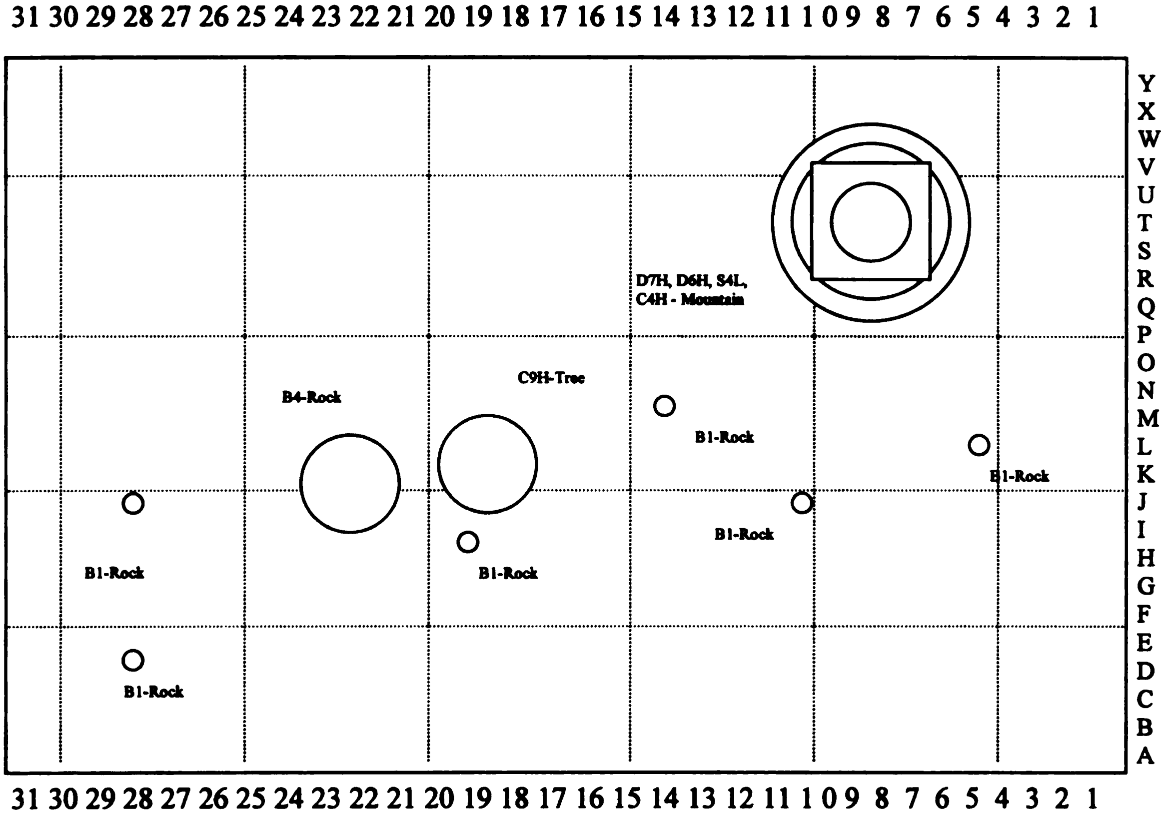

Figure 5-2. Interpretation of Mountain Biome (PS)

The student's interpretation of a mountain scene in Figure 5-2 included fourteen of the available objects. Broad symbolic representation was used to represent piles of rocks and clusters of trees. The combination of objects used to represent the mountain was especially interesting. She included four objects from three shape groups to build her model and all were used in a traditional configuration.

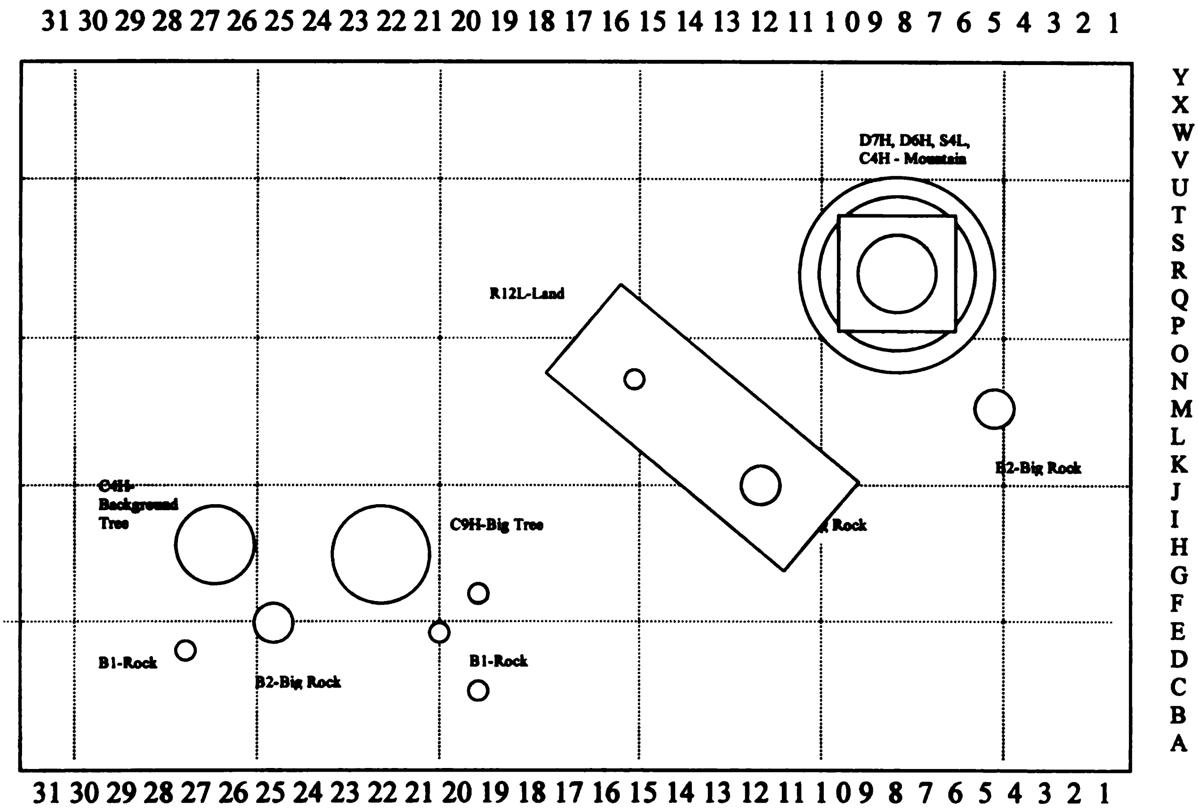

Figure 5-3. Interpretation of Mountain Biome (AB)

Sixteen total objects were used and all shape classes were included. Similar to Figure 5-2, the student's model in Figure 5-3 included the identical combination of objects, all used in a traditional configuration to build his mountain. In addition to broad scale representation of areas using a single object, the rocky area in the center of the image was encompassed with a large area, then built up with only two smaller objects.

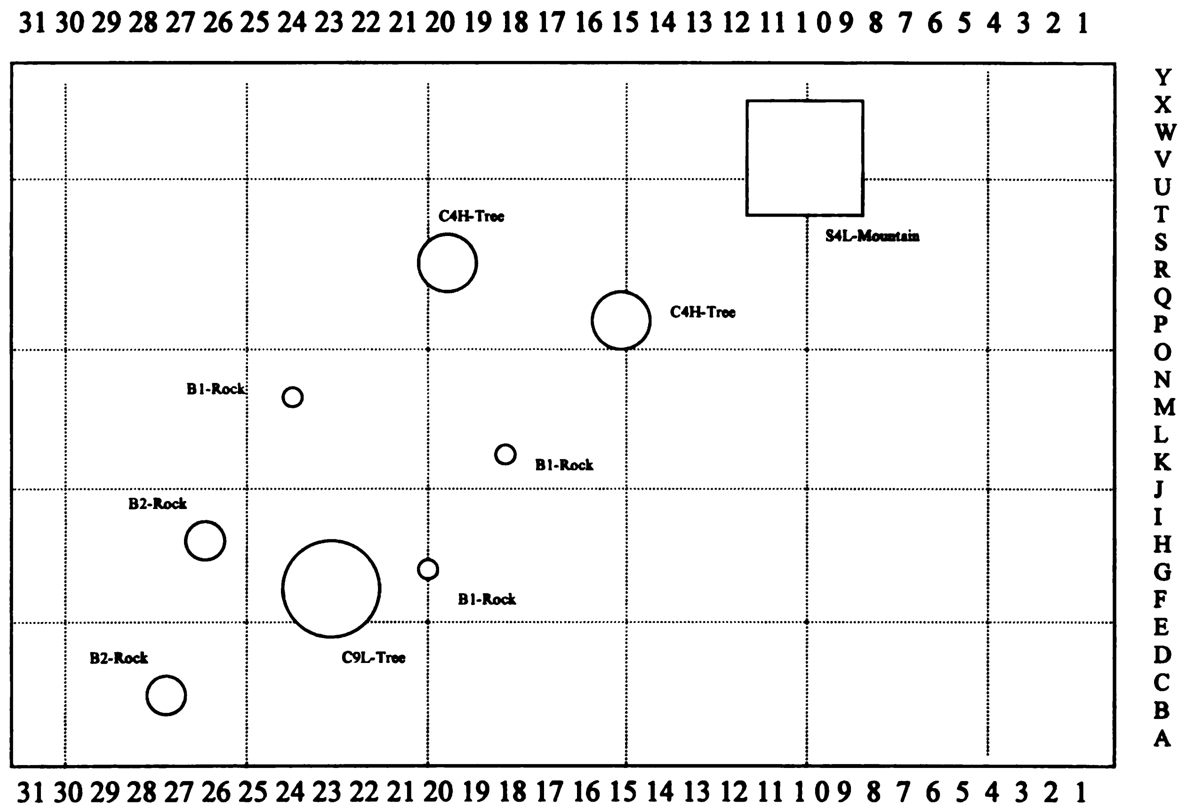

Figure 5-4. Interpretation of Mountain Biome (SR)

Figure 5-4 was the simplest of the models. This student summarized the image with only nine objects distributed as a 'spray' across the field. The mountain range in the far right rear was represented with a single block. Similarly understated, very different rock formations and tree clusters were symbolized with the use of balls varying only slightly in size.

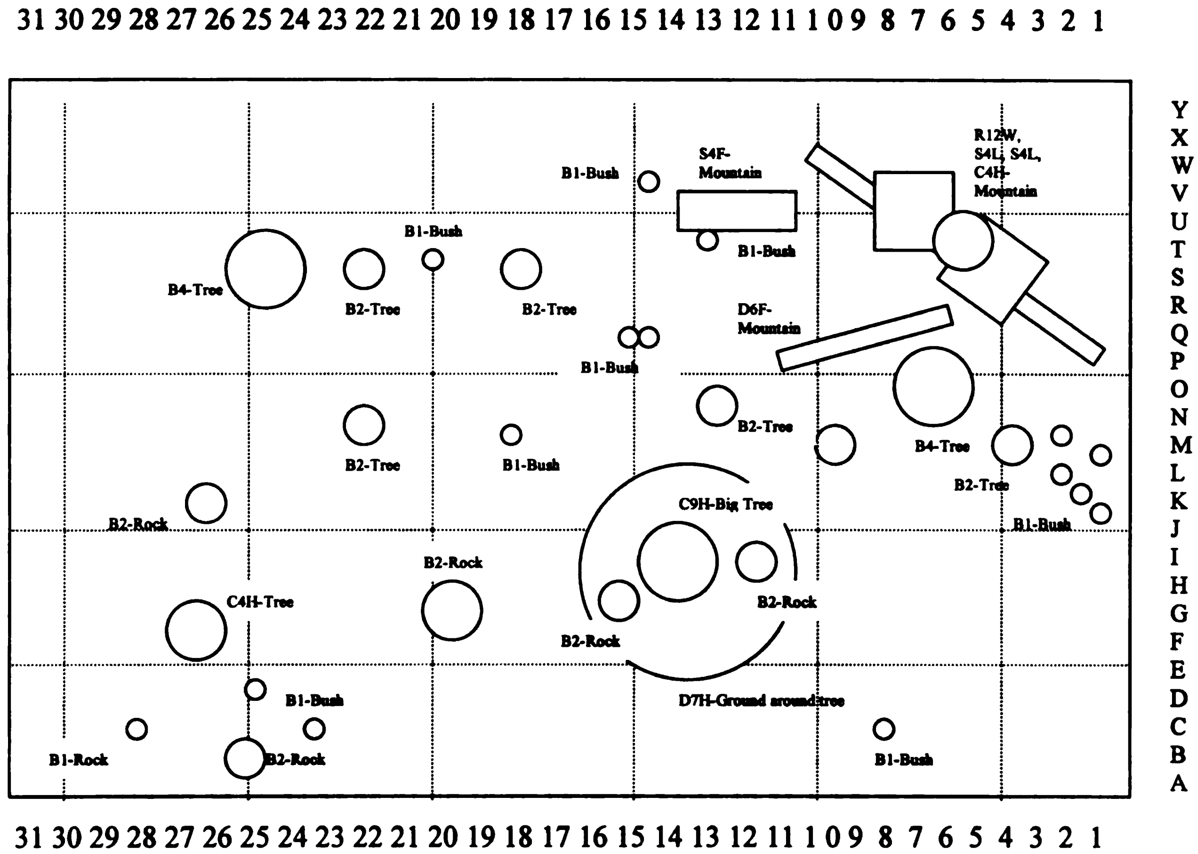

Figure 5-5. Interpretation of Mountain Biome (NB)

This student chose to use thirty-seven objects from all shape groups for his model. Great care was taken to build up complex areas in a way that maintained proportional scale from one group of elements to the next. Where possible, the number of objects used in the representation equaled the number of objects comprising the landscape element. Positioning within each cluster was as accurate as possible. Within the mountain range at the far rear right, angles were included to indicate that the range did not occupy only a single diagonal plane.

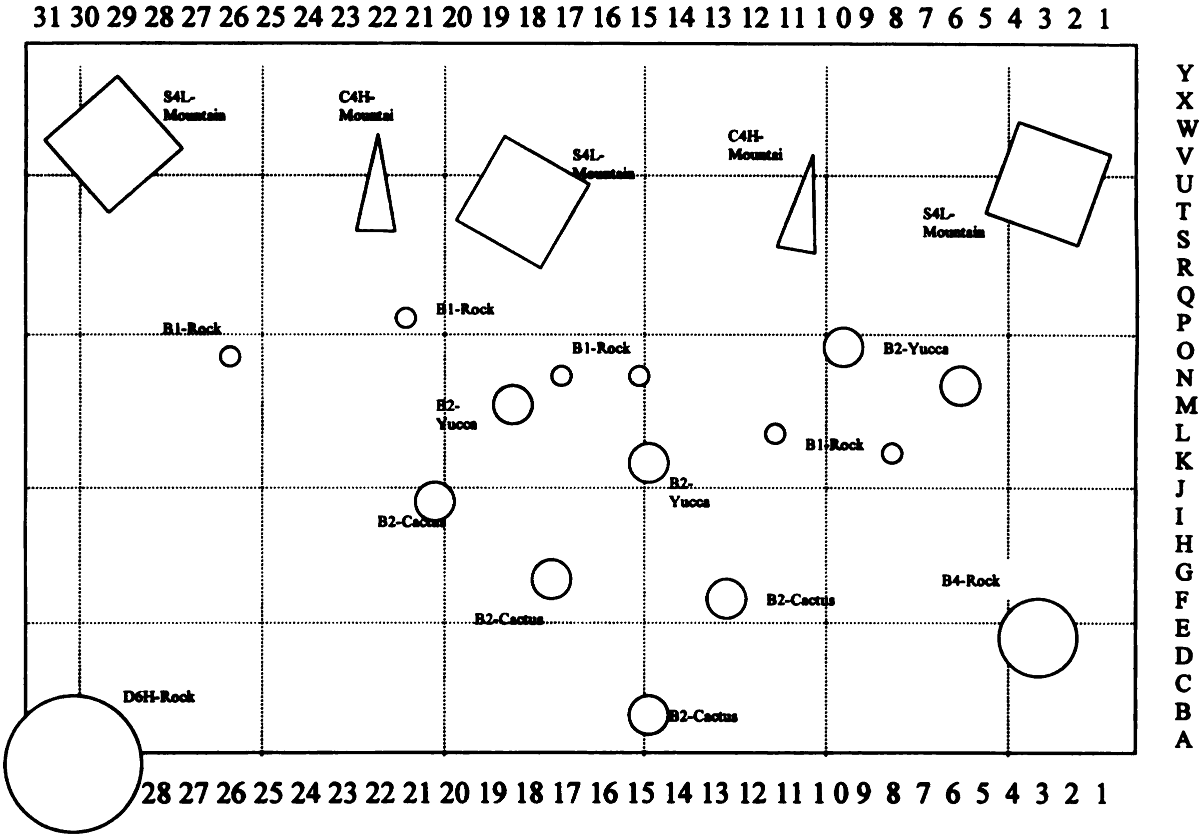

Figure 5-6. Interpretation of Mountain Biome (JS)

Despite a rather simple approach to the symbols used in the model shown in Figure 5-6 and an almost linear design layout, this student chose to ignore the artificial boundary imposed by the edge of the paper in the front left. Although twenty-one objects were used, none were combined as clusters. The mountain range was minimized by giving a nearly equal representation of scale to trees, rocks and other formations.

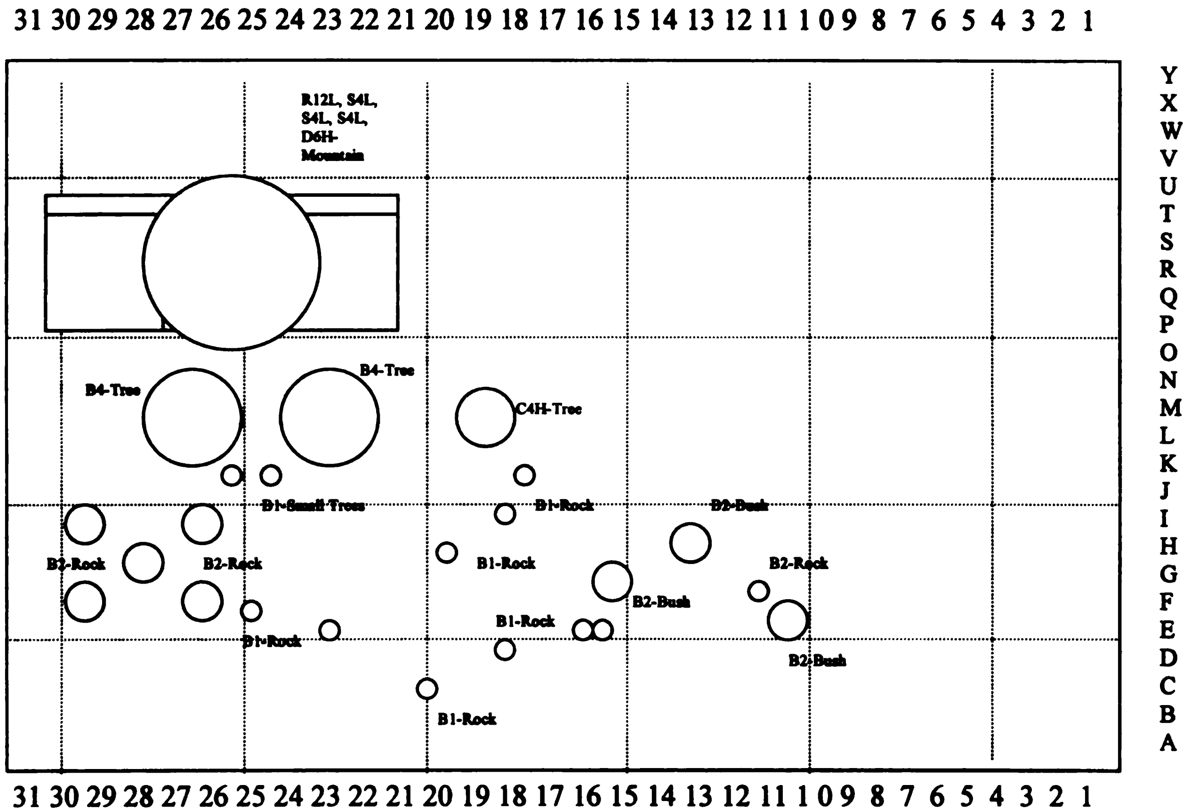

Figure 5-7. Interpretation of Mountain (DW)

Thirty-one objects were used in the representation shown in Figure 5-7. In general, the use of objects to represent the landscape elements and formations in this model was positionally accurate and appropriate in scale. However, the entire mountain range was built opposite to its actual position in the photograph. This selective reassignment of position was inconsistent with the student's otherwise correct interpretation and is interesting when we consider that the range represents the largest and most significant of the landscape features.

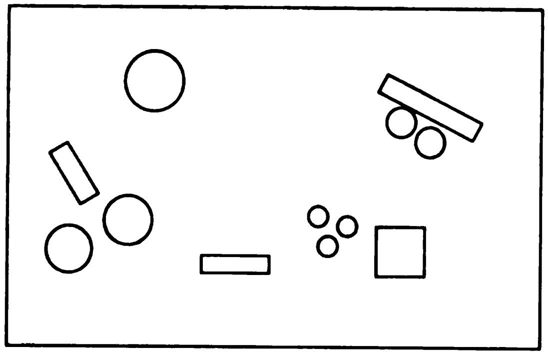

Figure 5-1

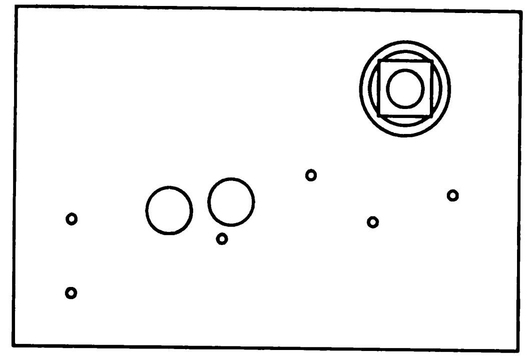

Figure 5-2

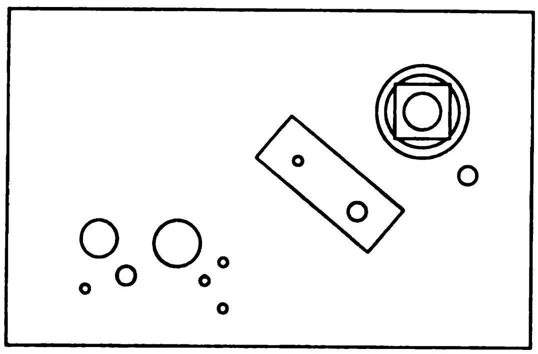

Figure 5-3

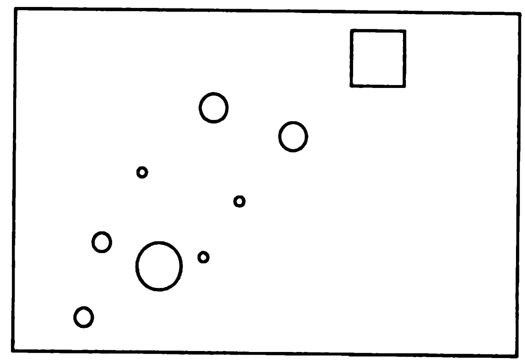

Figure 5-4

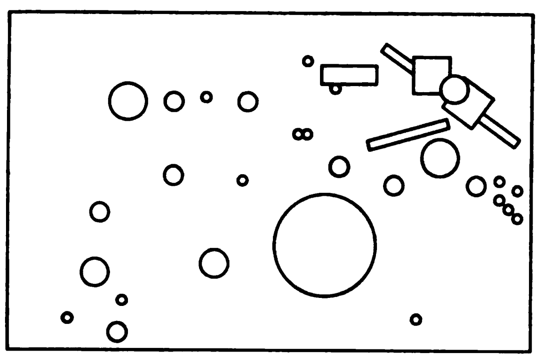

Figure 5-5

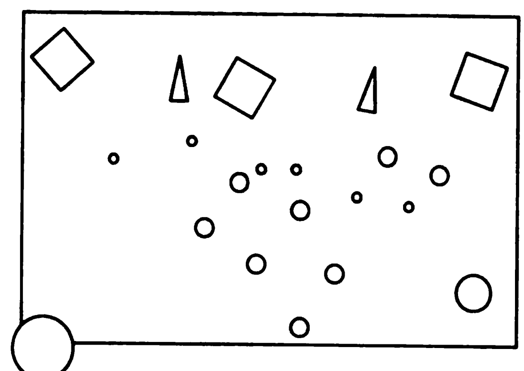

Figure 5-6

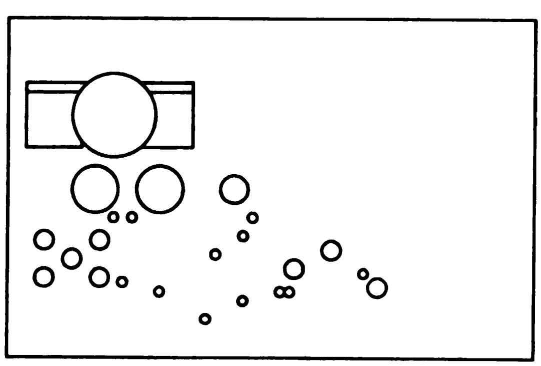

Figure 5-7

These seven diagrams represent seven very different interpretations of an identical landscape. All the students were in the same age class, had the same quantity of objects available to them and had no time limit for the creation of their models. The differing perspectives on scale, position and importance of landscape elements may hold clues for creating Earth Science learning activities.

Figure 5-8. Mountain Biome Landscape Models

The next activity in the Landscape Visualization suite is similar to the original Mini-Mountains activity but involves more complicated analysis, smaller manipulatives and the possibility of a computer lab. The goal again is to help students gain a sense that landscape patterns and landscape processes are interrelated. As with the previous activity, this has not been designed as an experiment but as a learning activity with very few restrictions.

Each student or group of students is given a set of manipulatives. In this exercise, wooden blocks and balls ranging from ¼" to 1" diameter were used. Each student also received a piece of craft canvas (a plastic grid available in craft stores), a bulldog clip, blank paper and a black felt pen. Several photographs of landscape characteristics of defined biomes were given to each student or group of students. Using the blocks and balls, the students created models of the landscape elements they saw in the photographs. After completing their models, pushing the felt pen through the holes in the plastic canvas covered by the manipulative created a 'footprint' of the landscape. These maps were then compared to the work of other students and the concepts of landscape elements and biogeochemical processes were discussed.

By using a grid to lay out the landscape models, the resulting footprints were easily converted to a vector matrix that could be used to generate graphs in a spreadsheet program like Excel. Wherever there was a "hit" or a dot on the map as a part of the footprint, the coordinates were entered into the database. After converting several of the maps to vector matrices, comparisons of interpretations could potentially be quantified. The students could carry their interpretive work from the classroom to the computer lab and continue with cross-curricular connections while remaining within a science theme.

This activity is included in its entirety in Appendix B. This exercise was not intended to be an experiment. However, based on the enthusiasm of the students and the exciting possibility of quantifying visual interpretations and landscape patterns, further research into this activity as a method for analysis of spatial interpretation of landscapes would likely prove valuable.

Chapter 6

INTEGRATING EARTH EDUCATION IN PUBLIC SCHOOLS

The preceding chapters have provided the reader with the philosophy of the Earth School model. Consistent with this model is a template for conversion of current research in the sciences to learning activities in the classroom and an outline for a biospheric curriculum (Figure 6-1) approach to Earth education. This chapter provides some suggestions about integration and program development for public schools.

In any effort to bring change to public education, we need to recognize that every school has its own culture, its own personality and its own underground. In some cases, the administrators are exciting and vital people who truly have vision and an eye to the future. In other cases, this is much too far from reality. The combined effect of administrators, teachers, students, and community structure creates the unique culture that surrounds the learner. This very combination of factions, each with its own agenda, is exactly the reason Earth education will be more successfully integrated on a small scale with teachers as the catalysts of change and students as the quiet leaders from within the system.

My suggestions for integration begin with the teacher. Ultimately, the teacher is the person who decides how the district's curriculum will be applied in the classroom. He or she is the one who decides how the text will be used, which experiments will be conducted, how tests are to be given and graded, and how students will perceive science at the end of their training. To that end, it is critically important that teachers spend time at various points in their development in careful appraisal of their own values. For teachers, these values will be used to filter information that is vital to the health and well being of the planet. The science teacher is the person most highly charged with responsibility for creating a scientifically literate population. No small task. The magnitude of this responsibility needs to be acknowledged and taken seriously. The process for values clarification outlined below is one I've used and taught. It's simple and can be applied to a wide variety of topics from nearly any discipline.

1) Consider the global picture
2) Define the issues
3) Locate relevant scientific principles, theories and processes
4) Identify opposition and support
5) Consider and frame arguments in alternative value systems

Among the critical global issues[1] at this writing are population, urban sprawl, resource allocation and use, threatened and endangered species, loss of diversity, freshwater use and diversion, bioinvasion, salinization and desertification of soil, global warming, air pollution, resource valuation, energy, human health and environmental racism. This brief list is by no means presented as all-inclusive. Additional sources for highlighting key issues of concern to the scientific and global communities can come from newspapers, professional journals, popular press, and observation.

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[1] Each year the Worldwatch Institute publishes their State of the World Report. This report, along with the annual Earth Journal published by *Buzzworm* magazine can offer a broad picture of environmental issues without adding undue pressure to the limited time of most teachers. For a highly readable and thought provoking analysis of globally significant issues, Daniel Chiras's Lessons from Nature published by Island Press is an excellent investment. Action plans proposed for environmental cleanup in Jon Narr's Design for a Livable Planet published by Harper and Row offers pages filled with information, ideas and classroom adaptable action plans on several critically important environmental issues.

In evaluating any issues, the reader should remember to consider the agenda of the publisher. It stands to reason that the publishers of *Worldwatch*, *Environment* and *National Wildlife* will present information differently than the Loggers' Union or *Economist* due their readers' interests. Awareness of the potential for biased reporting is essential for position and value clarification and should be included in any critical analysis of information.

The reader is encouraged to become very deliberate in breaking down significant issues into scientific principles. Based on these principles and accepted or controversial theories, what does the evidence indicate? How then, does this evidence support or disclaim your position? Persuasion in casual debate and in education is a valuable component of education. We persuade our listeners to consider what we're saying. We ask them to truly evaluate the evidence that they're seeing, reading or hearing. We further need to ask them to use this evidence to consider what we've said and to arrive at a position they can defend with a logical, persuasive argument. While the debate of untrained participants can quickly degrade into loud voices and irrational, emotionally based positions, this is seldom persuasive. An argument based on fear or ignorance does nothing to advance one's cause and can prove detrimental to the image and effectiveness of others who share the same perspective.

In an effort to clarify a position on ecological issues, begin with a clear definition of the issue. If asked whether they are for or against the loss of usable land, most people will generally be opposed or have no opinion. Get to the point of conflict. This same loss of land issue could be stated as a question such as, "Should a developer be allowed to build a mobile home park on agricultural property?" or "Should cities have the right to limit growth?" Either question could easily become the topic of a heated debate. This leads to the next phase of deciding where your vote would be cast. If an emotional response wells up with a clear NO!! to the question of the developer, ask yourself why. If the answer is based only on emotion or even on aesthetics, your position will be a weak one regardless of how strongly you feel. If the position is based on research indicating that a threatened species depends on the habitat provided by that agricultural land or if the land provides a critical biological corridor for wildlife or if changing land use would most likely result in degradation of ground water quality, these may be arguments worth investing in.

Determine what groups or individuals would hold opinions opposed to your own and consider why they would disagree. In our example, the landowner might be opposed to leaving agricultural land undeveloped based on his perception of lost financial opportunity. Those seeking economical housing might be opposed to your vote against the development because it limits their choices. City administrators might be interested in the possible tax dollars to be generated. When you have exhausted the list of possible supporters and detractors, consider the values they may hold that influence their opinions.

While we all like to believe that ours is the best possible decision from the facts, even facts change color as they travel through our value systems. Loss of land can certainly be considered an ecological or biological issue, but it is also a political issue, a social issue and a financial issue. To be persuasive, frame your argument in the context of more than one primary value. A position might be based on the biological considerations of habitat, heat islands, water quality or flood buffer zones. If the primary opposition operates from within a financially motivated value system, what argument would they consider persuasive? Would the cost of creating an artificial system of sewers and drains to replace the existing natural buffer offer a significant consideration to the developer? Would the revenue generating potential of the land be equal or greater with an alternative use? If you are speaking to someone in their own language, it is much easier for them to understand what you're saying.

To be scientifically literate includes the ability to speak knowingly and to think critically about globally significant scientific issues. These skills, once mastered by the teacher and nurtured in the students, can become the core of values formation and information assessment throughout one's life. With conscious attention to issues of concern to the global community and a clear sense of ones own positions and values, the integration of an Earth education curriculum becomes almost second nature. We start to teach from the heart and use available materials rather than teaching from the text and for the test.

Below are some suggestions for teachers who want to integrate Earth education into existing curricula.

<u>Critically evaluate the text used in your classroom</u>. My own experience has shown that many textbooks are filled with misinformation and outdated information. Read carefully in the context of your own ongoing research to locate and correct inaccuracies.

<u>Consider the flow of topics presented by the author(s)</u>. Because the information has been organized in a particular order does not mean this is the only or best way to structure your lesson plans.

Establish your annual plan. A curriculum guide has been suggested in this chapter (Figure 6-1). Use this or your own version of an Earth education curriculum to lay out your goals and activities for the entire school year.

Locate primary and supplementary materials. The use of a specific textbook may be favored by your school district. Even if you prefer to supplement heavily, materials found in the textbook can still be included as topics arise. Supplementary materials are perhaps the more critical component of a public school Earth education curriculum. Consistent with the call to use current research and innovative ideas to present science lessons, professional journals and the popular press are excellent sources of information when integrated with a critical evaluation.

A word of caution is in order for materials for on the web. Be aware that there is no governing body to assess the accuracy of materials found on the web. As such, you may wish to use only those sites developed by government agencies or reputable organizations like National Geographic, The Smithsonian, Nova and other familiar organizations. At a minimum, avoid having web-based materials as the only or as primary references.

Convert research for classroom use. Reading about current research is very much different from participating in an exciting discovery process. Although much of the research being conducted may be too difficult or equipment intensive to bring to the classroom, many investigations can be designed to duplicate, simulate or parallel current research. Examples or conversions have been included in the appendices and discussed in Chapter 5. Don't overlook the possibility of establishing your own research and including your students. I have found that simply doing my own work, whether pinning insects or mounting plant samples will always bring about student interest. While teaching an especially energetic and disruptive group of 7th graders, I asked one of my students why, with all of my assigned detentions, homework assignments, and calls to his house, he was in my room before school, during lunch and after school. His honest and unhesitating response was, "'Cause you've got cool stuff." Thanks Brian! You set me on my path to experiential education.

Earth Education Curriculum Guide

1) Acclimatization – Gaining familiarity with the natural world via the senses
   a) Sight
   b) Smell
   c) Sound
   d) Touch
   e) Taste
2) Observation and Inquiry – Learning to experience the world with an open and creative mind. Asking questions based on all the senses and intuition
3) The Biosphere – Overview of the living planet
   a) Biogeochemical Cycles – Basic to the understanding of everything else in the Earth system
   b) Hydrologic cycle
      i) Nitrogen cycle
      ii) Carbon cycle
   c) Energy flow – Directions and diversions within the Earth's circulatory system
   d) Lithosphere
      i) The landscape
      ii) Ecological Systems (begin where you live)
         (1) Desert
         (2) Prairie or Grassland
         (3) Temperate forest
         (4) Tropical forest
         (5) Mountains
         (6) Tundra and Ice caps
   e) Hydrosphere
      i) Oceans
      ii) Freshwater
   f) Atmosphere
4) Biostatistics and Measurement
5) Time – Geologic history and 7G decision making
6) Issues of scale – Differing perspectives from the molecular level to the universal
7) You – Values formation

Figure 6-1. Suggested Curriculum Guide for Earth Education

Position your students for success by honing their presentation skills. If integration of Earth education is to be successful, the students forming the core of the revolution must become ambassadors. Their work should be showcased at every opportunity. Help them create posters, exhibits, newsletters, websites, Power Point presentations, videos and models to replace the time-honored book report or lab notebook. A portfolio of the students' work can easily be modified to include not only the written work and research of a discovery project but also the disks, CD's and photos of models. This creates a dynamic means of assessing performance and makes use of the visual and kinesthetic learning capabilities of our students. Create opportunities for your students to present their work to others. This can be in the form of a mentor program with older students teaching younger students, open houses for parents or as extreme as the Experiential Learning Initiative (ELI) that provided annual outings to cooperative universities for presentations by the students.

Be accessible to your peers. Students themselves are likely to carry the momentum for a change to Earth education, but for the wave to spill into other classrooms, be receptive to fellow teachers. While ego will prevent many teachers from seeking help or information, some will want to know what you're doing to stir up such a fire in the students. (This fire can exist regardless of age, class size, culture, or previous history). New teachers are likely to become your best source of 'recruits'. If possible, make yourself available formally or informally as a mentor to these new teachers. Don't limit yourself to only science teachers. All teachers in all subject areas can be Earth educators.

Be cooperative with administration. Under the best of circumstances, administrators will offer full support and financial assistance. In other cases, the battle to use non-traditional methods will be hard fought. In either case, it makes sense to align your supporters and have patience with opponents. In the end, it is the success of your students that will persuade the administration, school board, and parents of the merit and worth of any program change. Always assume that opposition is based on fear or lack of understanding. Assuage their fears with student performance and create understanding with ongoing dialog and access to your philosophy. An old rule of thumb in business applies in education as well. If you make your boss look good, he or she will want you to continue doing what you do.

RECOMMENDATIONS

Science education in America has begun the critical shift from memorization of formulas and principles to a more engaging format. Teachers have heard the call for hands-on learning and are responding assertively to the many packages being offered by textbook publishers and others eager to maintain or capture market share. While many excellent and exciting options have become available through prepared materials, what is often still missing is the discovery that comes not from following cookbook instructions guaranteed to lead to one or more defined and explained outcomes, but the true discovery of doing science from a position of divergent thought and open-minded analysis.

Hands-on is a beginning. To expand on the learning potential of kinesthetic manipulation of materials, the addition of discovery, analysis and application should come from the learner rather than from the teacher. All members of the educational composite could benefit from a reform in thinking. Rather than viewing the sciences as discreet units suitable for a sequential progression in a defined curriculum, learners should be guided through the discovery process as they make observations, ask questions of their own latent knowing and look for relationships within a biospheric context. Such a biospheric approach and divergent method call for a new paradigm, one that incorporates current research to facilitate comprehension of accepted theories, and that accepts the scientific community not as apart from the educational process but, in fact, a critical base element in the evolution of tomorrow's general science. Teachers working with students and scientists as the core of a partnership that extends to include the families as well as local and global communities form the human infrastructure of the model proposed by this work.

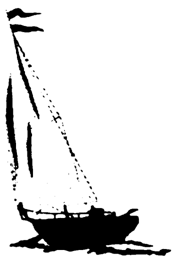
Essential to the discovery process is an open end. If we are less sure of the facts, if we are uncertain about cause and effect, then certainly, children and other learners are more able to become partners in discovery rather than the receivers of information. To this end, the use of current research is an important component of this educational model. By establishing a template for the conversion of current investigations within the professional scientific community for use in K-8 classroom, we offer young learners an opportunity to literally grow up with the discoveries of a changing world. No longer will they be lost in the lag time created by the limited paths by which findings from primary research enter the public domain. Teachers and other leaders can apply the conversion template to the daily classroom materials while districts can integrate the literacy training models as appropriate for their individual needs.

APPENDICES

APPENDIX A

APPENDIX A

Learning Activities
Watershed Suite



Background Information

3-Dimension, Multi-Factor Graphing
Vector Based Mapping: Lake Superior
GIS-mapping of the Watershed
Circulation Patterns and Nutrient Dispersion in the Great Lakes

The Great Lakes

The Great Lakes are the five inland fresh water lakes located in the northern Midwest region of the United States of America. The states of Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania and New York along with the Canadian province of Ontario share the shorelines of Lakes Superior, Michigan, Huron, Erie and Ontario.

Historically, the Great Lakes provided habitat for a unique assemblage of animals including many fur-bearers. The early settlers found a bountiful harvest in their trapping of an apparently limitless supply of muskrat, mink and beaver. Pines, birch, maple and a variety of other trees dominated the landscape until the clearing of land for agriculture, industry and urban expansion substantially reduced their numbers. Today, we can still find heavily forested areas and many of the animals associated with the early terrain surrounding the Great Lakes. Foxes, wolves, coyotes, deer and rabbits along with other fur-bearing animals such as mink and muskrat, and many fish and birds make their homes in the Great Lakes region. The fishing industry has been a cornerstone in the historical development of the Great Lakes states. Salmon, trout, bass and many other species provide not only food but also recreation in the form of sport fishing.

Circulation

The Great Lakes individually cover significant area and reach depths sufficient to hold the secrets of lost freighters and missing mariners for many generations. Collectively they amount to an incredibly complex matrix of freshwater lakes, rivers, and streams comprising the Great Lakes watershed. As working models for the physical phenomena characteristic of oceans, the Great Lakes are of exceptional value. They provide living examples of the effect of horizontal and vertical circulation and, to a lesser extent, the relationship between Coriolis force, basin topography and large-scale circulation patterns. Additionally, seasonal thermal stratification is well developed and provides an excellent vehicle for discussions about water density associated with temperature, salinity and nutrients.

The primary components of circulation include horizontal and vertical patterns along with the influence of basin topography and Coriolis force on each of these. Horizontal circulation is the movement of water across a plane within the system. This can be the actual surface of the lake or any significant plane established by stable stratification. The most significant impact on horizontal circulation comes from wind patterns. These patterns are created by the "wind shadows" cast from coastal landscape elements and upland topography. Wind stress associated with weather patterns is generally uniform across the lake basins but will be further modified by torque generated as differences in depth lead to higher or lower wind drag.

Vertical patterns are most strongly influenced by the dimictic nature of the Great Lakes. That is, the twice annual overturn of the water column. Fresh water reaches its maximum density at 4°C. Because maximum density occurs significantly above freezing temperature, overturn of the water column occurs as autumn brings cooler surface temperatures. As spring waters warm through the 4°C mark, they again cause overturn as warmer waters rise to the surface. As the entire surface temperature rises, warmer waters settle on cooler waters creating a weak stable stratification. This stability reduces the degree to which vertical circulation can occur and further affects large-scale horizontal circulation.

In the spring, the water near the shore increases in temperature more quickly than offshore waters. The resulting onshore-offshore pressure gradients created by the density differences tend to push the warm water offshore. The effect of the Earth's rotation (Coriolis force) is to deflect this offshore flow and set up fairly steady circulation with warm water moving counter-clockwise (Northern Hemisphere) and following the bottom contours. Comparing this pattern to that of summer, we find that during summer stratification the warm surface layer tends to slide downwind over an undisturbed thermocline (lower layer) as wind blows over the lake. At the downwind shore, the warm water will force the thermocline down. Where the warm water moves offshore the thermocline must rise. The pressure gradients associated with onshore-offshore flows generally mean that the strongest currents occur between 1 and 10 km from shore. Offshore, beyond 10 km, the currents are more variable and show a tendency in the summer to rotate clockwise. Very close to the shore, within the surf zone, additional currents are generated by the breaking surface waves.

As circular flow patterns associated with the effects of the Earth's rotation are combined with wind-driven horizontal circulation and density-driven vertical circulation, we can begin to analyze the very complex nature of nutrient and pollutant circulation within individual lake basins. When we also include the impact of in-flow and out-flow through the vast network of reaches (drainages) within the entire Great Lakes watershed, it becomes more evident that water-use decisions made anywhere in the system affect the entire system.

3-Dimensional, Multi-factor Graphing

Graphs allow us to visualize numerical data sets through the organized use of points lines and polygons. An individual data point may be shown as simply an x,y coordinate. Scatter graphs include many such points that form a pattern of distribution. Data may also form lines when x,y coordinates are linked in some meaningful way. Time sequences, growth rates and other data that show a progression are effectively represented with line graphs. The histogram or bar graph is frequently used to show quantity comparisons. Area or shape graphs and maps are useful for geographically referenced data. While any of these (and many other) styles can be used effectively for individual data sets or themes, combining themes offers a point of reference or comparison with other information.

Because we view the world in 3-dimensions, our ability to comprehend complex data sets is enhanced by the ability to present data 3-dimensionally. This can be accomplished by the creation of models, by viewing computer generated 3-dimensional graphs or by actually building a "graphic landscape" for multiple-theme data sets.

Vector-Based Mapping

Mapping is an essential element in biological and ecological studies. Maps are used to identify the locations of critical populations and to delimit specific landscape features such as wetlands, forests and agricultural boundaries. They are used to identify survey locations and to provide a visual shorthand for the larger picture. Comparing maps over time, trends are more apparent.

The ecological world is a very dynamic place. Shorelines change under the influence of erosion, the flow of a river shifts as it meanders. Hills form as sands push their way across the land. Mapping allows us to see these changes in a quantifiable way. All geographic, political and biological features on maps are represented with points, lines and polygons. A tower might be shown as a dot or point, while roads, rivers and highways are symbolized as lines. Cities and bodies of water are typically shown as colored polygons. We can go a step further and determine the specific location of each of these points, lines and polygons through a simple planar coordinate system. Each coordinate (x,y) represents the location of a point . The pairing of coordinates (x_1,y_1 and x_2,y_2) creates a line while coordinate sets (three or more points) can be used to create polygons. Simple graphing programs can be used to build or 'draw' maps simply by organizing sets of x,y coordinates on a grid. Since lines of latitude and longitude can be used to identify points on the planet, understanding a coordinate or vector-based map can be used as a bridge to understanding co-georeferenced points and associated attributes within a GIS mapping system.

GIS Mapping

Whether tracking wolves in Michigan's Upper Peninsula, cataloging the flora and fauna of national parks, or recommending the best site for a new hospital, Geographic Information Systems (GIS) are becoming an integral part of our daily lives. More than just a method for collecting or organizing data, GIS is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information. It combines hardware, software and special data to create customized maps defined by the user's interest and available data. Multiple attributes can be combined to give an infinite variety of comparisons. Scale can be adjusted up or down to reveal patterns not readily apparent.

Imagine several maps, each with a different focus. One map might show geographic boundaries, another the ecoregions and still another the distribution of agricultural land. All the data compiled to create those maps is georeferenced to a specific point on the map. Through GIS, those maps can be combined through an overlay process that keeps all data aligned with the specific location on the map. Data showing the population, mean income and ethnic diversity of Cleveland can be combined with land use to create a map of urban pressure on agriculture. Land managers in Michigan's Upper Peninsula can combine information about soil, fire damage in Christmas tree plantations and bark beetle infestations to analyze the effects of human and natural phenomena on tree production. Possible combinations of data and uses are virtually limitless.

The use of GIS technology to manage watersheds is proving to be very effective. By combining information showing local watersheds, rivers, reaches, regional and local land use, nutrient and pollutant levels from the many measurement stations nationwide, managers are able to get rapid assessment of the environment and make appropriate decisions based on current information.

As GIS technology becomes accessible to all sectors, its use will continue to expand. Our questions will become more sophisticated and our ability to visualize patterns and relationships will become richer. In concert with imagination, art and science, our understanding of the natural world can be taken into the 21st century while avoiding repetition of past mistakes.

Summary

The following suite of activities offers the user an opportunity to establish a foundation for understanding the complexities of a watershed, in this case, the Great Lakes. Water regime and circulation determine the potential impact of chemical influx and the resulting community composition. The plant and animal community drives and is driven by the water available. To communicate about and to analyze relationships or to track changes, mapping skills are essential. While vector-based mapping lays out a planar view, 3-dimensional and GIS-mapping combine many georeferenced planar views into a single picture.

Acknowledgment

Header clip art from Microsoft Clip Gallery 3.0

Shape files for Great Lakes region from Arc-View GIS software

Additional Reading and References

Ashworth, William. 1986. The Late Great Lakes: An Environmental History. Wayne State University Press, Detroit, MI.

Boyce, F.M. 1989. *Thermal Structure and Circulation in the Great Lakes*, Atmosphere-Oceans, 27 (4) 607-642.

Cohen, Karen C. (Editor). 1997. Internet Links for Science Education: Student-Scientist Partnerships. Plenum Press, New York.

Postel, Sandra. 1996. Dividing the Waters: Food Security, Ecosystem Health, and the New Politics of Scarcity. Worldwatch Paper #132. Worldwatch Institute, Danvers, MA.

Speidel, David H., Lon C. Ruedsili and Allen F. Agnew (editors). 1988. Perspectives on Water: Uses and Abuses. Oxford University Press, New York.

www.GreatLakes.com. 1999. The Canadian Hydrographic Service, Department of Fisheries and Oceans - Information about circulation in the Great Lakes.

Multi-theme Graphing In Two- and Three-Dimensions

Purpose
To become familiar with graphing methods used to combine multiple data sets on a single visualization.

Overview
During the exercises included here, students will combine multiple data sets on graphs to show the numerical relationships between themes. Graphs using identical data sets will be created to show the differences that can result from varying the sort sequence or scale. Additional exercises will be completed to see how different styles can be used to make the data visualization clear. Upon completion of two-dimensional multi-factor graphs, students will create true 3-dimensional representations of multiple data sets using Legos, Duplos or similar materials.

Time
One class session initially, followed by use whenever appropriate. (It's most helpful to begin the graphing activities early in the school year and continue using the methods throughout).

Level
Basic to advanced

Prerequisites
None
Prior experience with planar coordinate systems and vector graphing is helpful.

Key Concepts and Skills
Concepts
All data is relative
Multiple data sets can be effectively combined on a single graph.
Comparing data from multiple themes offers a relative comparison that can be useful in understanding broader concepts and systems.
Data may be presented more clearly on one type of graph than on another.
Technology has been partly driven by the data analysis and database management needs of the scientific community.

Skills
Graphing data
Managing and manipulating data sets
Conceptualizing relationships
Hypothesizing about biological and geophysical relationships

Materials and Tools

Transparencies of the graphs included in this exercise
Overhead projector and dry erase pens
Data sets (provided is a set that includes the date and measurements of water temperature and pH for lakes in the Michigan area. Data was collected by GLOBE (Global Learning and Observation to Better the Environment) students using GLOBE protocol).
Legos, Duplos or similar stacking and locking blocks (Lego "freestyle" are recommended for ages 5-12. For young children, the size certified for 3-5 year olds will be easier to handle).
Lego baseboard (optional but recommended).
Plain paper
Colored markers
Visualizations (graphs) showing computer generated multi-theme data. (Many are available through www.epa.gov or www.globe.gov or www. Great_lakes.com).

Preparation

1. Make transparencies of graphs included in this exercise and other graphs that show style differences.
2. Gather materials needed for activity (markers, plain paper, data sets).
3. Sort Legos into sets for easier distribution to groups.

Additional Resources and References

Glassman, Bruce S. (editor). 1996. The MacMillan Visual Almanac. Blackbird Press, Simon and Schuster MacMillan Company. New York. 608 pages.

Acknowledgment

Header clip art from Microsoft Clip Gallery 3.0
EPA Region 5 shape files were created using Storet Data Hydrostat.
Data imposed on Region 5 shape files were collected by GLOBE schools.

What To Do and How To Do It

1. Show the transparencies of the graphs in this activity. Point out the differences in representation although all the data is identical. Compare data presentation based on different sort priorities

2. Distribute data sets (use sets provided or use data the students have generated or found), colored markers and plain paper. Graph paper may be used but to promote more creative representation of data, plain paper is less restrictive.

3. Provide students with a general overview about the data. Include information about how it was collected (if known) and who might be interested in using the data.

4. Have students create "flat" graphs using the data. The more creative the better but...the data shouldn't get lost in the artwork.

5. Compare the students' graphs and discuss which graphs are confusing and which ones help you understand the data.

6. Show students transparencies or printouts of visualizations created with multiple data sets or themes. Geographically referenced data is especially good for this part of the lesson. Other sources of good 3-dimensional representations of multi-theme data come from medical and other scientific fields.

7. Distribute Legos (or other blocks) and have the students create true 3-dimensional graphs of the same data they worked with in two dimensions during the previous activity. Suggest different x, y, and z axes for each group to allow for later comparison. (Groups of 2 or 3 students are recommended. The concept sounds simple until you actually get started. After that, a collaborator might be very much appreciated). Tip: Use the Lego colors to establish the number of classes to be used in organizing data. Then create stacks based on progression through the classes. For example if there are 5 colors there would be 5 classes. If the data ranged from 4-23, data points of 4 or 7 might be represented by a white Lego. Data point of 8 or 10 would be represented with a yellow block stacked on a white block. At the top of the data range, the Lego stack would include a block of each color.

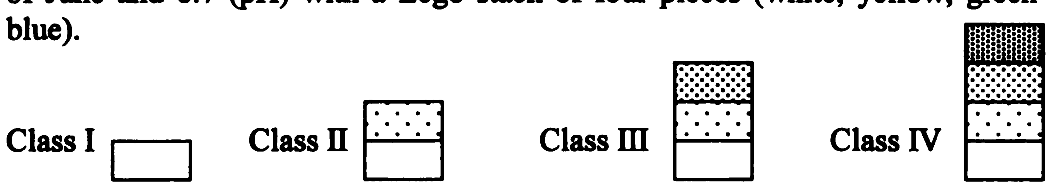
Sample:

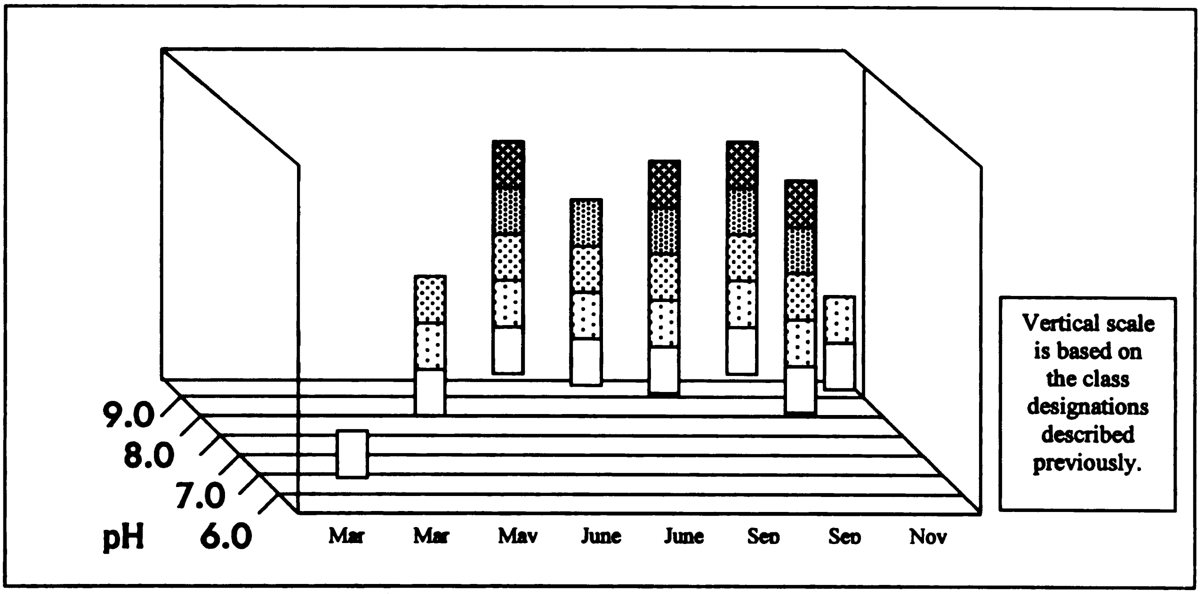
	1	2	3	4	5	6	7	8
Month	Mar	Mar	May	[illegible]	Jun	Sep	Sep	Nov
Temperature	4.5	15	21	19	21	22	23	8
pH	6.5	8.4	8.7	8.7	8.2	8.6	8	8.7

If we use the x-axis for time (month and year) and the y-axis for pH, we can build up dimension with our temperature data. Color classes may be defined as follows:

4-7°C	8-11°C	12-15°C	16-19°C	20-23°C
White	Yellow	Green	Blue	black

Stacks of blocks would reach a maximum of 5 pieces. In our example, point 1 data would be at the coordinates of March (x-axis) and 6.5 (pH on y-axis) with a Lego stack of one white and one yellow piece. Point 4 data would be at the coordinates of June and 8.7 (pH) with a Lego stack of four pieces (white, yellow, green and blue).





Sample 3-Dimensional, Multi-factor Graph

Vocabulary

Shape file – A large collection of data points that, when used in a planar coordinate system, create a shape outline or a lake, region or other geographically referenced polygon

Trend line – A moving average showing the general up, down or stable trend

Theme – A group of data sets about a common descriptor such as temperature, pH, dissolved oxygen, ammonia, and so on

Discussion Questions

What are some of the benefits and disadvantages of combining data sets on a single graph?

How does the addition of a second y axis scale make data comparisons more relevant?

What differences (and difficulties) might be encountered by listing months with their names instead of their numbers. (Eg. April 1998 vs 0498)?

Give examples of information that would be best presented as a pie chart, a histogram, a shape map or a line graph.

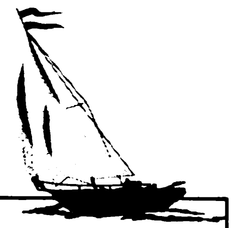
Further Investigations

Use Microsoft Excel or other spreadsheet and database software to create a variety of single and multiple factor graphs.

Design an investigation and determine the best method for graphing your data.

Locate examples of graphs in your local newspaper. How else could the data be shown?

Vector Based Mapping: Lake Superior



Purpose

To use vector-based mapping as a vehicle for presenting the concept of relationships existing between surface thermal structure and depth in lakes.

Overview

Students will create visual representations of the thermal structure and depth of Lake Superior using vector-based mapping. After locating ten coastal and ten open water research stations by their coordinates, temperature and depth data organized into classes will be added to the base map using colored dots. Students will be asked to consider the biological and geological implications of the surface temperature distribution.

Time

45 minutes with extensions possible

Level

Basic to intermediate

This learning activity can be as basic or as sophisticated as the students' skill levels permit. Providing a variety of data sets allows 'layering' and creates a visualization foundation for discussion of biological and geophysical relationships.

Prerequisites

Some experience with graphing is helpful.

Prior knowledge about thermal regulation and conductivity will allow greater depth of understanding.

Advanced data sets may require familiarity with biogeophysical cycles and energy flow through aquatic systems.

Key Concepts and Skills

Concepts

Maps are created from points, lines and polygons.

All points on a map are identifiable by specific coordinates.

Relationships exist between the depth of water and the water's temperature.

Water temperature and depth impact the resident biological community.

Skills

Creating base maps within a planar coordinate system

Using point coordinates to locate specific locations

Grouping data by class

Visualizing data classes with gradient color

Hypothesizing about biological and geophysical relationships

Materials and Tools

Copies of each of the two base maps from this activity
3/4" stickers of four colors (blue, green, yellow and orange)
Colored markers, pencils or crayons
Overhead transparencies of base map, data sets and instructions (Optional for teaching style preference).

Preparation

1. If there isn't already a map or globe in your classroom, locate one for this exercise.
2. Determine the quantity of stickers each student or group will need for the visualization(s).
3. When using new data sets, always do the visualizations yourself before class.
4. Create overhead transparencies if desired. Use erasable markers in several colors during introduction and summary phases of activity.
5. Review biogeochemical cycles if necessary.

Vocabulary

Attribute – A piece of information describing a map feature. An attributes of a lake might include name, depth and land area..
Line – A pair of x,y coordinates
Planar coordinate system – A two-dimensional measurement system that defines locations on a map based on their distance from an origin along two axes.
Point – A single x,y coordinate
Polygon – A set of x,y coordinates
Raster format – A cell-based representation of map features. Each cell in the structure has a value and a group of cells with the same value represents a feature.
Theme – A set of features of the same type such as pH readings, nitrogen counts or surface temperature at all the research stations on Lake Superior
Vector format map – a coordinate-based representation of map features

What To Do and How To Do It

1. Point out that points, lines and polygons represent all features on maps. Depending on the skill level in your class, it may be helpful to begin with a simple graph drawn on the blackboard or overhead. Remind students that the x-axis is the horizontal line and the y-axis is the vertical line. Allow several students to locate specific points on the graph by using coordinates you give them. After several points have been correctly located on the graph, connect two points and offer the students a definition for the term 'line' that includes wording such as, "A line is represented by a pair of coordinates." After locating several lines, create a closed shape on the graph. Ask the students if they know the name of the shape that you've created. They are likely to say hexagon, octagon or pentagon. Introduce the term polygon, meaning 'many sides'. As a working definition, you can add that a polygon is a group of coordinates.

2. Review (or introduce) latitudes and longitudes on maps. Stress that latitude lines always run parallel to the equator at equal distances and that lines of longitude converge at the poles. Equate the point 0,0 from the graph to a point on the globe at the intersection of the equator and the prime meridian.

3. Show students Lake Superior (or other lakes as appropriate) on a map or globe. Remind them that all map features were created using points, lines or polygons and that with enough points, they can create an outline of Lake Superior or any other landscape element. Small towns may be represented with points while roads, rivers and reaches are represented by lines.

4. Point out also how color and symbols help us visualize specific features. Locate a large city and talk about how it is shown in a particular color and covers more space than a smaller city or town shown in the same color. What are the most common colors on your sample map and what do the colors symbolize? Examples may be blue for water, yellow for cities and red for highways.

5. Ask the students what some colors represent to them. It is useful at this point in the introduction to help students associate cool colors such as blue or purple with cold temperatures or deep water. Likewise, an association between red and orange with hot, warm or shallow water will be useful later in the exercise.

6. Discuss how research stations collect information for many different purposes. What types of agencies might want data about water? What are some indicators we might use for water quality studies? Students may need prompting about the kinds of things that determine water quality. Pollution...what kind of pollution?...Chemicals...what kinds of chemicals?...Pesticides...Can you name any pesticides? ...Trash...why is trash bad?...Dead fish...Why did the fish die?

7. Before we can analyze data about chemicals, we need to know a little about the lake's structure. This exercise will focus on temperature and depth[1]. Both of these attributes are significant in the lake's ability to diffuse and filter nutrients and toxins. (Save any discussion about the relationship between temperature and depth until after the students have completed both maps. See the background section for more information about this and other relationships in aquatic systems).

8. Stress the need to follow the directions printed on each activity sheet. Remind the students to re-read any instructions they don't understand and to refer to the examples done during the introduction.

9. Students will divide the twenty temperature means and depth measurements into four classes of each. Students will apply their stickers to the maps using the color that represents the class for each particular temperature mean or depth reading. If this is the first time students have worked with data classes, it will be helpful to arrive at the class intervals together. The temperature range is from 5-16° C. If students are asked

[1] For the purpose of this exercise, data has been reformatted from figures 5-1, *Profile of the Great Lakes*, and Figure 5-2, *Surface temperature patterns for Lake Superior* in Perspectives on Water: Uses and Abuses. Original temperature data is for July 29, 1964, from an airborne infrared radiometer.

to arrive at four equal classes, they are most likely to say 1-4, 5-8, 9-12 and 13-16. Point out that with the classes divided like that, there would be no data for the first class. This point can be exaggerated by suggesting classes 1-25, 25-50 and so on. Although these are equal classes they do not provide an efficient scale for organizing the data. Again ask the students to suggest the range for four equal classes. This time they should arrive at 5-7, 8-10, etc.

10. Provide students with enough time to locate each station, add a sticker to each station representing the class for that station's temperature reading and depth measurements and to discuss the patterns shown by the placement of stickers. Where is the water the coldest? The warmest? Why do they think the edges are the warmest spots? Do you see any distinct patterns?

11. As a homework assignment, pens, pencils and markers can be used in place of stickers to color each circle with the appropriate class color. While coloring generally moves the exercise along more quickly, the use of stickers provides more physical activity and adds an element of fun to the learning activity.

12. If it isn't possible to include time in class for discussion, the discussion questions listed below should be answered in writing and handed in as soon as possible after completion of the maps.

13. Include the vocabulary either formally by assigning the vocabulary list or informally through inclusion in your introduction and summary phases.

Discussion Questions

What differences do you see between coastal and open water temperature readings (depth readings)?

What are some possible explanations for these differences?

Do these twenty points give you an accurate picture of the surface temperature patterns (or depth patterns) for Lake Superior?

How could this map be made more informative?

Do surface temperatures give you a good clue as to deep-water temperatures? Why? Why not?

Where is the deepest part of the lake? Why do you think so?

What would you expect the temperature map to look like for spring, fall or winter?

What additional data would you expect research stations to collect?

How does water temperature impact the biological communities in a lake?

Any questions about biological, chemical and geophysical relationships are appropriate. (Adjust as needed for your students' backgrounds. Dissolved oxygen, biological oxygen demand, turbidity, vegetation, freezing and thawing, water density associated with temperature, stratification, overturn, indicator species, urban influence, thermal pollution and freshwater classification are among the many possible discussion topics possible from this exercise).

Further Investigations

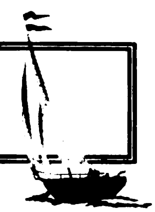
Add more research stations and data points to this activity
Repeat the exercise using the other Great Lakes.
Search the web for additional data sets to incorporate into your maps. (www.epa.gov and www.globe.gov are good places to start).
Create similar activities in a raster-based format and compare the two types of maps. Have students create their own maps (town, school, house, local ponds, etc.) using point coordinates on Microsoft Excel.
Explore Geographic Information System (GIS) software.
Explore the role of Global Positioning Systems (GPS) in satellite generated maps.

Vector Based Mapping: Lake Superior

Temperature and Depth

Name______________

1. What is the temperature range for the twenty stations listed? ____________________
2. What is the depth range for the twenty stations listed? ____________________
3. Create four groups or "classes" for the temperature data and for the depth data. Write the temperature and depth ranges for each class in the spaces below.



> The range for each class must be the same but the classes do not need to contain the same number of stations.

Temperature (low to high)

Class 1 (Blue) = ____________ Class 3 (Yellow) = ____________

Class 2 (Green) = ____________ Class 4 (Orange) = ____________

Depth (shallow to deep)

Class 1 (Orange) = ____________ Class 3 (Green) = ____________

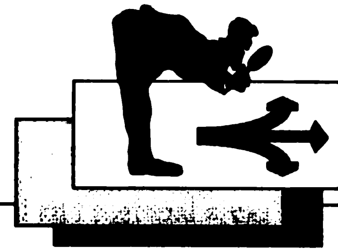
Class 2 (Yellow) = ____________ Class 4 (Blue) = ____________

4. Put an "X" in the box in Table 1 for the class represented by each station's temperature and depth reading.
5. Indicate the temperature class on your first map by attaching the correct color sticker for each station.
6. Use your second map to indicate the depth class represented by each station's depth reading.

Station	July Mean (x) Temperature °C	Class	Class	Class	Class	July Depth In Meters	Class	Class	Class	Class
14	16					10				
23	16					18				
25	11					40				
28	12					24				
29	12					26				
33	10					92				
34	12					100				
35	14					26				
36	6					305				
39	10					140				
41	5					400				
43	7					285				
44	7					190				
48	12					35				
49	7					240				
52	7					200				
55	8					180				
56	12					30				
57	10					65				
58	12					30				

Table 1. Temperature and Depth Data

Visualizing Your Watershed With GIS-style Mapping



Purpose
To learn Geographic Information System (GIS) principles through the creation of local and regional watershed maps.

Overview
Students will use the principles of GIS-mapping to create a series of overlays representative of their local watershed. Transparencies can be co-georeferenced to include a shape map showing the relative location of schools, reaches, rivers and lakes comprising the local watershed. This local representation will be put into the context of a larger regional watershed by continuing the activity with increasingly broader measures of scale.

Time
45 minutes with possible extensions

Level
Basic to advanced

Prerequisites
Completion of the previous activity, "Vector-based mapping: Lake Superior".
Students should be able to draw parallels between the concept of vector-based graphs and georeferenced landmarks.
Students should understand that a watershed can be delimited relative to scale. Included are local water bodies, regional water systems and the entire Earth system of oceans, lakes and rivers.

Key Concepts and Skills
Concepts
A watershed is a geographic area defined by the flow of water from high to low elevations.
The definition of watershed is dependent on issues of scale.
The watershed impacts community composition.
Water flows in predictable patterns relative to elevation and topography.
Reaches, rivers and lakes may be seasonal or permanent.
Water flows into progressively larger systems. (Eg. Reaches to rivers to lakes to oceans).

Skills
Mapping a familiar area by isolating its components
Visualizing the positions of locally significant water bodies and aquatic systems relative to GLOBE schools
Identifying the position of the local area relative to the regional watershed

Materials and Tools

Several clean transparencies for each pair or small group of students
Water-base overhead markers
Overhead projector, light table or window
Maps, aerial photos and/or satellite images of the GLOBE local and regional areas

Preparation

1. If there isn't already a map or globe in your classroom, locate one for this exercise.
2. Collect visual representations of your local and regional areas. These might include local and state maps, satellite images or aerial photographs.
3. Create a basic map of your school's territory showing main roads, the school, other schools in the district, major landmarks or other elements you consider significant. This map can serve as an orientation reference for overlays of additional attributes. Make a copy (on paper or transparency film) for each pair or small group of students. If possible, 'ground truth' the local map.
4. Locate GLOBE student data for land cover biology and hydrology from your school. If your school does not collect hydrology data, check data archives for neighboring schools. Have data available in either printed form or by providing the appropriate URL for your students.

What To Do and How To Do It

1. Discuss the components of typical maps. All maps will include boundaries of one type or another. For some, these boundaries might be political in the form of county or state lines. On other maps, there are no political boundaries but demarcations determined by shorelines, mountains or other major landforms. Conservation areas, resource availability or depletion, economic distribution and population distribution are among some of the many other themes that can be used to create maps.

2. Show students maps depicting various themes and begin a brainstorming session about how themes may be interrelated. For example, if a map of the local watershed were compared to a map of agricultural production or of urbanization, what relationships stand out?

3. Show students a series of overhead transparencies beginning with the shape-map of the Great Lakes region. (Transparency masters have been included at the end of this activity). Leaving this map on the overhead, position or co-georeference additional maps of the Great Lakes showing GLOBE schools, local watersheds, rivers and reaches.

4. Lead a brief discussion about agricultural and manufacturing distribution within the Great Lakes region. Discuss the relationships between water and vegetation, or water and commerce.

5. Distribute a shape-map of your school's area (or have the students create one), several clean transparency sheets, water-base markers and data sets (if applicable) to each pair or small group of students.

6. Instruct students to begin by aligning the first clean transparency with the local shape map.

7. Color in all areas where lakes and rivers are located. When creating your local base map be sure to use a large enough scale to include water that might be located a few miles from your school.

8. Choose another color marker and on a second clean transparency, color in all the areas where vegetation is found. This might include parks, playgrounds or residential lawns.

9. On a third overlay, color in all commercial or industrial areas.

10. Steps 7-9 can include mapping anything of significance in your area. Urban schools might focus on industry, commerce and parks while a rural setting would call for mapping crops, grazing territory or forests. The key to choosing themes for this mapping activity is to look for areas that are familiar to your students and related biologically or economically.

11. After several overlays have been completed, have students compare them and look for relationships.

Vocabulary

Attribute – A piece of information describing a map feature. Attributes of a lake might include name, depth and land area.
Geographic Information Systems (GIS) – A computer system capable of assembling, storing, manipulating and displaying geographically referenced information.
Line – A pair of x,y coordinates
Planar coordinate system – A two-dimensional measurement system that defines locations on a map based on their distance from an origin along two axes
Point – A single x,y coordinate
Polygon – A set of x,y coordinates
Raster-based mapping – A cell-based representation of map features. Each cell in the structure has a value and a group of cells with the same value represents a feature.
Theme – A set of features of the same type such as pH readings, nitrogen counts or surface temperature at all the research stations on Lake Superior
Vector-based mapping – a coordinate-based representation of map features

Discussion Questions

How might GIS tracking be used to aid decision making in agriculture?
How can GIS technology be used to reduce human fatalities caused by natural disasters?
What are some limitations of GIS technology or data?
Describe ways that GIS might aid in cataloging biodiversity.
Could a similar mapping strategy help us learn more about other planets?
What data sets would you combine to do an analysis of water quality 300 miles downstream from a nuclear reactor?
How could GIS technology be used to gauge the success of a program designed to reintroduce a threatened butterfly species?

Further Investigations

Choose an environmental issue and brainstorm ways that GIS could be used to research or correct the problem.

Use the GIS software ArcVoyager to create similar maps on the computer.

Explore the role of Global Positioning Systems (GPS) in satellite generated thermal maps.

Potential websites serving as links for additional information and activities

United States Geological Survey – Information about GIS and its applications
http://www.usgs.gov/research/gis/special4.html

Information about GIS application software for K-12 students
http://www.esri.com/industries/k-12/k-12.html

GIS activities for K-12 using ArcVoyager software
http://www.esri.com/industries/k-12/voyager.html

The Earthwatch Global Classroom
http://www.earth-watch.org/ed/home.html

Locate Your Watershed
http://www.epa.gov/surf2/locate/

United States Environmental Protection Agency
www.epa.gov

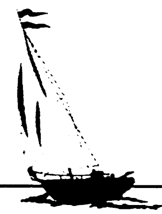
Transparency Master
The Great Lakes Region

Transparency Master

Watersheds in the Great Lakes

Transparency Master
Rivers in the Great Lakes Region

Horizontal Circulation in the Great Lakes



Purpose
To explore horizontal circulation patterns in lakes.

Overview
Students will begin the exercise by creating light and wind shadows with dimensional objects. After observing actual shadows, the students will predict shadow patterns based on a set of given wind headings. These predictions can then be used to determine horizontal circulation on a lake's surface when the effects of Coriolis force are imposed. By taking into consideration the effect of the surrounding landscape on the circulation patterns in lakes, students can predict the circulation and dispersion of various nutrients and toxins from strategic points around the Great Lakes.

Time
45 minutes with extensions possible

Level
Basic to intermediate
Providing a variety of shoreline features such as bays and inlets and landscape elements such as cliffs, high terrain or upwind farmland will increase the complexity of the predicted circulation patterns.

Prerequisites
Students should have some knowledge about global wind patterns. (The Great Lakes are under the influence of "Westerlies").
Students should recognize that some materials are water-soluble and others are not.
Students should understand the concept of density, specifically as it relates to the vertical layering of materials submerged in water.

Key Concepts and Skills
Concepts
Circulation patterns are predictable for any body of water.
Nutrients tend to stay along the coast and do not readily mix with central waters.
Biological productivity tends to be higher in coastal waters than in central waters.
Circulation patterns in water bodies are influenced by the Earth's rotation, the moon, landscape elements, temperature and water depth.
Nutrients and pollutants are dispersed in patterns that are predictable based on their density, solubility and concentrations.

Skills
Visualizing wind 'shadows' based on observation of light shadows.
Predicting the influence of landscape elements on circulation patterns.
Hypothesizing about biological and geophysical relationships.

Materials and Tools

"Wind Shadows" worksheet package for each student or group.
Dimensional objects ranging from simple cubes to complicated natural materials.
Light source for each group. A movable lamp, microscope illuminator or flashlights with stands are all good options. Any light source direct enough to cast a shadow will work.
Broad-line colored markers, pencils or paints.

Preparation

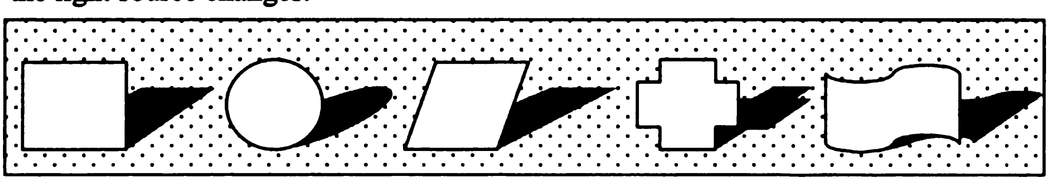
1. Locate or collect the objects to be used. Each student should have a minimum of three objects.
2. Check that flashlight batteries and bulbs are fresh. Because this exercise is heavily dependent on a reliable light source, be sure to have extra batteries and bulbs on hand.
3. Create overhead transparencies if desired. Use erasable markers in several colors during introduction and summary phases of activity.
4. Review the concepts of density and solubility if necessary.

Vocabulary

Coriolos force – The effect of the Earth's rotation on fluids
Density – The measure of a substance's mass per unit volume. (D x V = M)
Dimictic – Lakes that undergo vertical mixing at 4°C twice each year
Gradients – Gradual increases or decreases in some measurable element
Isothermal period – Time of uniform temperature in a lake
Pelagic - A region of open water extending from the surface to the depth of light penetration
Solubility – How much of one material (solute) can be dissolved into another (solvent)
Stratification – Division caused by temperature differences in a water body
Thermal bar – A vertical division between near-shore waters and central waters
Thermocline – A division within a water body based on an abrupt change in temperature
Torque – Twisting or turning motion around a pivotal point

What To Do and How To Do It

1. Discuss with your students the concept of shadows being created as light is blocked by an object. Remind students that an eclipse is a very specific type of shadow. Additional shadows include rain shadows that occur on the leeward side of mountains and snow shadows that occur as a system passes strongly in one direction. Finally, discuss the idea that winds also create shadows. Wind is blocked by objects, landforms or landscape elements and these shadows affect wind flow (and wind stress or torque) over a body of water. Demonstrate variations in shadows as the angle of the light source changes.



2. Instruct students to complete the observation activity during which they use a flashlight or other direct light source to create shadows around the cubes, balls and other objects in their exercise kits. Worksheets can be easily created using the example in Figure 1 – Wind Shadows Observed. This can also be completed as a part of your mini-lecture or eliminated to accommodate time constraints. It is important, however, to bring to the surface the students' existing knowledge about shadows.

Wind Shadows Observed

(a) Position each of your dimensional objects as indicated on the worksheet template.
(b) Use the guide indicators (arrows) located along the edges of your worksheet to position your light source with the location having the same pattern.
(c) Use your markers, pencils or crayons to completely outline and fill in the shadows cast by the objects.

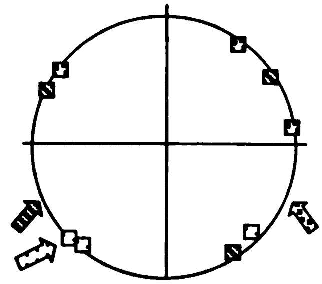


Figure 1. Wind Shadows Observed

3. For the next activity, begin by drawing a large circle on the board and asking the students to identify the points on a compass beginning with north (0/360°). After identifying north, south (180°), east (090°) and west (270°), have the students identify each quadrant as NE, SE, SW and NW. The previous activity asked students to observe shadows whereas this activity asks them to predict shadows. A simple worksheet can be created by drawing a lake (real or hypothetical) and surrounding it with a compass. Indicate with symbols some landforms or landscape elements that might be found around the perimeter of a lake. Draw a small compass around each landscape element and have the students locate an assigned wind heading for each quadrant. It is important to include the smaller compass around each landscape element. Without this, it is common for students to adjust the direction of wind flow to meet the correct point on the larger compass. An important lesson in this section is that wherever you are, east is still east and 230° is still 230°. (See Figure 2 – Conceptualizing Wind Direction).

Wind heading 090° (Wind is from the east).

A. Incorrect interpretation of winds from 090°. B. Correct interpretation of winds from 090°.

Figure 2. Conceptualizing Wind Direction

4. Instruct students to complete the next activity by predicting and drawing shadow patterns. (See Figure 3 – Wind Shadows Predicted)

Wind Shadows Predicted

(a) Identify the major points on the lake's compass
(b) Name each compass quadrant (eg. NE, SW, etc.).
(c) Draw a compass around each landscape element.
(d) Locate the wind direction assigned for each landscape element in each quadrant. (You'll have a different wind heading assigned for each quadrant).
(e) Draw a predicted wind shadow for each landscape element.

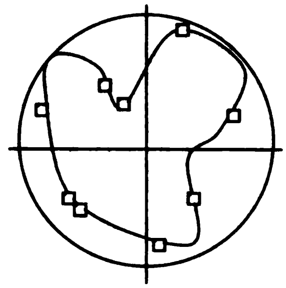


Figure 3. Wind Shadows Predicted

5. The presence of certain landscape elements results in protection from wind. If wind on water is reduced by the 'shadows' cast by mountains, hills or a floodplain forest, the horizontal circulation patterns are most directly affected. Once students have predicted shadows for a given diagram, they should be able to identify areas of the lake that would be characterized by relative calm and those open areas where wind would have a greater impact. In Figure 4, we might expect the upper portion of the NW quadrant to be relatively calm while the SW quadrant, characterized by open water, would likely have rougher water.

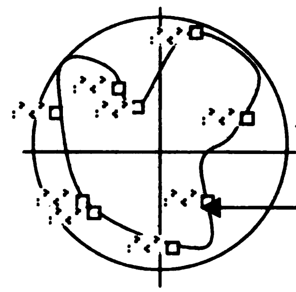


Figure 4. Analysis of Shadow Patterns

6. If it isn't possible to include time in class for discussion, the discussion questions listed below should be answered in writing and handed in as soon as possible after completion of the exercises.

7. Include the vocabulary either formally by assigning the vocabulary list or informally through inclusion in your introduction and summary phases.

Discussion Questions

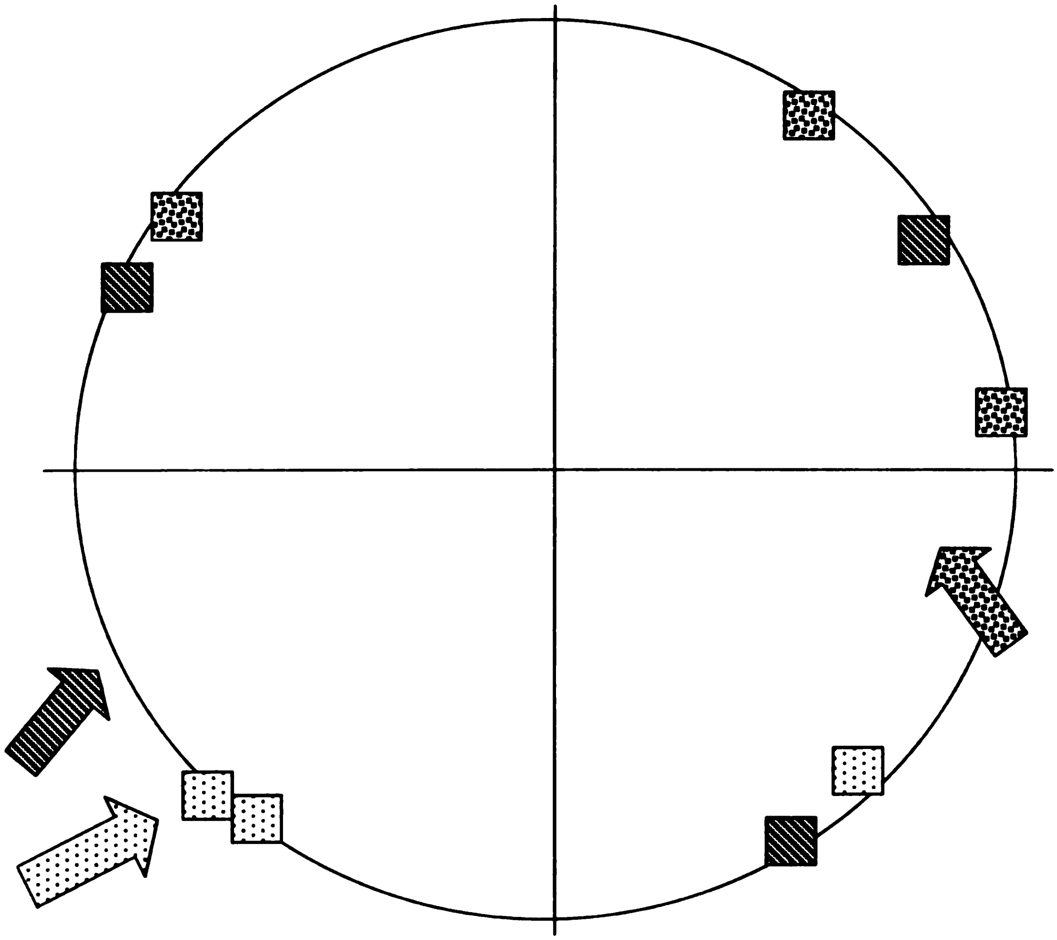
Do surface temperatures give you a good clue as to deep-water temperatures? Why? Why not?
How do density differences drive circulation?
What impact would a sudden influx of fresh water have on a salt-water system?
Why do the circulation patterns differ in the southern and northern hemispheres?
How does thermal stratification impact the biological community?
What would you expect the temperature map to look like for spring, fall or winter?
How does water temperature impact the biological communities in a lake?
(Any questions about biological, chemical and geophysical relationships are appropriate. Adjust as needed for your students' backgrounds. Dissolved oxygen, biological oxygen demand, turbidity, vegetation, freezing and thawing, water density associated with

temperature, stratification, overturn, indicator species, urban influence, thermal pollution and freshwater classification are among the many possible discussion topics possible from this exercise.)

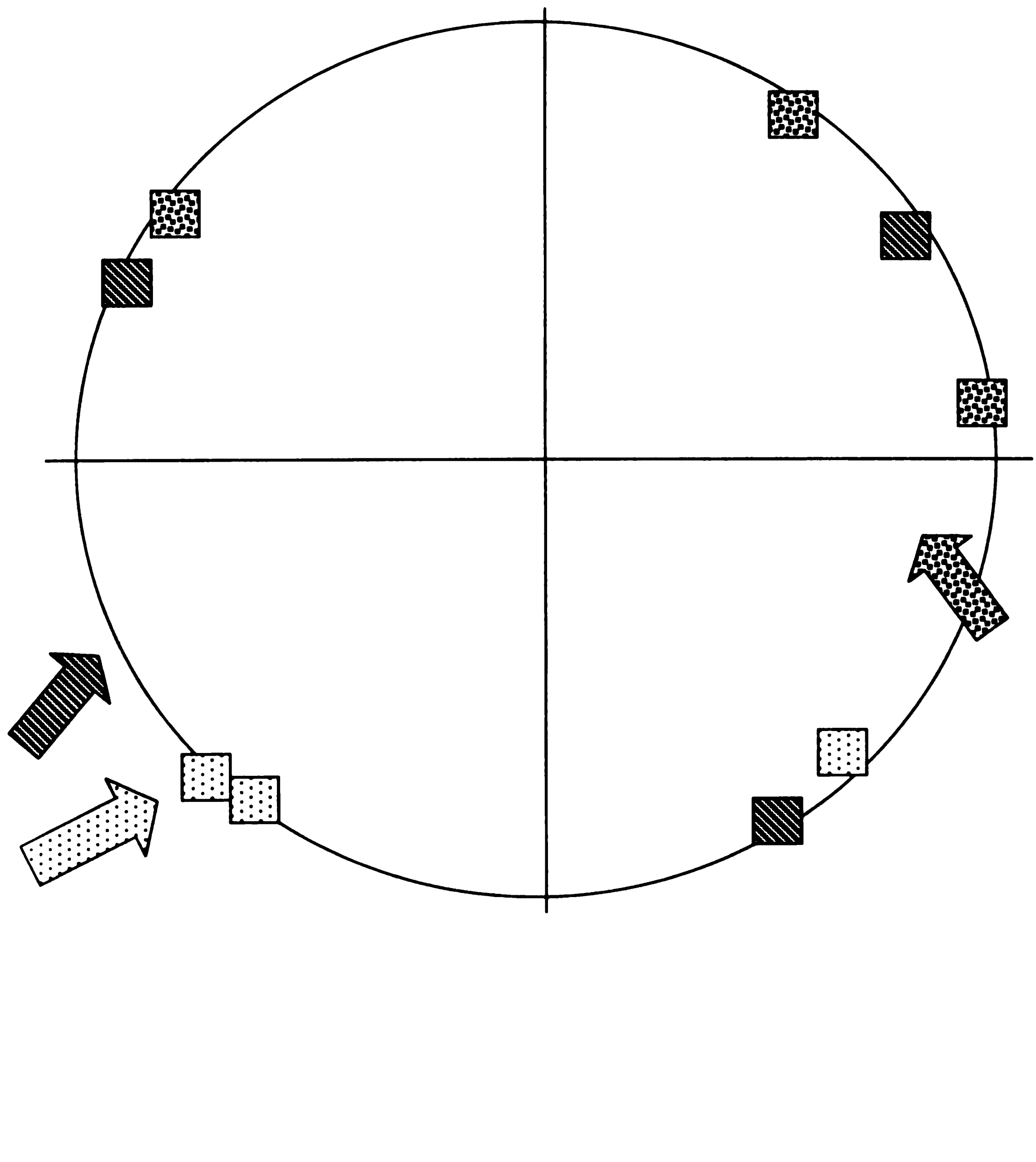
Further Investigations

Research the various methods by which temperature readings are taken in water bodies around the globe.
Repeat this exercise using specific freshwater lakes.
Search the web for interesting data sets to incorporate into your maps. (www.epa.gov and www.globe.gov are good places to start).
Create a model of a lake (true-to-scale) and simulate circulation patterns.
Compare biological communities around the perimeter of the lake.
Explore the role of Global Positioning Systems (GPS) in satellite generated maps.

Observing Light Shadows
(Duplication Master)



Observing Light Shadows
(Duplication Master)

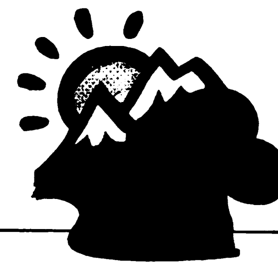


APPENDIX B

APPENDIX B

Learning Activities
Landscape Visualization

Mini-Mountains
Landscape Visualization
Intermediate Level



Purpose
To introduce students to the concept of spatial relativity of elements within a biome.

Overview
The beginning level of Mini-Mountains is intended to give students an opportunity to gain a physical connection with the relationships that exist among the elements comprising a biome. Students will use 3-dimensional manipulatives to create representations of standardized biome images. Students will then mark their layouts on a grid and compare to the layouts of other students.

Time
One to Five class periods

Level
Beginning

Prerequisites
None

When he parts from the land, man is no longer able to maintain the stability of the heart.

Masanobu Fukuoka

Key Concepts and Skills
Concepts
Landscapes are comprised of a mosaic of biotic and abiotic elements.
Landform elements can be represented by common shapes and combinations of common shapes
The spatial relativity of biotic and abiotic elements is biologically significant.
Relationships exist based on spatial relativity of landforms within a biome and biogeochemical cycles.
Landform patterns are specific to biome types.

Skills
Observing landscape photographs
Interpreting observed associations
Using symbols for representation of landforms
Mapping by transferring interpretations to a grid system

Materials and Tools

Wooden objects provided in activity kit (Suggested quantities in Table 1 are based on student usage with an unlimited supply of materials).
Plastic canvas
Landscape photographs
Fine tip felt pens (black and red)
Tape or 'Bulldog' clips
Plain paper

Preparation

Sort wooden objects into kits and choose landscape photographs for the students to interpret.
Highlight each 10-square increment on the plastic canvas using a permanent marker.
Label each photograph in the biomes collection. (One set for every 2-3 students is recommended).

What To Do and How To Do It

1. Give each student a sheet of the plastic canvas and 2-3 sheets of plain paper.

2. Give each student (or group of students) a set of standardized photographs from the biomes collection and a kit containing the manipulatives as listed in Table 1.

Manipulative	Code	Quantity in each kit	Symbolic representations (typical representations are listed but they will vary by student)
1 1/2 inch ball	LB	4	Rocks, trees, mountain formations, water, shrubs, bluffs, buttes, falls and cliffs.
3/4 inch ball	MB	10	
3/8 inch ball	SB	20	
1 inch cube	LQ	10	
3/4 inch cube	MQ	15	
1/2 inch cube	SQ	20	

Table 1. Contents of Manipulatives Kits

3. Have the students position the manipulatives on the plastic canvas to duplicate the biome(s) in their photograph(s). There is no time limit in this exercise but ask the students to note their beginning and ending times. They may use as many or as few of the manipulatives as they think are needed to represent the biome. (See Figure 1).

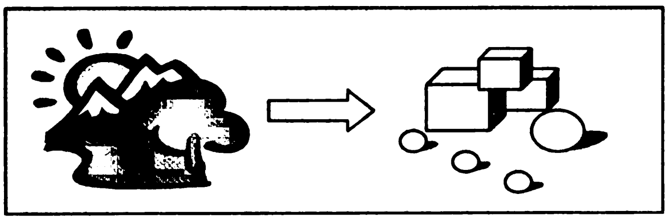


Figure 1. Interpret the landscape by using blocks.

4. After they are satisfied with their layouts, have the students mark the "footprint" of each object or formation by pushing their felt pen through each hole covered by a manipulative. These need not be exact but should be very close to the actual coverage.

5. Make a note beside each "footprint" indicating what the wooden manipulative (or group) represented (eg. rock, tree, etc.).

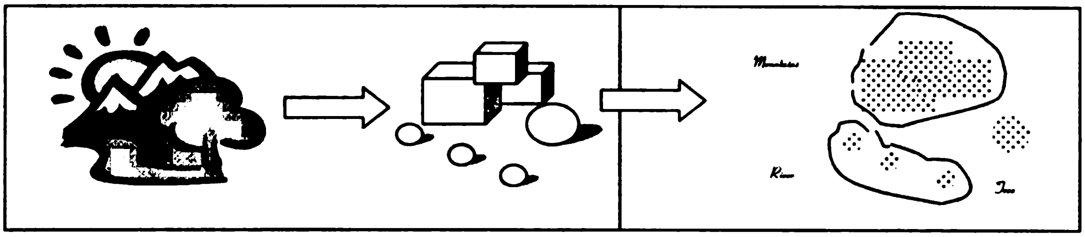


Figure 2. Outline groups

6. If a group of manipulatives is being used to represent a larger area such as a mountain range, the group should be circled as in Figure 2.

7. Return the manipulatives to storage.

Discussion Questions

Are all the layouts the same? What are some of the differences?

How much variation was there in the number of pieces used? Or in the amount of time used?

Discuss the relationships that exist between the biotic and abiotic components of each scene.

Further Investigations

Develop a series of 'what if' problems for each biome. What if a patch of trees was moved south of the mountain? What if several years of dry weather reduced the pond volume or the stream depth? What if there was a fire?

Create mapping and navigation exercises using the layouts.

Have students complete layouts and compare patterns for several biomes.

Use grids of different sizes and discuss differences of scale and resolution.

Use a software program (such as Excel) to input the data coordinates for the landscape footprints. Create a digital "map" by selecting the scatter point graphing command.

Mini-Mountain
Landscape Visualization Activity 1

Name ________________

Supply list

- Wooden objects (see table 1 for a complete list)
- Plastic canvas
- Landscape photographs
- Fine tip felt pens (black)
- Tape or 'Bulldog' clips
- Plain paper

Manipulative	Code	Quantity in each kit	Symbolic representations (typical representations are listed below)
1 1/2 inch ball	LB		Rocks, trees, mountain formations, water, shrubs, bluffs, buttes, falls and cliffs.
3/4 inch ball	MB		
3/8 inch ball	SB		
1 inch cube	LQ		
3/4 inch cube	MQ		
1/2 inch cube	SQ		

Table 1. Contents of manipulatives kits

1. Before you get started, make sure you have all the things listed on the supply list and double check to see that you have as many manipulatives as Table 1 shows you should have.

2. Tape or clip the sheet of plain paper to the plastic canvas so that the lower left corners of the paper and the canvas match up.

3. Position the wooden manipulatives on the canvas to represent the landscape scene you've been given. There isn't a time limit but write down the time you start and the time you finish your interpretation.

TIME

Begin	End
Begin	End
Begin	End
Begin	End
Begin	End

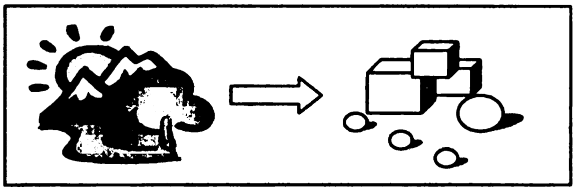


Figure 1. Interpret the landscape by using blocks.

1. After you are satisfied with your layout, mark the location of each object by pushing your black felt pen through each hole covered by a manipulative. These need not be exact but should be very close to the actual coverage. This creates the landscape "footprint" or pattern.

2. Make a note beside each tracing indicating what the wooden manipulative represented (eg. rock, tree, etc.).

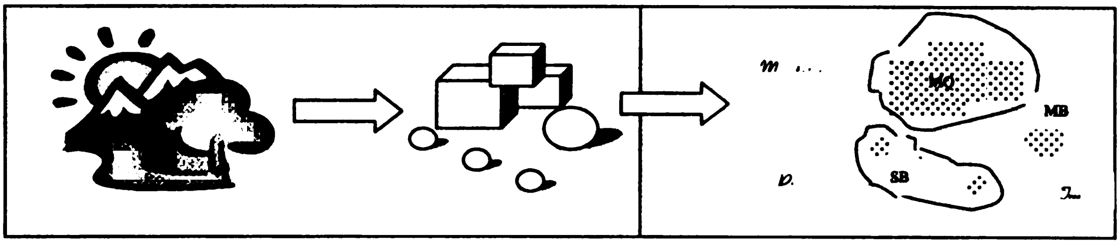


Figure 2. Outline groups

3. If a group of manipulatives is being used to represent a larger area such as a mountain range, the group should be circled as in Figure 2.

4. Return the manipulatives to storage.

Discussion Questions

A. Are all the layouts the same? What are some of the differences?

B. How much variation was there in the number of pieces used? Or in the amount of time used?

C. Discuss the relationships that exist between the biotic and abiotic components of each scene.

D. How does the presence of water influence plant communities?

E. What do rock formations tell us about an area?

F. How can a mountain impact the water cycle?

G. What animals would you expect to find in each of the scenes you interpreted?

APPENDIX C

APPENDIX C

Sample Learning Activity
Water Studies

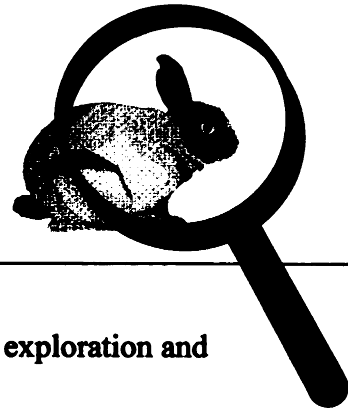
Background Information

Treasure hunters
Troubled Water

The following learning activities form the first two sections of an activity suite focusing on floodplain forest wetlands. The first of these is an acclimatization exercise during which urban students, generally unfamiliar with wetland habitats, can gain familiarity and comfort in the habitat. It is during this first and most critical stage that students gain trust in their abilities to navigate nature. History has taught me that to begin formal research without at least some degree of acclimatization yields a rather empty, short-term experience. This may be the case with most children and it is certainly the case with inner city minority youth.

During the second activity, more formalized testing is initiated. Basic water quality measurements such as turbidity, dissolved oxygen (DO), nitrites, ammonia and pH are taken and a community survey including plants and insects can be started and continued over many years. Individual research projects may be proposed by the students and included with these investigations.

Treasure Hunters:
An Acclimatization Activity For Floodplain Forest Wetlands



Purpose
To become acclimatized to a forested wetland area by free exploration and directed treasure hunting.

Overview
During an exploration designed to help urban students become familiar with and comfortable in this type of environment, students will attempt to find items typical of forested wetlands. Each small group (4-10) of students will search for items on a list that includes both collectable and non-collectable plants, fungi, insects and animal evidence. Evidence of animal activity might include signs of damage such as tunnels or holes in bark created by beetles or tracks left by deer, raccoons, rabbits and other animals.

Upon completion of the treasure hunts, each group will prepare a display of their finds from the trip. A brief description of techniques used for collection and the habitat (or micro-habitat) where the items were found or sited will accompany each section of the display.

Time
Two hours or more in the field followed by time for assimilation, display creation and discussion in class. (Note that there are several additional activities in this suite).

Level
Basic to intermediate

Prerequisites
None

Any prior experience with outdoor skills will add to a student's comfort level in the field. Those with no experience can be led gently into a new world of sights, sounds and smells.

Key Concepts and Skills
Concepts
Water levels cycle through a high associated with spring thaw to a low associated with late summer dry-down.

Upland forest communities are affected by the temporal nature of water.

Deciduous forests all share common characteristics and communities.

Skills
Observing nature

Identifying components of specific habitats

Collecting and managing samples

Materials and Tools

First-Aid kit
Insect nets (Aerial and aquatic)
Funnels (Sunny-D bottles work very well)
  Use to transfer water samples into quart jars.
Small vials with alcohol
Flat forceps
Baggies
  For holding moss, bark with lichen, nuts, bones, etc. Keep litter items such as cigarette butts separate from natural items.
Small jars or film canisters
  For holding insects
Baggies with pre-measured amount of plaster-of-Paris
  Add 1 cup of plaster mix to each baggie. When animals' tracks are found, add enough water to the plaster to make a mixture with the consistency of melted ice cream. Create a band around the track using heavy cardboard. Pour the plaster into the tracks and allow it to set-up (about 20 minutes). Carefully remove the cast. Let the cast dry thoroughly before attempting to clean off excess dirt and leaves.
Treasure hunt lists
Pencils
Small field notebook
Material for pitfall trap (eg. Rocks, coffee can and flat board to cover it)
Kritter-keepers or other safe houses for insects
Identification guides (flowers, insects, trees, etc.)
Sorting trays (white enamel pans)
Probes
Eyedroppers
Pruning clippers
Marker flags
Shovel or trowel
Cellular phone and list of emergency numbers

Preparation

1. Choose a site for the field trip and arrange for permits or permission from local authorities or private landowner. Typical government agencies associated with public lands include the Forest Preserve District, The Department of Natural Resources or Environmental Quality or the County Sheriff or city/village police department.

2. Distribute permission slips early enough for students to have them signed and returned. Because there is some potential risk involved (although minor) from water, insects, ticks, etc., it is strongly recommended that an additional form granting permission to arrange for life-saving emergency care be signed. This form should include the name and phone number for the student's doctor or clinic, insurance information and choice of hospital. It is also important to include the name and phone number for an emergency contact with the student's family. Do not rely on information given to the school months previous. This information must be current.

3. Arrange for a bus and driver if needed for transport to the site.

4. Determine what lunch arrangements will be needed. If you will be providing lunches, get purchase order number or check from school. If students are to provide their own lunches, remind them several times and decide what you'll do in the likely event someone forgets his lunch.

5. Provide water and cups. Pop, juice and milk are not metabolized the same way as water. To avoid dehydration, water should be taken every 15-30 minutes.

6. Review the supply list (a suggested list is provided) and make additions or deletions as appropriate. Gather or order supplies. Lead-time for ordered material should not be less than two weeks (the longer, the better).

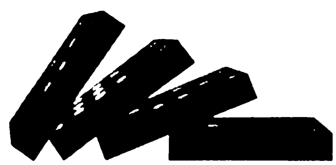
7. Do a reconnaissance trip if possible. This activity has been designed to work with or without a pre-walk of the site. By doing a pre-walk, you will be able to customize the treasure hunt list, choose routes and survey for potential problems. If you are not able to do a pre-walk, be extra cautious and observant during the actual trip. A smaller student/trail guide ratio may also be needed without reconnaissance.

8. Arrange for "trail guides". (AKA chaperones, helpers, assistants, aids, etc.). Have a brief meeting with guides in advance if possible or, for experienced trail guides, a quick on-site review. Advance distribution of material to guides is certainly helpful.

Background

Wetlands are among the most productive habitats on this planet. Unfortunately, they are also among the least understood and most vilified. From the earliest settlers, humans have wanted to dredge, fill or otherwise control these wonders of nature. Included in the very long list of natural functions served by wetlands are flood control, habitat for breeding birds and biologically sensitive animals, buffer zone for chemical contaminants, transition zone for import and export of nutrients to surrounding areas, and a natural sponge for gradual release of stored water. When wetlands exist in a complex covering a large geographic area, their benefits are multiplied and use by migrating birds and other animals is intensified.

After years of filling or dredging wetlands to increase available agricultural land, several problems began to surface. The water retention provided by the unique character of wetland soils and the associated plants was gone. Areas previously protected from seasonal highs and lows began flooding. Once the flooding subsided and the wet season passed, lands became exceptionally dry. The same physical characteristics that allowed wetlands to hold water at bay also provided for the gradual release of water over the entire season. Without this slow release, the cycle of flood and drought were intensified. Along with the flooding was loss of valuable topsoil carried downstream in the flood. Without the fertile topsoil,



fertilizer needs increased. The increased use of fertilizers meant that more nutrients would be carried away with next year's flood and someplace downstream would have an overabundance of otherwise limiting nutrients. A sudden influx of limiting nutrients sets the stage for population explosions where such explosions are unwanted, namely, algae and small plants. Blooms of algae or eutrophication of small waterways, altered the chemical composition of the water by reducing light, submerged plants and dissolved oxygen. Without the proper levels of dissolved oxygen (DO) many fish and arthropods with high biological oxygen demands (BOD) died off and the biological quality of the waterway was compromised. No oxygen, no trout or salmon or other valuable game fish.

Not enough? The reduction of available wetlands and wetland complexes along flyways meant that migrating birds including many songbirds, ducks and geese, had nowhere to breed or rest during their long migratory flights. Their numbers went steadily down until the people at Ducks Unlimited noticed the trend, put their heads together and identified the causal elements, too few wetlands. Now was a time for action. The consequences of misguided land use were staring squarely into the faces of those who could make changes. Government agencies and private landowners were encouraged to stop destroying their wetlands. Ducks Unlimited purchased acre after acre of threatened land and many dredge and fill operations became illegal unless accompanied by proper permits issued by the Army Corps of Engineers.

There still exist no clear and specific protections for many small wetlands. Riding on the coattails of legislation designed to protect threatened and endangered species, some wetlands are out of danger. Also, within Part 404 of the Clean Water Act some protection is afforded. The Soil Conservation Districts, Departments of Environmental Quality and Environmental Protection and Forest Preserve Districts each have programs designed to increase wetland acreage. This all helps, but enforcement is an issue, lack of understanding remains an issue and many of the wetlands already lost are now covered with major cities including Chicago. Gone is gone in these cases. Our hope for today and tomorrow is to increase understanding and appreciation of these tremendously valuable resources, demand legislation targeted at their protection, increase enforcement efforts and reduce the political bow to developers.

Values were at the heart of the problem. Agricultural production and urban expansion were held above environmental awareness or concern. There have always been visionaries who oppose such actions but small in number often means small in voice. Through the following activity, students have an opportunity to explore a critical habitat outside the restrictions of the classroom environment. To integrate an experience into one's set of values means letting one have his or her own experience. This is especially important during first and early exposures. The treasure hunt offers direction (find the objects) without forcing any particular agenda (complete and hand in this.....). Allow time to think, to reflect and to have a sensory experience. Talk about observations when the students are interested. Now...later...when appropriate. Avoid making too aggressive an invasion into their explorations. For many urban children, this will be the first experience of significance with the mysterious out-of-doors. Keep it safe, fun and personal. Only after acclimatization activities should any formal research begin. (See '*Further Investigations*')

Resources

Bates, John. 1997. Seasonal Guide to the Natural Year: Minnesota, Michigan, Wisconsin. Flucrum Publishing. Golden, Colorado.

Benyus, Janine M. 1989. The Field Guide to Wildlife Habitats of the Eastern United States. Simon and Schuster. New York, NY.

Chinery, Michael. 1994. Questions and Answers About Forest Animals. Kingfisher Books. New York, NY.

Cohen, Karen C. (Editor). 1997. Internet Links for Science Education: Student-Scientist Partnerships. Plenum Press, New York.

Headstrom, Richard. 1968. Nature Discoveries with a Hand Lens. Dover publications, Inc. New York, NY.

National Wildlife Federation. 1989. Naturequest Day Hike Activities Guide. National Wildlife Federation and Johnson Camping, Incorporated. (Pamphlet)

Sheehan, Kathryn and Mary Waidner. 1991. Earth Child. Council Oak Books. Tulsa, Oklahoma.

Thomson, John. 1994. Natural Childhood. Simon and Schuster. New York, NY

Acknowledgment

Header clip art from Microsoft Clip Gallery 3.0

What To Do and How To Do It

1. Divide students into small groups. Groups should be between 4 and 10 students with a guide for each group. Have each group identified by tags, wrist bands, T-shirts or some other recognized method. Your trail guides may not be as familiar with the students as you are so make it easy for them to identify their charges.

2. Give each trail guide a list of his or her students.

3. Distribute supplies (see list) and treasure hunt check sheets to each member of the group. The trail guide should keep a master list for the entire group.

4. Demonstrate the use of any equipment. (For large groups, each trail guide can do the demonstration for his or her smaller group).

5. Establish a time and place to reassemble the entire group. Hold everyone who is wearing a watch responsible for keeping track of the time. If the bus is scheduled to leave at 1:30, you might have the groups reassemble at 1:00 to allow for stragglers. You can always use the extra time to discuss the activity or organize the materials. You also want to allow time to reorganize the equipment or gear.

6. If each group is to lunch on their own, distribute lunches or establish a time and place to eat as a group.

7. Send the groups out in different directions if possible or stagger their departures if only a single trail is available.

EACH GROUP

8. Review the use of any equipment or gear.
9. Begin the search for items on the list (Attachment 1).
10. Instruct the group to stay reasonably close together. Reasonable depends on the location, age and experience of your group. In any case, no fewer than two and ideally four students should be together at all times. (Having four students allows one to stay with an injured hiker while two seek help).
11. Enjoy the hike. If ever there was a time to watch for the "teachable moment" this is it! Review the background and discussion questions sections of this activity before the hike. Seek opportunities to talk about trophic levels, energy flow, nutrient cycling, communities and microcommunities, abiotic and biotic factors and anything else that strikes your interest or your students'.
12. AVOID THE "GATHER 'ROUND AND LISTEN TO ME" STYLE OF GUIDING!!! Your students will ask questions that naturally allow you opportunities to share your knowledge. Be the guide not the boss and students will enjoy their exploration more naturally.
13. Sign off those finds that are to be left in place after being found. Help students manage all other samples properly. Explanations are given with the supplies list.
14. Keep track of time and get students back to the designated spot with time enough to pack gear.

Vocabulary

Abiotic factor - Non-living factors impacting an environment. Examples include light, heat, moisture, wind, rocks and, debatably, soil.

Adaptive coloration – Coloration on an organism that gives it a competitive advantage in a habitat. Mammals, birds, amphibians, reptiles and insects all provide some examples of species exhibiting adaptive coloration.

Biotic factor – The living elements in a habitat. Examples include bacteria, plants, animals and fungi

Consumers – Organisms beyond the producer level in a food chain. Herbivores, carnivores and omnivores are included.

Decomposers – Those organisms responsible for breaking down organic material in nature. Examples include fungi, bacteria and many insects.

Eutrophication – The shift from a low nutrient level, clear water body to one high in nutrients and biological productivity.

Hydrophytes – Plants that have adapted to living in wet conditions

Oligotrophic – A water body with a low nutrient level and high clarity. Most lakes and rivers considered good for recreation are oligotrophic.

Producers – Those organisms responsible for converting the sun's energy into products of caloric value (food energy). Green plants including macrophytes, algae and phytoplankton are included

Riparian zone – The zone along rivers or stream banks subjected to periodic flooding

Riverine system – The area specifically referring to the channel or outer banks of a river or stream

Symbiosis – Relationship existing between two or more organisms. These relationships may be mutually beneficial, mutually benign or parasitic.

Trophic levels – Level progressing up the food chain as energy is converted and ultimately flows through each subsequent consumer level

Wetland – An area characterized by predominantly aquatic or semi-aquatic plants, hydric soils and periods of inundation (water coverage) during each annual cycle.

Discussion Questions

Which items on the list were found near the water? What items were found the farthest from the water?

What was the biggest surprise of your exploration?

How does the location of water affect where an animal makes its home?

What are the major abiotic factors at play in a forest? In a river?

How do you think the light level in a forest changes from April through November?

Do changing light levels have any impact on the plant communities?

What relationships do you think exist between plants, insects and other animals in a wetland forest?

Why is the riparian zone considered so productive?

How does periodic flooding rather than continuous water flow affect the nutrients available?

How has this productivity been exploited along the Mississippi corridor?

What problems are associated with construction in the riparian zone?

Should the government continue to provide disaster relief for weather related damage along rivers?

Further Investigations

Continue and expand investigations in the same wetland. Examples might include surveys of animal, insect or plant communities. Compare the surveys over the year and over several years.

Locate Satellite or high altitude aerial maps of the wetland. Compare these maps to topographic maps and road maps.

Ground truth the topographic maps of the area by using a handheld GPS (Global Positioning System).

Create a diorama representative of the forest wetland, the riparian zone or the river.

Locate Your Watershed – Find the watershed that includes your wetland. Review research currently underway.
http://www.epa.gov/surf2/locate/

GIS activities for K-12 using ArcVoyager (GIS) software
http://www.esri.com/industries/k-12/voyager.html

United States Environmental Protection Agency
www.epa.gov

Troubled Water:
A Water Quality Exploration For Floodplain Forest Wetlands

Purpose

To use community composition to evaluate water quality in a floodplain forest wetland.

Overview

Students will sample water from a floodplain forest wetland and conduct a variety of field and laboratory analyses. Included in the analysis and subsequent profiling of the wetland will be macroscopic invertebrates and algae, macrophytes, pH, temperature, turbidity and dissolved oxygen. Additional measurements as appropriate for the ages of the students can include nitrogen, phosphates, and microscopic organisms.

Time

Two hours or more in the field followed by time for sorting and identification in the laboratory. Additional time should be allowed, either in class or as home enrichment to create a display to be used in presenting a discussing the students' findings.

Level

Basic to advanced

Prerequisites

Students should be briefed on the use of all gear prior to beginning fieldwork. This may include but not be limited to use of nets, traps, preservation jars (kill-jars), Secchi disks and any chemical test kits.

Key Concepts and Skills

Concepts

Water clarity influences the depth of light penetration.

Light penetration has a large influence over the presence or absence of certain macrophytes and algae.

The movement of water, composition of plant communities and temperature determine the level of dissolved oxygen in an aquatic situation.

Dissolved oxygen (DO) is a limiting factor in the survival of many invertebrate species, therefore invertebrate community composition can be used as an indicator of a system's health.

The presence or absence of certain species of algae is a diagnostic indicator of environmental stresses on an aquatic system.

Skills

Developing environmental testing strategies

Collecting and managing samples in a field situation

Organizing data

Displaying and presenting research findings

Materials and Tools

First-Aid kit
Insect nets (Aerial and aquatic)
Funnels (Some plastic juice bottles work very well)
Use to transfer water samples into quart jars.
Pruning clippers
Marker flags
Shovel or trowel
Small vials with alcohol
For preserving insects
Baggies
Small jars or film canisters
For holding insects
Flat forceps
Probes
Eyedroppers
Sorting trays (white enamel pans)
Zipper-close type plastic bags
Plastic rulers (clear)
Plant presses or newspapers
Pencils
Small field notebook
Identification guides (trees, wetland plants, insects, algae, etc.)
Kritter-keepers or other safe houses for insects being kept alive for observation
Cellular phone and list of emergency numbers

Preparation

Refer to the previous activity, "Treasure Hunters: An Acclimatization Activity for Floodplain Forest Wetlands". The preparation list given includes everything from permission slips to reconnaissance.

Background

Each year as the winter snow begins to melt and water levels rise, streams and rivers overflow their banks and give the floodplain a much needed dose of minerals and nutrients. Plants and animals associated with the floodplain forest are well adapted to the seasonal nature of these life-giving floods. Trees may have systems allowing them to respire aerobically or anaerobically, some plants germinate only after the rich flood waters have receded, animals are able to swim or move quickly and birds may seek perches high enough to afford both protection and view.

Unfortunately, not all water entering a system is beneficial. The upland or upstream waters may be a source of otherwise limiting nutrients such as phosphates and nitrates or they may carry toxins and waste materials from industry and urban runoff. The influence of these factors may be minor and contribute very little to the wetland community or there may be disastrous results from upsetting the natural balance established from years of selection and adaptation.

Many plants and animals have fairly narrow ranges of tolerance for temperature, light, nutrients and oxygen. Because their presence or absence tells us a great deal about the overall condition and health of an aquatic system, we'll be looking at algal, plant and macroinvertebrate community composition to begin creating a profile for a floodplain forest wetland. In addition to cataloging the community composition, measurements of water temperature, turbidity (clarity) and dissolved oxygen (DO) levels give important information about a wetland or river. Cold water holds more oxygen than warm water so the relationship between DO and water temperature is an important one. Too, the turbidity or clarity of water determines how deeply light can penetrate, and in turn, what plants are able to survive. Since plants are a primary source of dissolved oxygen (by-product of photosynthesis), their presence or absence directly affects all other communities.

Resources

See also the reference list provided in the previous activity, "Treasure Hunters: an Acclimatization Activity for Floodplain Forest Wetlands".

Fassett, Norman C. 1957. <u>A Manual of Aquatic Plants</u>. The University of Wisconsin Press. Madison, WI.

Prescott, G.W. 1978. <u>How to Know the Freshwater Algae</u>, third edition. Wm. C. Brown Company publishers. Dubuque, IA

Other identification guides as available and age appropriate. (After several trips to the same site, you might consider creating a customized key for your wetland and the associated floodplain and upland area).

Acknowledgment

Header clip art from Microsoft Clip Gallery 3.0

What To Do and How To Do It

1. Divide students into small groups. Groups should be between 4 and 10 students with a guide for each group. Have each group identified by tags, wrist bands, T-shirts or some other recognized method. Your trail guides may not be as familiar with the students as you are so make it easy for them to identify their charges.

2. Give each trail guide a list of his or her students.

3. Distribute supplies (see list) to each group.

4. Demonstrate the use of any equipment. (For large groups, each trail guide can do the demonstration for his or her smaller group).

5. Establish a time and place to reassemble the entire group. Hold everyone who is wearing a watch responsible for keeping track of the time. If the bus is scheduled to leave at 1:30, you might have the groups reassemble at 1:00 to allow for stragglers. You can always use the extra time to discuss the activity or organize the materials. You also want to allow time to reorganize the equipment or gear.

6. If each group is to lunch on their own, distribute lunches or establish a time and place to eat as a group.

7. Assign each group an area to survey. Define the boundaries of each assignment with marker flags or some other indicator.

INDIVIDUAL GROUPS

8. Review the use of any equipment or gear.

9. Set "Lobster Traps" by unwinding the tether and driving the anchor points into the ground just at the water's edge. Force water into the trap by holding it underwater with the rim of your aquatic net or by hand. The trap should move freely near the surface of the water within the length of the tether (approximately 1-meter). If the water is too shallow to cover the entire opening, make a note in your field book and either use a smaller trap or be certain that at least the opening of the funnel into the bottle is submerged.

   Insects swimming or crawling into the trap will be unable to escape. Occasionally, frogs, fish or tadpoles will wander into the traps. These should be noted and released. The sooner frogs can be released, the better. They are amphibians remember, and can actually drown in the trap waiting for you to rescue them.

10. Mark each trap location with a flag .

11. Different insects will be collected by using a D-net to tap around vegetation or to stir up those insects living on the bottom of the pond. Carefully lower the net into the water and either agitate the bottom of the pond slightly or tap the stems of plants growing in the water. Raise the net straight up out of the water and invert it into a water-filled sorting tray, a zipper bag or other container. Swish the inverted net in the contained water to free any insects.

    Be consistent with the number of 'dips' for each sample. In other words, if you do five 'dips' in one location, each location should be sampled using five 'dips'. You may choose to "catch and release" or keep and preserve your insect specimens. For first field trips, it may be necessary to keep and preserve for the purpose of establishing a teaching collection. After such a collection has been created, "catch and release" is desirable to reduce over-sampling of the area.

12. Decide in advance whether insects will be identified in the field or taken back to the lab for identification. Time will likely be the deciding factor. Preserved specimens will last indefinitely. If preserving samples, put the insects in a container partly filled with 75% ETOH. The insects can be sorted later and transferred in to clean vials with fresh alcohol.

    Be certain to include location tags in any bottles of preserved insects. The date, collection method and location should all be included on the tag. Use a pencil for the tags. Ink will smear, run or fade but pencil lead holds up nicely. Save several vials of the water from each location. Once back at the lab, these samples can be used for measuring pH, analyzing nitrates or phosphates and for finding algae and other plankton with the use of a microscope

13. If the water is deep enough and there is safe access, lower a Secchi disk or other turbidity measurement device until it can no longer be seen. Record the depth. For shallow areas, a similar measurement can be taken with a clear ruler. Lower the ruler into the water and try to determine at what depth the numbers become fuzzy or disappear entirely. For sloughs and other temporary retention areas, this method works fine and can be done easily by any age group.

14. Plant samples can be taken throughout the investigation. For a quantitative study, cataloge all plants by their dominance level in a specified area (One or more square meters) or within a 1-meter path along a transect representative of the area. If plants are to be collected, they should be transported flat between newspapers and in a press if possible. Submerged plants can be taken back to the lab in zipper bags partly filled with water. Identification is easier when submerged plants are wet. After identification, they can be pressed using the same method as for terrestrial plants.

15. Keep track of time! Once back at the lab, samples can be sorted, plants and insects can be identified and preserved and specific water quality tests can be completed. Many good test kits are available through supply catalogues or greenhouses. All kits come with specific instructions that can be easily followed by most middle schoolers.

Vocabulary

Abiotic factor - Non-living factors impacting an environment. Examples include light, heat, moisture, wind, rocks and, debatably, soil.

Aerobic – With oxygen (reference to respiration)

Anaerobic – Without oxygen (reference to oxygen)

Biotic factor – The living elements in a habitat. Examples include bacteria, plants, animals and fungi.

Hydrophytes – Plants that have adapted to living in wet conditions

Oligotrophic – A water body with a low nutrient level and high clarity. Most lakes and rivers considered good for recreation are oligotrophic.

Riparian zone – The zone along river or stream banks subjected to periodic flooding

Riverine system – The area specifically referring to the channel or outer banks of a river or stream

Turbidity – The clarity of water

Terrestrial – Living on land

Qualitative – A non-numerical analysis. Can take the form of presence or absence

Quantitative – A numerical measurement of something

Macrophytes – Plants large enough to see without a microscope

Slough – A temporary pool formed as water is held in low-lying areas

Wetland – An area characterized by predominantly aquatic or semi-aquatic plants, hydric soils and periods of inundation (water coverage) during each annual cycle

Discussion Questions

What were your greatest difficulties with the collection methods used to sample insects?

What was the biggest surprise of your exploration?

Were all areas equally turbid?

Were you able to notice any associations between plants and insects?

What differences did you notice between plants near the river's edge and those at the edge of the floodplain?

How does periodic flooding rather than continuous water flow affect the nutrients available?

What adaptations do you think a plant or animal might require to be successful in a habitat characterized by periodic flooding?

Further Investigations

Measure flow and volume of the river. Do these change over the season?

Continue and expand investigations in the same wetland. Compare the surveys over the year and over several years.

Compare the pH, temperature, DO and insect survey results for each sample location. What differences and similarities do you notice?

Set up a database using Microsoft Excel or Access. Each season add new data to the file.

Create a 3-dimensional graph of temperature, DO and pH (Excel).

Create cogeoreferenced files from your data for use in generating GIS maps.

Create a vegetation map of the wetland.

Create a display of the insects found in your survey.

Create a public service commercial for wetlands.

Locate Your Watershed – Find the watershed that includes your wetland. Review research currently underway.
http://www.epa.gov/surf2/locate/

GIS activities for K-12 using ArcVoyager (GIS) software
http://www.esri.com/industries/k-12/voyager.html

United States Environmental Protection Agency
www.epa.gov

BIBLIOGRAPHY

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American Association for the Advancement of Science. 1990. Science for All Americans. Oxford University Press. New York.

American Association for the Advancement of Science. 1993. Benchmarks for Science Literacy. Oxford University Press. New York.

American Association for the Advancement of Science. 1998. Blueprints for Reform. Oxford University Press. New York.

Anderson, Eileen S. 1992. *A Longitudinal Test of a Model of Academic Success for At-Risk High School Students*. The Journal of Educational Research, 90(5), 259-267.

Anton, Ted and Rick McCourt (Editors). 1995. The New Science Journalists. Ballantine Books. New York.

Ashworth, William. 1986. The Late Great Lakes: An Environmental History. Wayne State University Press, Detroit, MI.

Atha, Jason T. and Ann M. L. Cavallo. 1999. *Aquatic Ecology: A Learning Cycle Investigation Using Daphnia magna*. The Science Teacher. 65(2), 26-29.

Bates, John. 1997. Seasonal Guide to the Natural Year: Minnesota, Michigan, Wisconsin. Flucrum Publishing. Golden, Colorado.

Bencze, Larry and Derek Hodson. 1999. *Changing Practice by Changing Practice: Toward More Authentic Science and Science Curriculum Development*. The Journal of Research in Science Teaching. 36(5), 521-539.

Benyus, Janine M. 1989. The Field Guide to Wildlife Habitats of the Eastern United States. Simon and Schuster. New York, NY.

Berman, Sheldon and Robert Tinker. 1997 (November). *The World's the Limit in the Virtual High School*. Educational Leadership. 52-54.

Birdin, Vinston E. 1999. Assistant Superintendent of Schools, Bellwood, Illinois School District 88. Personal Communications.

Boyce, F.M. 1989, *Thermal Structure and Circulation in the Great Lakes*. Atmosphere-Oceans. 27 (4), 607-642.

Brody, David Eliot and Arnold R. Brody. 1996. The Science Class You Wish You Had. Perigree Books. New York.

Brown, Stephen C., Kevin Smith and Darold Batzer. 1997. *Macroinvertebrate Responses to Wetland Restoration in Northern New York*. Environmental Entomology. 26(5), 1016-1024.

Bruce, Bertram, Susan Bruce, Rebecca Conrad, Hui-Ju Huang. 1997. *University Students as Curriculum Planners, Teachers and Role Models in Elementary School Classrooms*. Journal of Research in Science Teaching. 34(1), 69-88.

Budiansky, Stephen. 1995. Nature's Keepers. The Free Press. New York.

Buege, Douglas J. 1999. *Nature Network..* The Science Teacher. 66(4), 34-36.

Canadian Hydrographic Service. 1999. *Circulation in the Great Lakes*. The Canadian Hydrographic Service, Department of Fisheries and Oceans. www.GreatLakes.com.

Cheek, Dennis W., Robert Briggs, Robert Yager, Editors. 1992. Science Curriculum Resource Handbook: A Practical Guide for K-12 Science Curriculum. Millwood, NY: Kraus International Publications.

Chinery, Michael. 1994. Questions and Answers About Forest Animals. Kingfisher Books. New York, NY.

Chiras, Daniel D. 1992. Lessons From Nature. Island Press. Washington, D.C.

Cohen, Karen C. (Editor). 1997. Internet Links for Science Education: Student-Scientist Partnerships. Plenum Press, New York.

Collins, Angelo. 1998. *National Science Education Standards: A Political Document*. Journal of Research in Science Teaching. 35(7), 711-727.

Cuban, Larry. 1989 (June). *The 'At-Risk' Label and the Problem of Urban School Reform*. Phi Delta Kappan. 780-801.

Decker, Kelly A. 1999. *Meeting State Standards through Integration*. Science and Children. 36(6), 28-32, 69.

Dede, Chris. 1997 (November). *Rethinking How to Invest in Technology*. Educational Leadership. 12-16.

Ebbers, Margaretha and Sandy Cross. 1999. *Electrifying Encounters: Linking the Elementary School, University, and Community through Science and Technology.* Science and Children. 37(1), 28-32, 72.

Eccleston, Jeff. 1999. *Girls Only Please: An After-School Science Club for Girls Promotes Understanding and Involvement.* Science and Children. 37(2), 21-25.

Edwards, Mary, Julie Luft, Teresa Potter and Gill Roehrig. 1999. *Extended Inquiry Activities.* The Science Teacher. 66(6), 45-47.

Ehrlich, Paul R. and Anne H. Ehrlich. 1990. The Population Explosion. Simon & Schuster. New York.

Escalada, Lawrence and Dean Zollman. 1997. *An Investigation on the Effects of Using Interactive Digital Video in a Physics Classroom on Student Learning and Attitudes.* Journal of Research in Science Teaching. 34(5): 467-489.

Fassett, Norman C. 1957. A Manual of Aquatic Plants. The University of Wisconsin Press. Madison, WI.

Forsyth, Adrian and Ken Miyata. Tropical Nature. Charles Scribner's Sons. New York..

Flavin, Christopher. 1996. *Facing up to the Risks of Climate Change. in* State of the World 1996. W.W. Norton & Company, New York.

Flavin, Christopher and Nicholas Lenssen. 1994. Powering the Future: Blueprint for a Sustainable Electricity Industry. Worldwatch Paper 119. Worldwatch Institute, Washington, D.C.

Franken, Carol and Robert James Wallace. 1996. *Science in the City: Urban Children and Scientist Team up to Gather Complete Ecological Data on a Local Lake.* Science and Children. 34(4), 13-22

Friday, Gerald. 1997. *Environmental Niches: Students Assess Water Quality by Surveying Larval Insect Populations.* The Science Teacher. 64(5), 38-41.

Gannaway, Susan P. 1996. *Watching the Watershed.* Science and Children. 34(4), 16-21

Gardner, Howard, 1991. The Unschooled Mind. BasicBooks. New York.

Gardner, Howard. 1993. Multiple Intelligences. BasicBooks. New York.

Glassman, Bruce S. (editor). 1996. The MacMillan Visual Almanac. Blackbird Press, Simon and Schuster MacMillan Company. New York.

Grumbine, Edward. 1992. *Wilderness, Wise Use and Sustainable Development. in* Deep Ecology for the 21st Century. George Sessions, ed. 1995. Shambala Publications. Boston, MA.

Gunderson, Adolf G. 1995. The Environmental Promise of Democratic Deliberation. The University of Wisconsin Press. Madison. Wisconsin.

Gunkel, Kristin L. 1999. *Ecosystem Explorations: Connecting an Ecology Field Experience to the Classroom*. Science and Children. 37(1), 18-23.

Hand, Brian and Carolyn W. Keys. 1999. *Inquiry Investigation*. The Science Teacher. 64(4), 27-29.

Headstrom, Richard. 1968. Nature Discoveries with a Hand Lens. Dover Publications, Inc. New York, NY.

Hogan, Kathleen and JoEllen Fisherkeller. 1996. *Representing Students' Thinking about Nutrient Cycling in Terrestrial Ecosystems: Bidimensional Coding of a Complex Topic*. Journal for Research in Science Teaching. 33, 941-969.

IUCN, Inter-Commission Task Force on Indigenous Peoples. 1997. Indigenous Peoples and Sustainability: Cases and Actions. IUCN Indigenous Peoples and Conservation Initiative. International Books. Utrecht, The Netherlands.

Illinois State Board of Education. 1997 (June). Proposed Illinois Learning Standards. Illinois State Board of Education. Springfield, IL.

Jeffries, Carolyn. 1999. *Activity Selection: It's More Than the Fun Factor*. Science and Children. 37(2) 26-29, 63.

Johnson, Lucinda B. and Stuart H. Gage. 1997. *Landscape Approaches to the Analysis of Aquatic Ecosystems*. Freshwater Biology. 37, 113-132.

Kali, Yael and Nir Orion. 1996. *Spatial Abilities of High-School Students in the Perception of Geologic Structures*. Journal of Research in Science Teaching. 33(4), 369-391.

Kesselheim, Craig, Roxie Graves, Rochelle Sprague and Mary Ann Young. 1998 (May). *Teacher and Scientist: A Collaboration of Experts*. Science and Children. 35(8), 38-41.

League, Martha B. 1997. *Leadership Grows in the Schoolyard*. Science and Children. 35(2), 18-21.

Mader, Sylvia S. 1985. Biology: Evolution, Diversity, and the Environment. Wm. C. Brown, Publishers. Dubuque, Iowa.

Manzanal, R. Fernandez, L. M. Rodriguez Barriero and M. Casal Jimenez. 1999. *Relationship Between Ecology Fieldwork and Student Attitudes Toward Environmental Protection*. Journal of Research in Science Teaching. 36(4), 431-453.

Margolis, Brian. 1999. *Aquatic Biomonitoring*. The Science Teacher. 66(4), 23-26.

Marks, Steven K., John D. Vitek and John R. Giardino. 1999. *Feedback from the Research Frontier: Making Connections Between Cutting Edge Research and K-12 Education*. The Science Teacher. 66(7), 40-43.

Mattingly, Rosanna L. 1994. *Mitigating Losses of Wetland Ecosystems: A Context for Evaluation*. The American Biology Teacher. 56(4), 206-214.

Mayer, Victor J. 1997. *Global Science Literacy: An Earth System View (Guest Editorial)* Journal of Research in Science Teaching. 34(2), 101-105

McArthur, Julia M. and Karen Wellner. 1996. *Reexamining Spatial Ability within a Piagetian Framework*. Journal of Research in Science Teaching. 33(10), 1065-1082.

McKibben, Bill. 1989. The End of Nature. Anchor Books. New York.

Means, Barbara, Kerry Olson and Ram Singh. 1995 (September). *Beyond the Classroom: Restructuring Schools with Technology*. Phi Delta Kappan.
69-72.

Meredith, Joyce E, Rosanne W. Fortner and Gary W. Mullins. 1997. *Model of Affective Learning for Nonformal Science Education Facilities*. Journal of Research in Science Teaching. 34(8), 805-818.

Middleton, James A., Alfinio Flores and Jonathon Knaupp. November 1997. *Shopping for Technology*. Educational Leadership. 20-23.

Million, Steven K and Jonathon W. Vare. May 1997. *The Collaborative School: A Proposal for Authentic Partnership in a Professional Development School*. Phi Delta Kappan. 710-713.

Mitsch, William J. and James G. Gosselink. 1993. Wetlands, Second Edition. Van Nostrand Reinhold, New York.

Moscovici, Hedy and Tamara Holmlund Nelson. 1998. *Shifting from Activitymania to Inquiry*. Science and Children. 35(4), 14-17, 40.

Naar, Jon. 1990. Design for a Livable Planet. Harper & Row. New York.

Nash, Roderick Frazier. 1989. The Rights of Nature: A History of Environmental Ethics. The University of Wisconsin Press. Madison, Wisconsin.

Nation Research Council. 1996. National Science Standards. National Academy Press. Washington, D.C.

National Science Teachers Association. 1998. *The National Science Education Standards: A Vision for the Improvement of Science Teaching and Learning*. Science and Children. 35(8), 32-34.

National Wildlife Federation. 1989. Naturequest Day Hike Activities Guide. National Wildlife Federation and Johnson Camping, Incorporated. (Pamphlet)

Orion, Nir and Avi Hofstein. 1994. *Factors that Influence Learning during a Scientific Field Trip in a Natural Environment*. Journal of Research in Science Teaching. 31(10), 1097-1119.

O'Neal, Lyman H. 1995. *Using a Wetland to Teach Ecology & Environmental Awareness in General Biology*. The American Biology Teacher. 57(3), 135-139.

O'Sullivan, Elaine and Lorin Driggs. 1999. *Wetlands at the Water's Edge*. Science and Children. 36(8), 33-36.

Papert, Seymour. 1993. The Children's Machine. BasicBooks. New York.

Pekarek, Rebecca, Gerald H. Krockover and Daniel Shepardson. 1996. *The Research-Practice Gap in Science Education*. Journal of Research in Science Teaching. 33(2), 111-113.

Piaget, Jean and Barbel Inhelder. 1969. The Psychology of the Child. BasicBooks. New York.

Pool, Carolyn R. 1997 (November). *A New Digital Literacy: A Conversation with Paul Gilster*. Educational Leadership. 6-11.

Postel, Sandra. 1996. Dividing the Waters: Food Security, Ecosystem Health, and the New Politics of Scarcity. Worldwatch Paper #132. Worldwatch Institute, Danvers, MA.

Prescott, G.W. 1978. How to Know the Freshwater Algae, third edition. Wm. C. Brown Company Publishers. Dubuque, IA

Renner, Michael. 1997. *Transforming Security. in* State of the World 1997. W.W. Norton & Company. New York.

Rifkin, Jeremy. 1991. Biosphere Politics. HarperCollins Publishers, New York.

Roberts, Elizabeth and Elias Amidon. 1991. Earth Prayers From Around the World. Harper San Francisco. New York.

Rodriguez, Alberto J. 1997. *The Dangerous Discourse of Invisibility: A Critique of the National Research Council's National Science Education Standards*. Journal of Research in Science Teaching. 34(1), 19-37.

Roth, Wolff-Michael. 1996. *Teacher Questioning in an Open-Inquiry Learning Environment: Interactions of Context, Content, and Student Responses*. Journal of Research in Science Teaching. 33(7), 709-736.

Sachs, Wolfgang. 1993. *Global Ecology and the "Shadow" of Development*. In Deep Ecology for the 21st Century. George Sessions, ed. 1995. Shambala Publications. Boston, MA.

Schlechty, Phillip. 1997. Inventing Better Schools. Jossey-Bass Inc. New York.

Schneider, Stephen H. *The Science of Climate-Modelling and a Perspective on the Global-Warming Debate*. in Global Warming the Greenpeace Report. Jeremy Leggett, Editor. 1990. Oxford University Press. Oxford, England.

Schullery, Paul (Editor). 1996. Echoes from the Summit. Harcourt Brace & Company. San Diego. Page 14. Photo credit Keith S. Walklet.

Serri, Paul. 1999. *Practical Assessment: Realistic Assessment Strategies Help Educators Attain Curricular Objectives*. The Science Teacher. 66(2), 34-37.

Sessions, Geoorge. 1995. *Ecocentrism and the Anthropocentric Detour. in* Deep Ecology for the 21st Century. George Sessions, Editor. 1995. Shambala Publications, Inc. Boston, Mass.

Sheehan, Kathryn and Mary Waidner. 1991. Earth Child. Council Oak Books. Tulsa, Oklahoma.

Speidel, David H., Lon C. Ruedsili and Allen F. Agnew (editors). 1988. Perspectives on Water: Uses and Abuses. Oxford University Press, New York.

Stein, Scott. 1997. *Stream Studies: Outdoor Activities Incorporate Open-Ended, Student-Designed Labs*. The Science Teacher. 64(9), 47-49.

Teutsch, Mark R. 1998. *Wildlife Counts: Invoking Federal Laws to Protect Local Wetlands*. The Science Teacher. 65(2), 30-33.

Thomson, John. 1994. Natural Childhood. Simon and Schuster. New York, NY

Tolley, Kimberly. 1994. The Art Science Connection: Hands-on Activities for Intermediate Students. Addison-Wesley Publishing Company. Menlo Park, CA

VanMatre, Steve. 1990. Earth Education: A New Beginning. The Institute for Earth Education, Cedar Cove, Greenville, West Virginia..

Webb, James M., Ellen M. Diana, Pamela Luft, Elizabeth W. Brooks and Elizabeth L. Brennan. 1997. *Influence of Pedagogical Expertise and Feedback on Assessing Student Comprehension from Nonverbal Behavior*. The Journal of Educational Research. 91(2), 89-97.

West, Bernadette, Peter M. Sandman and Michiael R. Greenberg. 1995. The Reporter's Environmental Handbook. Rutgers University Press. New Brunswick.

Wirag, Deborah R. 1997. *Share Your Bench with a Bug: Teachers' Attitudes Toward Science and Nature Influence Students' Perceptions*. Science and Children. 35(3), 24-25.

Wollons, Roberta (Editor) 1993. Children at Risk in America. State University of New York Press. New York.