Environmental Literacy Scope and Sequence

Providing a systems approach to environmental education in Minnesota

Minnesota Office of **Environmental Assistance**

Project Partners

Minnesota Department of Children, Families and Learning (DCFL). A state agency formerly known as the Department of Education. The mission of the DCFL is to increase the capacity of Minnesota communities to measurably improve the well being of children and families.

Minnesota Office of Environmental Assistance (OEA). A state agency whose mission is to help Minnesotans make informed decisions and take actions that conserve resources and prevent pollution and waste to benefit the environment, economy and society. The OEA promotes environmental responsibility by means of education and assistance. It is the home of the Environmental Education Advisory Board (EEAB), SEEK (Sharing Environmental Education Knowledge), and the Environmental Education Teacher Preparation Project.

GreenPrint Council, Blandin Foundation. An organization whose purpose was to bring statewide environmental education projects together with state resource people in order to coordinate with the state graduation standards and promote environmental education at the state level.

State Environment and Education Roundtable. A consortium consisting of the representatives of 12 (now 16) state departments of education who are collaborating on the implementation of a program entitled *Environment as an Integrating Context.* Its purpose is to involve students, teachers, and community in the study of their own communities in terms of the interactions between natural and social systems.

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For additional information

For additional information on environmental education or *Environmental Literacy Scope and Sequence,* check out the SEEK web site at *mnseek.net.* This document is available in full at *mnseek.net*.

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Minnesota Office of Environmental Assistance
520 Lafayette Rd. • St. Paul, MN 55155-4100 • 651-296-3417 • toll free 800-657-3843
www.moea.state.mn.us
mnseek.net

Authors

Principal Authors: Pam Landers, Mike Naylon, Annette Drewes

Project Manager: Denise Stromme

Editor: Theresa Gaffey

Cover Design: Scott Andre

Contributors

This document is the result of contributions by many dedicated individuals and organizations. Our thanks and appreciation to the following for their role in the development of the *Environmental Literacy Scope and Sequence.*

Lloyd Bakke, New London-Spicer High, Teacher

Jim Ballard, Lake Crystal High School, Teacher

Catie Belleveau, Red Lake Elementary, Teacher

Karen Branden, Prairie Wetlands Learning Center

Sherry Brown, Duluth Public Schools, Early Childhood

Joanne Drenkow, Moorhead Junior High, Teacher

Jim Ellingson, Education Consultant, Elementary

Linda Erickson-Eastwood, MN Department of Natural Resources

Les Gunderson, Perham High School, Teacher

Wilma Hanson, Frazee-Vergus Elementary, Elementary

Ed Hessler, SciMathMN

Ann Hoehn, Milaca Elementary School, Teacher

Dianne Hoffman, New London-Spicer Middle School, Teacher

Bob Holtz, Concordia College (St. Paul), Higher Education

Carol Jackson, Washington Middle School (Brainerd), Teacher

Nancy Jacobson, Frazee-Vergus Elementary, Elementary

Mary Lou Klinkhammer, Williams Elementary (Shoreview), Elementary

Joyce Kloncz , Moundsview Schools, Science Education

Judy Kuechle, University of MN Morris, Higher Education

Keith Leiseth, Benilde St. Margaret's (St. Louis Park), Secondary Science

Kathleen Lundgren, MN Dept. of Children Families and Learning

Michael Mageau, University of Maryland (Duluth), Higher Education

Tom Moffatt, Wood Lake Nature Center, MN Naturalists Association

Bob O'Hara, Cooper High School (New Hope), Teacher

John Olson, Arlington High School (St. Paul), Secondary Science

Marcie Oltman, Minnesota Children's Museum, Early Childhood

Becky Rennicke, Prairie Wind Middle School (Perham), Teacher

Patty Riley, Education Consultant, Environmental Learning Centers (ELCs)

Deanne Roquet, Lake Superior College (Duluth), Higher Education

Nikki Schneider, Tamarack Nature Center, ELCs

Colleen Schoenecker, MN Office of Environmental Assistance, GreenPrint Council

Angie Smith, Kennedy Elementary (Hastings), Teacher

Shannon Stewart, Tamarack Nature Center, ELCs

Frank Taylor, Anthony Community Middle School (Minneapolis), Teacher

Liz Thornton, Wayzata High School, Secondary Science Teacher

Jen Tjaden, Hawley Elementary, Elementary

Jean Tushie, Eden Prairie High School, Secondary Science Teacher

Rod Vacek, Anoka District, Science Curriculum Specialist

Joe Walker, Minnetonka High School, Teacher

Diane Wanner, Minnesota Office of Environmental Assistance

Jerry Wenzel, Central Middle School (East Grand Forks), Teacher

Jody Yungers, Ramsey County Parks and Recreation

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Foreword

Environmental education has been such a struggle for as long as I have been a part of it, and that has been over thirty years. It was difficult to define, difficult to communicate, difficult to find or write usable curricula, and difficult for educators who were not intuitively interested to perceive any value in it, other than as something nice to do in extra time. We struggled for all those years, groping towards providing a rigor to what was essentially an intuitive conviction that a very important core understanding did exist, something that was not just diluted applied science. We were hovering about the edges of this core for many years, but were never really able to put our fingers on exactly what that was.

We probably should have caught on long ago. The essence lay in the battered, bedraggled (and vastly oversimplified) old phrase "everything is connected." This hoary old phrase had been around as long as I have been in the field. At a day-long meeting of the Minnesota Environmental Education Board in the early 70s, after endless hours trying to decide what the mission of the board was to be, I can remember thinking wearily that of all that was said, if we could just help people understand that interdependency is *the* key concept, I would truly be doing my job. That day, those discussions, and my conviction repeated and repeated over the years like unending groundhog days.

We would say again and again "everything is interconnected," yet go right on teaching as if it weren't, or we would teach in such a way that the lesson was often lost in the methodology and details. We also seemed to have a very narrow concept of what we meant by *everything*. Often, everything didn't seem to include people.

It wasn't until the late 90s, in a fascinating case of convergent idea evolution, that enough people in powerful positions finally buckled down to the real task. That task was to ask, "What is the core of understanding we are seeking that is clearly different from, but would add significant value to, both science and social science? What is it that we are trying to define that would make a difference in how people would understand and treat both our physical and social worlds?"

Within just a few years of each other, a number of groups set out to search for this answer. In all cases, they began to home in on two major ideas: the concept of systems as a way to take apart and study the idea of connectedness and interdependency, and the reality that natural systems and human social systems are constantly and intricately interacting. In fact, separating them as I just have in this sentence into *natural* and *human* is merely a device we use to talk about and analyze them.

I think Dr. Fred Finley, professor at the University of Minnesota and participant in the state's 10 university cooperative environmental education teacher preparation project said it best in the mid-90s when he proposed a goal statement for the project at an initial conference. He said we should take as our focus that "the planet is a set of interacting natural and social systems." This began to light some bulbs in the brainpower that was attending the conference. That teacher preparation project would have been far better conceived and carried out if we had made a better attempt to pounce on that statement and really determine how best to teach it.

This simple statement rang all kinds of familiar bells for me. In the early 1970s when I had been studying anthropology in graduate school at the University of Minnesota, Dr. Luther Gerlach, a professor in the department, had been teaching his students about the importance of understanding systems in order to understand how human social systems worked. Fascinated by the concept of social change, he was interested at the time in social movements in the

United States, one of which was the ecology movement. He was one of the first to analyze the intricacies of interrelationships between how human cultures ordered life, and the natural systems upon which all humans depend for survival. His work and his mentorship became important influences on the direction of the search for a definition of environmental literacy.

That statement of Fred Finley's, summarizing Dr. Gerlach's significant body of work, defined the area of study that is unique to environmental education, and is the core of environmental literacy. It is not just science and not just social science; it is the *interface* between the two that is so crucially important to what happens in both the natural and social worlds. That interface is touched upon by both disciplines, because of its sheer inevitability. It takes a great deal of effort to ignore the importance of the one to the other; (though numerous educators have shown, to our loss, that it can be done). However, this interface is focused on by neither.

At about that same time, two other major state and national projects were coming to the same conclusions. The California Guide for Environmental Literacy Project, initiated within the state's Department of Education, made the assumption that the problems of the world are based in relationships. If that is true, they reasoned, systems thinking can be used to direct attention toward connections and the networks they form. The California committee wrote their guide to environmental literacy to help teachers educate about systems across all disciplines.

While this project was in its final stages, representatives from the Departments of Education from 12 states were meeting, supported by the Pew Charitable Trusts, to discover how best to enhance environmental education in those states. That group was the State Education and Environment Roundtable (SEER) headed by Dr. Jerry Lieberman. One of its proposed projects was to develop an assessment for environmental literacy that could be used nationwide to discover just how environmentally literate our students were and what was the size of the education job yet to be done. In order to develop an assessment, it's necessary to know exactly what is to be assessed. SEER chose a committee, of which I was a member, to meet five or six times over a six-month period, to define that core of knowledge that would be necessary for an environmentally literate student to know and be able to do. After those grueling meetings, the bare essence of the core this committee defined was the same as Dr. Fred Finley's statement.

In Minnesota, meantime, the state Department of Children, Families and Learning (DCFL) had taken up with gusto the national challenge to create sets of educational standards for students. The Minnesota Environmental Education Advisory Board persuaded the state department to include a standard on environmental systems. The essence of the standard (and, coincidentally, another written quite apart by the committee working on resource management) turned out, again, to be based on the goal of teaching the interaction of natural and social systems.

This convergence by such separate but highly credible groups on the core knowledge necessary for environmental literacy was, for me, momentous. Just being able to define where we needed to go with our educational task caused me to breathe a great sigh of relief. It was like breaking the surface of the water after a long, deep, dark dive. Now, not only did we know where we wanted to go, but we had questions to ask that would tell us if learners had arrived there. That is, could they tell us and demonstrate that they knew how systems worked, and how natural and social systems interacted? And could they use that knowledge to make informed decisions? We had a way to assess environmental literacy.

But up above the water surface, standing on the shore, was another question the size of an elephant. If that's where we wanted learners to go, how were we going to help them get there?

SEER and DCFL agreed that we needed to build a series of connected learning steps from kindergarten, or even prekindergarten to adulthood. Since Minnesota needed to do this for all of its education standards, SEER decided to support Minnesota's effort, and, if it was a good one, to use it nationwide.

Over the following five years, the two organizations, ably supported by the Minnesota Office of Environmental Assistance, did develop that sequence of steps in such a way that at each grade level the progress toward the goal could be measured. Many teachers, DCFL staff, and environmental education resource people spent countless grueling hours working towards this sequence.

Early in the sequence development work, Ed Hessler, from DCFL, brought about a major breakthrough in the effort. Clearly, what a student was capable of learning and understanding about systems at each separate level had to be the basis for each of the steps. Employing a child development specialist to work with the committees would have been very expensive monetarily, but even more so in time. We all groaned at the thought because we had spent so much time already, and were impatient to have the thing done and in play.

Wonderfully, Ed discovered that most of this work had already been done. The American Association for the Advancement of Science (AAAS) had already published such a sequence of steps for learning about systems in general. AAAS's *Benchmarks for Science Literacy* give us a thorough analysis of systems and their characteristics; they also provide a sequence for teaching systems to students and adults.

The task of the committees then became one of adapting the more general systems grade level learnings (now called benchmarks, implying their use as measuring devices) to be more specific to social and natural systems and their interactions. One of their major tasks within this was to identify the major concepts and ideas necessary for learners to master in order to reach the goal of environmental literacy as we have defined it.

The results of the hours of work, communications and miscommunications, abraded egos, long phone calls, passionate e-mails, people entering and leaving the project, grinding teeth, and moments of sheer gratitude, relief and satisfaction are in this publication. I fervently hope it will take away some of the frustration and feelings of being lost in a black hole many environmental educators endure, and leave you with a clear sense of purpose and task. If it does, please take a moment to think kind thoughts about the many people who were a part of it. I can only mention some of the very key ones; Dr. Luther Gerlach, whose research and writings were basic to our current definition of environmental literacy, and who mentored the environmental education community in Minnesota; Kathleen Lundgren with the Department of Children, Families and Learning; Dr. Jerry Lieberman with the State Education and Environment Roundtable; Mike Naylon who worked with me throughout the project; Bill Linder-Scholer with Science and Math in Minnesota (SciMathMN), and Annette Drewes and Denise Stromme who have taken on the task of publishing this *Environmental Literacy Scope and Sequence* and all of its supporting materials.

Pam Landers

Pam Landers has worked in environmental education for over 30 years. She is the former Executive Director of the GreenPrint Council. She also served as Formal Environmental Education Coordinator for the Minnesota Environmental Education Advisory Board and as Project Manager of the Minnesota Teacher Preparation Project. In 1996, she won the North American Association for Environmental Education award for "Outstanding Service to Environmental Education by an Individual at the Local Level."

Introduction

Why should we want to be environmentally literate?

Throughout every day, all of us in all our roles are making decisions that affect the environment we depend on. A county commissioner has to decide whether to grant a building permit. A business person chooses which supplies to buy or what kind of vehicle fleet to build. A homeowner ponders whether to install central air conditioning. A family mulls over whether to move to the edge of town and create a long commute or live downtown where both employed people can walk to work. A voter is in a quandary about whether to give her support to a candidate who has strong, well-articulated opinions on environmental issues, but is less interested or concerned about good education.

Each of these decisions, when taken by millions of people, will and do create major changes in environmental systems. Each of these decisions is also intertwined with myriad personal and social considerations that might override what little each knows about the environmental impacts they are creating. Yet in the long run, we know that just these kinds of decisions are changing both the physical and social world and each of our own little pieces of it. Would we change our decisions if we had full knowledge of how what we do affects our own futures? Maybe—and maybe not; but without that knowledge, we are shortchanging ourselves by unwittingly creating changes we might not have chosen, had we known.

If we are environmentally literate about our own choices, we travel with eyes wide open into our futures. We are far better prepared for any unwelcome consequences that we endure because we valued the trade-off more, and we are better prepared to live within the physical and social boundaries we know are there.

If this is something we want, why are we not more environmentally literate right now?

Often it takes a long time to build knowledge. The environmental education (EE) community has been struggling with defining what we need to know and be able to do for some time, both as individuals living our lives and as educators working with students of all ages. Often our subject matter has been too narrow, focused only on material that is really primarily science. Since environmental education is not a discipline, whether it is taught at all often depends on the teacher's or organization's interest. We have made no concentrated efforts to carry the education through in a connected way from lower to upper grades, so understanding is piecemeal at best. Moreover, we haven't done a good job of defining

Minnesota Statute §115A.073 outlines the state's environmental education goals and plan as follows: **"Pupils and citizens should be able to apply informed decision-making processes to maintain a sustainable lifestyle.**

In order to do so, citizens should:

1. understand ecological systems;
2. understand the cause and effect relationship between human attitudes and behavior and the environment;
3. be able to evaluate alternative responses to environmental issues before deciding on alternative courses of action; and
4. understand the effects of multiple uses of the environment."

exactly what core of knowledge is absolutely necessary in order to make those informed decisions for which we are striving. That results in very fuzzy ideas of what is really important to know. This lack of clarification has resulted in many environmental educators focusing on nature study, ecology, or environmental issues.

So what do we need to do to build environmental literacy?

We need to tackle the problems:

- by identifying what we need to know and what we need to be able to do to make informed environmental decisions—*the scope*
- by creating a step-by-step guide from prekindergarten through adult ages to achieve the scope—*the sequence*
- by finding a way to measure whether the guide works

The problems we have created in the world today will not be solved by the same level of thinking that created them.

—Albert Einstein

We hope the *Environmental Literacy Scope and Sequence* is a step in that direction. It defines what students should know and be able to do to be environmentally literate. It is a guide for building a curriculum from prekindergarten to adult levels that should enable the learner who has mastered it to make informed environmental decisions. It can be used for curriculum development and adaptation by educators in schools, environmental learning centers, higher education institutions, agencies, and nonprofit organizations. Furthermore, the Scope and Sequence gives us a way to measure how well students are doing in achieving environmental literacy.

Defining the core knowledge

Environmental educators are finally coming to some consensus about what people need to know and be able to do. The National Environmental Education Advisory Council of the U.S. EPA (Environmental Protection Agency) defines environmental education as:

> *The interdisciplinary process of developing a citizenry that is knowledgeable about the total environment in its natural and built aspects and has the capacity and commitment to insure environmental quality by engaging in inquiry, problem solving, decision-making and action.*

A GreenPrint for Minnesota: State Plan for Environmental Education, (*GreenPrint),* defines the mission of environmental education to:

> *Develop a population that has the knowledge, skills, attitudes, motivation and commitment to work individually and collectively toward sustaining a healthy environment..*[1]

[1] *A GreenPrint for Minnesota: State Plan for Environmental Education.* Minnesota Environmental Education Advisory Board. St. Paul. 1993, revised edition 2000.

These two definitions agree fairly well. Each includes the concept that there is a core of knowledge that is important to master in order to become environmentally literate. Though this consensus is spreading, until a few years ago no one had really come to grips with identifying what that core knowledge consisted of.

So what is this core knowledge?

One of the major agreements among environmental educators is that science may be the basis on which the core knowledge is built, but it is *more* than science. If that is true, then what is the environmental educator's perspective that is different from but builds on and adds to the knowledge gained by studying science and social science?

In the 1990s, several thoughtful groups of people spent a great deal of effort on this question. These included representatives of 10 Minnesota universities involved in the Environmental Education Teacher Preparation Project; representatives of 12 state departments of education in the Pew Charitable Trust's State Education and Environment Roundtable; and several committees working to define the Minnesota Environmental Systems graduation standard.

These three groups independently came to this definition:

> *The Earth is a set of interacting natural and social systems. An environmentally literate person must understand the relationship of the parts of a system and the interdependence of human and environmental systems.*[2] *The content of environmental education is the exploration of the relationships between social and natural systems.*[3]

This is the ***scope*** for environmental literacy, the vision of what students should have achieved at the end of their entire learning experience.

What is new about this core knowledge definition?

There are two important new elements in this definition: 1) the idea of the importance of learning how systems work, and 2) the recognition that the study of the interaction between natural and social systems is crucial to understanding what is happening in the world.

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[2] North American Association for Environmental Education (NAAEE). *Guidelines for Excellence in Environmental Education.* (Draft.)

[3] Lieberman, Gerald A. and Linda L. Hoody. 1997. *Putting the Pieces Together: Improving Student Learning with the Environment as an Integrating Context.* State Education and Environment Roundtable. Pew Charitable Trusts. Lieberman, Gerald A. and Linda L. Hoody. 1998. Closing the Achievement Gap. Using the Environment as an Integrating Context for Learning. State Education and Environment Roundtable. Pew Charitable Trusts. Science Wizards, Poway, CA.

Why systems?

Traditional environmental education accepted as a basic concept that everything was connected. This was the underlying idea behind most environmental education efforts. However, we never really examined that whole idea in terms of what it meant, exactly, and how it should be taught clearly and understandably. The concept of system allows us to explore what that interconnectedness is and how it works.

A system is a collection of interrelated parts consisting of objects, materials, phenomena, processes, ideas, principles, rules, organizations or people that interact to form a distinguishable whole. It consists of parts that work together in ways that cannot be understood only by studying the parts alone. Systems are characterized by what arises from the interactions of the parts; and these interactions are often as much a part of the study as the parts themselves.[4]

Using this systems school of thought, the Minnesota Scope and Sequence Development Team created the *Environmental Literacy Scope and Sequence*. The team was made up of experienced practicing environmental education professionals and representatives of preK through adult education, state agencies, higher education, and environmental learning centers. Because the Scope and Sequence is based on both state and national standards, it enables environmental education deliverers to build, adapt or integrate curriculum and assessments that are most appropriate for their particular grade level or audience. The *Environmental Literacy Scope and Sequence* is designed to help create opportunities for mainstreaming environmental education in a way that has not been possible before.

System is an idea that helps us think about parts and wholes. It draws attention to the interactions of the parts of something with one another and the relation of the parts to the whole. The idea also emphasizes effects—what influences the behavior of something and what, in turn, that thing accomplished.

—AAAS

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

Environmental Literacy Scope and Sequence

According to the environmental education goals and plan outlined by the Minnesota Legislature (Minn. Stat. §115A.073), "pupils and citizens should be able to apply informed decision-making processes to maintain a sustainable lifestyle. In order to do so, citizens should:

1. understand ecological systems;
2. understand the cause and effect relationship between human attitudes and behavior and the environment;
3. be able to evaluate alternative responses to environmental issues before deciding on alternative courses of action; and
4. understand the effects of multiple uses of the environment."

Surveys in the 1990s indicate that while teachers are improving their knowledge of environmental education content and methodology and their confidence in using these, they are still far from feeling comfortable integrating environmental education into the curriculum. The problem, however, was that there was no standards-based model of environmental literacy that described and ordered the sequence of knowledge and skills people must acquire to be environmentally literate. The *Environmental Literacy Scope and Sequence* can serve as an approach to focus the efforts of teachers and deliverers of environmental education to unify their many independent efforts.

The Scope and Sequence makes it possible for all its deliverers, no matter how diverse, to maximize their ability to contribute to student achievement in environmental education. In addition, a curriculum based on the Scope and Sequence is able to:

- Build on what the grade level or audience has learned before.
- Contribute to what that audience will learn later.
- Enable teachers and other environmental education deliverers to create coordinated programs that allow students to have a seamless learning experience as they:
    - Move up the grade levels.
    - Participate in out-of-classroom programs conducted in the community or at day visit and residential sites.
    - Apply more precise assessments.
    - Progress through an articulated series of developmentally appropriate concepts and skills that lead, measurably, to their becoming environmentally literate and enabled citizens.

Scope: *The vision of what the students should have achieved at the end of their entire school experience.*

Sequence: *A series of age-appropriate achievements that students succeed at during their school experience in order to master the Scope.*

The *Environmental Literacy Scope and Sequence* consists of:

1. Environmental Literacy Benchmarks

The Benchmarks help define the scope of knowledge students need to understand in order to become environmentally literate. These benchmarks are sequenced so that new knowledge is constructed on prior knowledge. Successful environmental education programs will build upon these benchmarks, utilizing the social and natural systems identified in their communities.

2. Key Systems Concepts and Supporting Concepts

Key Systems Concepts and Supporting Concepts of natural and social systems. The five Key Systems concepts, which assist in understanding the application of each Benchmark to environmental lessons are to be used as a guide to formulate questions about the social and natural systems being examined. The Supporting Concepts provide further detail and clarification for the Key Systems Concepts.

These two pieces together provide the framework for developing successful environmental education in working towards environmentally literate individuals and societies.

Key Systems Concepts

- *parts and objects*
- *interactions and relationships*
- *subsystems*
- *inputs and outputs*
- *change over time*

Environmental Literacy Benchmarks

The Environmental Literacy Benchmarks define the scope of knowledge students should understand, at the end of each level, in order to become environmentally literate. These Benchmarks are sequenced so that new knowledge is constructed on prior knowledge. Successful EE programs will build upon these Benchmarks, using them to organize instruction and learning experiences for preK to adult audiences.

Grades preK - 2

- Social systems and natural systems are made of parts.
- Social systems and natural systems may not continue to function if some of their parts are missing.
- When the parts of social systems and natural systems are put together, they can do things they couldn't do by themselves.

Grades 3 - 5

- In social and natural systems that consist of many parts, the parts usually influence one another.
- Social and natural systems may not function as well if parts are missing, damaged, mismatched or misconnected.

Grades 6 - 8

- Social and natural systems can include processes as well as things.
- The output from a social or natural system can become the input to other parts of social and natural systems.
- Social and natural systems are connected to each other and to other larger or smaller systems.

Grades 9 – 12 (adult)

- The interaction of social and natural systems can create properties that are different from either individual system.
- Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs.
- Feedback of output from some parts of a managed social or natural system can be used to bring it closer to desired results.
- It is not always possible to predict accurately the result of changing some part or connection between social and natural systems

Key Systems Concepts and Supporting Concepts

Achieving the Benchmarks will require that students, be they age four or forty, understand the five Key Systems Concepts and their Supporting Concepts. These Key Systems Concepts, *parts and objects, interactions and relationships, subsystems, inputs and outputs, and change over time*, derived from the Environmental Literacy Benchmarks, are to be used as a guide to formulate questions about the social and natural systems being examined. The Supporting Concepts help clarify the application of each Benchmark to environmental lessons examining the interaction between social and natural systems.

Parts and objects	Interactions and relationships	Subsystems	Inputs and outputs	Change over time
Abiotic factors	Cause and effect	Biome	Artifact	Accumulation
Biotic factors	Change and constancy	Boundary	Communication	Climate
Group	Chaos	Communication	Energy and energy flow	Cycles
Ideas and concepts	Communication	Community	Innovation and invention	Diversity
Individual	Cycles	Economics	Instruction	Evolution
Member	Ecosystem	Ecosystem	Products	Extinction
Properties	Feedback	Family and kinship	Resources	Geomorphism
Similarities and differences	Formal and nonformal	Habitat	Technology	Ideas and concepts
	Function	Language	Waste	Innovation and invention
	Ideal and real	Niche		Knowledge
	Migration	Politics		Migration
	Patterns	Religion		Mutation
	Predation	Scale		Population
	Population	Stratification		Probability
	Probability			Rate
	Reciprocity			Redundancy
	Structure			Scale
	Synergy			Species
	Trophic level			Threshold

Concepts in natural and social systems

The following table highlights the five Key Systems Concepts and their Supporting Concepts, based upon whether they are commonly used with social systems and/or natural systems.

Concepts most commonly used with natural systems	Concepts shared by both natural and social systems	Concepts most commonly used with social systems
Parts and objects		
	abiotic factors, biotic factors, individuals properties, similarities & differences	group ideas and concepts, member
Interactions and relationships		
trophic level	cause and effect, change and constancy chaos, communication, cycles, ecosystem, feedback function, migration, patterns, predation population, probability, reciprocity, structure, synergy	ideal and real formal and nonformal
Subsystems		
biome, ecosystem habitat, niche	boundary, communication community, population, scale	economics, family and kinship language, religion, stratification politics
Inputs and outputs		
	communication, energy and energy flow products, resources, waste	artifact, innovation/invention instruction, technology
Change over time		
	accumulation, climate, cycles, diversity, evolution, extinction geomorphism, migration, mutation, population probability, rate, scale, species, threshold	ideas and concepts knowledge, innovation/invention

Environmental Literacy Benchmarks and Concepts by grade level

Arranged by grade level, these tables highlight the Key Systems Concepts and Supporting Concepts that underlie the appropriate Benchmarks, by providing real world examples of social and natural systems and their interactions. These examples are provided for reference and are meant to provide more insight into possible areas of research for students.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Examples of natural and social systems and their interactions
Grades preK – 2 **Social systems and natural systems are made of parts.** **Social systems and natural systems may not continue to function if some of their parts are missing.** **When the parts of social systems and natural systems are put together, they can do things they couldn't do by themselves.**	**Parts and objects** individuals, groups, ideas and concepts, biotic factors, abiotic factors, similarities and differences, properties **Interactions and relationships** structure, function **(See individual concept sheets.)**	**Single system examples** • If bees were removed from an ecosystem, all the flowering plants that depend on them for pollination (the bees' **function** within this system) are affected. • Objects in natural systems have observable **properties**, e.g. size, weight, color, shape or existence in different states. • **Similarities and differences** of the properties of the parts of natural systems form the basis of the taxonomic system of classification used to characterize species and their relationships to other groups of organisms. • Family is a social system that we are all aware of. For younger students, identifying the members of the family, and the roles they play help them to see **similarities and differences** in a personal way. **Interactions** • **Individual** humans make decisions that are often very dependent on the social systems of which they are a part, like family. These decisions affect other **individuals** in the system. • **Groups** utilize the environment for air, water, food, energy, space and a place to put their wastes. • Humans can make changes in the **biotic factors** influencing a garden, influencing the plants that grow there. • Fishermen use their knowledge of light, temperature and oxygen preferences (**abiotic factors**) of fish to locate them for angling.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Examples of natural and social systems and their interactions
Grades 3 – 5 **In social and natural systems that consist of many parts, the parts usually influence one another.** **Social and natural systems may not function as well if parts are missing, damaged, mismatched or misconnected.**	**Parts and objects** similarities and differences **Interactions and relationships** structure, function, patterns, trophic level, cycles, change and constancy, migration, predation, feedback, communication **(See individual concept sheets.)**	**Single system examples** • The **structure** of an ecosystem is based on its interacting biotic and abiotic parts. Producer, consumer, and decomposer are dependent upon green plants that, in turn, are dependent upon certain abiotic factors. Changes in an ecosystem's structure influences its other parts. • Wildlife species will **migrate,** adapt or die if their existing habitat no longer meets their survival needs. • Humans **migrate** in response to population pressure, e.g. settlement of the New World and the Irish response to the potato famine. Humans **migrate** in response to cultural pressures such as war or persecution. Humans **migrate** in the desire to better their lives or obtain advantages for themselves and their children. • Bats vocalize ultrasonic sound waves that bounce off objects and return to the bats' ears. This **feedback** is used by bats to locate food and navigate in their environment. • Social structure is any reoccurring **pattern** of social behavior. Individuals create and participate in a variety of social structures such as family, education, government, and religion. **Interactions** • **Cycles** in natural systems affect the activities of social systems. The seasons are **cycles**. During winter, shipping on Lake Superior stops until the ice breaks up in the spring • People can **change** the composition of plants and animals in an area by changing the biotic or abiotic factors (e.g. overgrazing, building dams, irrigation • **Communication** occurs between people and natural systems. Animals, plants, and the overall environment cannot **communicate** the way humans do, so people have to pay close attention in order to discover what the natural systems need. By monitoring the types of aquatic insects in a stream, a biologist learns about water quality. Some species will be absent in polluted water.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Examples of natural and social systems and their interactions
Grades 6 – 8 **Social and natural systems can include processes as well as things.** **The output from a social or natural system can become the input to other parts of social and natural systems.** **Social and natural systems are connected to each other and to other larger or smaller systems.**	**Interactions and relationships** population, structure, function, change & constancy, cycles, ideal and real, formal and nonformal, trophic level, feedback, reciprocity, predation, migration, communication **Subsystems** habitat, biome**,** boundary, scale, family and kinship, stratification, politics, economic, religion, language, niche, communities **Inputs and outputs** artifact, waste, technology, instruction **Change over time** diversity, rate, ideas and concepts, geomorphism, accumulation, threshold, mutation, evolution, extinction, knowledge, innovation and invention, species (group) **(See individual concept sheets.)**	• **Artifacts** produced by societies can have profound effects on both social and natural systems. The invention of agriculture and agricultural tools enabled human populations to spread over a wide territory, to live in stable, permanent communities and to produce enough surplus to support a more complex way of life, including cities. At the same time, it allowed humans to change the landscape in major ways, turning natural ecosystems into human-managed systems. Some **waste artifacts** created by social systems can disrupt the normal function of natural systems, i.e. chlorofluorocarbon **waste** from refrigeration and air conditioners get into the atmosphere and reduce the amount of ozone that protects us from ultraviolet radiation. • **Changes** in natural system **boundaries** can affect social systems. If the earth's atmosphere is indeed warming, climatological **boundaries** to snowfall will have a major effect on the recreational **patterns** of people in Minnesota, and therefore on the economy in the areas of the state dependent on heavy snowfall to bring in tourists such as snowmobilers and skiers. • The consumption lifestyle of a **population** is important to understand. How much food and water does one person need vs. how much water does one person use? Can the earth provide for all of us if the **population** keeps growing? If it cannot, who will be provided for and who will not? • Social systems are influenced by the **biomes** in which they are located. **Biomes** influence the economic systems of the humans that inhabit them; people who live near forests are often part of the wood industries; people who live in the Red River Valley of Minnesota are agricultural, growing sugar beets, wheat and sunflowers—crops that can thrive in a dryer prairie area. • Sportsmen's groups (**informal**) lobbied their legislators (law making **formal**) to have a national tax on the sale of sporting goods (Pittman Robertson Act) to generate money for fish and wildlife habitat management that would supplement federal budget allocations for this purpose. • Urban sprawl, energy production and agriculture needed to produce food and fiber required by human **communities** have impacts on natural systems. All of the aforementioned require space and reduce the capacity of an area to support the plants and animals that occupied the former **habitat**.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Examples of natural and social systems and their interactions
Grades **9 – 12 (adult)** **The interaction of social and natural systems can create properties that are different from either individual system.** **Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs.** **Feedback of output from some parts of a managed social or natural system can be used to bring it closer to desired results.** **It is not always possible to predict accurately the result of changing some part or connection between social and natural systems.**	**Parts and objects (all)** individual, biotic factors, abiotic factors, similarities and differences, properties, member, ideas and concepts, group **Interaction and relationships (all)** trophic level, structure, function, ideal and real, change and constancy, patterns, cycles, feedback, migration, predation, population, reciprocity, communication, synergy, cause and effect, probability, chaos, ecosystem, formal and nonformal **Subsystems (all)** habitat, biome, ecosystem, boundary, scale, community, politics, population, religion, language, family and kinship, stratifcation, economics, niche, communication **Inputs and outputs (all)** energy and energy flow, resources, products, communication, technology, waste, innovation/invention, artifact, instruction **Change over time (all)** climate, geomorphism, probability, diversity, species, evolution, cycles, scale, rate, accumulation, threshold, migration, population, mutation, extinction, ideas and concepts, knowledge, innovation/invention **(See individual concept sheets.)**	• Sparrows and starlings were introduced to this country as biological control agents as people in Europe had observed that they were competitors. However, they expanded into new habitats in America, displacing native species through competition for food, shelter, and places to raise their young. In the example above, the social system predicted how the natural system would **probably** respond, but other variables in the natural system were not thoroughly understood. • Natural systems are affected by the demands of social systems for **energy**. Electrical generating plants often use water from rivers or lakes to cool equipment. The waste heat from the plant is transferred to the water that is returned to the aquatic ecosystem from which it was drawn. Under some conditions, the increase in temperature of the water in the natural ecosystem can have a negative effect on the organisms living there. • The actions of a social system can result in creating **chaos** in natural systems, other social systems, and its own social system. The practice of cities dumping raw sewage into river systems reduced the dissolved oxygen content of the water below four parts per million. This threw the aquatic system into chaos, killing all species that could not survive at that level of oxygen. • Conservation groups use the knowledge about the **synergistic** relationship between bacteria and ruminants and introduce deer herds to certain foods prior to starvation periods in winter. This helps guarantee that adequate populations of bacteria are present in the deer's stomachs when their normal diet needs to be supplemented. • Conservation is a major enterprise in Minnesota. Multiple agencies have been created and citizen groups have been formed that have overlapping (**redundant**) or shared environmental concerns. Reduction of the activities of some agencies working on soil conservation does not mean that soil conservation efforts will end. • Synthetic chemicals invented by social technologies are not always recyclable by natural processes nor in a timely fashion. Many of these compounds (**products**) are harmful to the environment and people.

Teaching the Key Systems Concepts from the tables above can be summarized as follows:

In grades preK-5

Students should be introduced to examples of natural and social systems, and learn to identify the different *parts and objects* of these systems. Discussion of how one part affects another encourages students to explore *interactions and relationships* between the parts of a natural or social system. Experiences should include a variety of systems, and involve questions on how well a system works or doesn't work, when parts are missing or broken. The focus in the elementary grades should be on **single** systems and their parts and relationships.

In grades 6-12 (adult)

Students should begin to look at *interactions and relationships* between **multiple** systems. In their study of natural and social systems, students should begin manipulating and observing systems to identify *subsystems*, the relationship of *inputs and outputs* to systems function, and learn to recognize how systems *change over time*. Observing how an aquarium or garden changes over time, and how it is affected by changing its parts or inputs, is one such example. In the higher grades, students should be able to apply systems thinking to many diverse interactions between natural and social systems.

Concept reference pages

This section provides an easy-to-use reference for each of the 64 Concepts involved in a systems-based approach to environmental lessons and environmental issues. Concepts are listed in alphabetical order.

Individual Concept reference pages include:

- a definition of the Concept
- a statement of student understanding of the Concept
- a brief discussion of the basic ideas of the Concept

In addition, the Concept's application to natural systems and social systems is described and examples are provided of the interaction between natural and social systems.

Concepts and their applications to natural and social systems

Concept **Abiotic factors**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition Nonliving factors in the environment. **Statement** Students demonstrate understanding that abiotic factors in the environment are interrelated, and they are also related to plants and animals. **Discussion** Abiotic factors may be: • Substances - minerals, water, carbon dioxide, soil • Forces - wind, gravity • Conditions - temperature, light These factors may be studied or measured individually, but they must always be considered in terms of their interacting effects upon organisms and each other. In any given habitat, these factors constitute a system of conditions that act on organisms and influence their potential survival. Orientation of a slope relative to the sun can create quite different relationships of temperature, moisture, and amount of sunlight available to plants. This results in differing plant communities that may support very different populations of other organisms.	▪ North and south facing slopes on the same ridge will demonstrate different sets of abiotic factors when measured. ▪ Fish will migrate to locations where sunlight, oxygen, and temperature conditions are optimal for them. ▪ Many desert animals are active at night when temperature conditions are less severe. ▪ Some plant communities will die out when an essential mineral is depleted from the soil. ▪ Aquatic plants will grow only in depths of water that enough sunlight reaches to run photosynthesis. ▪ Many trees growing on mountains are shaped by the prevailing winds.	Abiotic factors are the nonliving components of ecosystems, such as air, water, and soil type. Living components of ecosystems (including humans) depend on these abiotic factors to survive. For example, animals (including humans) and plants living in a desert environment must become able to endure hot, dry weather, store moisture efficiently, take immediate advantage of any moisture that becomes available, and find, grow, or manufacture cooling systems. Humans create social systems that help them with these adaptations, e.g. economic systems that produce goods and services to help accomplish the above tasks.	Human systems influence abiotic factors, which then feed back to have effects on other human systems. For instance, the American ideological system based on the ideal of individual freedom has encouraged the use and proliferation of the automobile. The car affects abiotic factors such as air, land (land use), and water quality. In response, humans must devise systems that mitigate some of these effects, such as emission controls, international agreements, and land use planning. ▪ Farmers add fertilizers to the soil to replace substances that have become depleted by growing crops. ▪ Fishermen use their knowledge of light, temperature, and oxygen preferences of fish to locate them for angling. ▪ Aquatic biologists try to control excessive nutrients in lakes to reduce the frequency of problem algae blooms and excessive vegetation, which when they occur, decreases the ability of sunlight to reach deeper into the lake. ▪ Houses and landscape plantings are often oriented to maximize sunlight in the winter and provide shade in the summer.

Concepts and their applications to natural and social systems

Concept **Accumulation**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The act of amassing or gathering. **Statement** Students demonstrate understanding of the causes, processes, and results of the accumulation of manufactured chemicals and wastes in the environment. **Discussion** The introduction of chemicals into the environment can have serious effects on ecosystems because these chemicals can enter at a low, relatively unconcentrated rate at the bottom of the food chain then increase in concentration as they rise through the food chain.	Some substances can enter the food chain and become concentrated as they move up the food chain (trophic levels). Some substances accumulate in an area by the natural process of evaporation (salt flats, oceans). For example, if it takes 10 pounds of protein to make one pound of protein at the next trophic level in the food chain, a chemical in the lower trophic level becomes 10 times more concentrated at the next higher level. ▪ Bald eagles nearly disappeared after the widespread use of DDT as an insecticide in the late 1940s and 1950s. The insecticide entered the food chain because fish, mammals, and birds fed on insects that had ingested the pesticide. Fish, for example, eat many insects, so the amount of insecticide in those insects would become concentrated in the fish. Eagles eat many fish, so the concentrated DDT in the fish would become even more concentrated in the eagles. At those high levels, the DDT in the eagles' bodies interfered with egg production, so that the eggs laid had very thin shells that would crack before the eaglets were ready to hatch.	This term is not significantly useful to this discussion of social systems. It is not a term that is commonly used in the analysis of social systems.	Landfills not only take up open space (loss of habitat), but they can also release chemicals into the groundwater system. People create materials that do not readily break down by natural processes and therefore must be stored. Some human-made chemicals can weaken, kill, or cause mutations in organisms (herbicides, pesticides, and radioactive materials). Some of the chemicals that people create get into the atmosphere and can cause large-scale changes (greenhouse effect, hole in the ozone layer). For example, polychlorinated biphenyls (PCBs) are man-made chemicals that are often used as an insulator in electrical equipment. Before humans were aware of their effects, these chemicals were disposed of by burying in the ground or dumping in lakes and streams, where they entered the food chain through the organisms that live in the water and the ground. Now they are sometimes found in high concentrations in fish that live in the Great Lakes, as well as humans that live around the Great Lakes and eat the fish. In turn, those PCBs may be interfering with the fertility of humans and other Great Lakes animals.

Concepts and their applications to natural and social systems

Concept **Artifact**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A structure or substance not normally present, but produced by some external agency or action. b) An object produced or shaped by human workmanship; especially, a simple tool, weapon, or ornament of archaeological or historical interest. **Statement** Students demonstrate understanding that artifacts are products of social systems and can serve as evidence of human activity. **Discussion** Many artifacts are the products of human social systems, and can help build understandings of both past and present activity of social and natural systems. Tools, shelters, and ornaments provide clues about the environments and lifestyles of people living in different times, in different places, and under different conditions. We can gain a better understanding of different ideologies and lifestyles by looking at and analyzing what cultures and nations are currently producing/manufacturing. In addition, human-made artifacts (sometimes called technology) can have profound effects on natural systems.	Although this term is generally associated with social systems, some processes in natural systems do produce artifacts, i.e. structures or substances not normally produced by the interaction of abiotic factors in the environment: ▪ Termites build large mounds that are created with debris excavated from their tunneling beneath the earth. ▪ Fossilized dinosaur prints and bones are routinely found in our west central states. ▪ Fossilized tunnels created by burrowing organisms are found in marine sediments that have been uplifted above sea level. ▪ Birds' nests are constructs that are not formed by natural processes.	Human cultures all produce artifacts that are the products of their social systems. These can range from the tiniest ornamental bead to the largest skyscraper, from a wooden bow to an entire system of highways stretching across the country, from a printed book to the Internet system. Looking at what societies produce to work with, to live in, to work in, to get around in, and to wear, can tell us much about the underlying ideological and organizational systems. For instance, even though the United States and the Scandinavian countries are both part of the Western industrial world, people in the Scandinavian countries have many fewer cars and walk or use public transportation much more than Americans do. This may reflect less emphasis on the individual and individual freedom among other things.	Artifacts produced by societies can have profound effects on both social and natural systems. The invention of agriculture and agricultural tools enabled human populations to spread over a wide territory, to live in stable, permanent communities, and to produce enough surplus to support a more complex way of life, including cities. At the same time, it allowed humans to change the landscape in major ways, turning natural ecosystems into human-managed systems. The creation of products by a complex economic system such as plastics, chemicals, fertilizers, and pesticides that are distributed widely by a broad transportation/communication system has created additional challenges to the integrity of natural systems. In addition, it has caused additional human systems to be created to lessen the problems created by unintentional consequences. For instance, major industries are now built around cleaning up oil spills and disposing of hazardous wastes.

Concepts and their applications to natural and social systems

Concept **Biome**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition A major ecological region defined by the community of living organisms within it, e.g. deciduous forest, tallgrass prairie, and tundra. **Statement** Students demonstrate understanding that a biome is a climatically controlled area, which includes a number of different plant communities and that this condition in turn influences the food webs of the animals that live there. **Discussion** Conditions such as altitude, latitude, and moisture combine to control the types of plant communities that can become established in any given region. Scientists have determined that there are about 12 major world biomes based on the dominant plant species found in each.	Plants, or the scarcity of them, influence the kinds and numbers of herbivorous animals that can survive in an area. This influence is felt all the way up the food chain. For instance, the animals that can live in a grassland are different from those that thrive in a northern forest. Examples of biomes include: • alpine tundra • arid • arctic tundra • boreal forest • deciduous forest • desert • grassland • mixed forest • montane forest • tropical forest • tropical savanna • woodland and chaparral Plant communities in a biome are usually in various stages of succession, i.e. an orderly progression from one or more dominant plant species to other dominant species. The entire region is dominated by a typical climax type of plant but will also include a number of diverse climax types.	This term is not significantly useful to a discussion of social systems and is not a term that is commonly used in the analysis of social systems.	Social systems are influenced by the biomes in which they are located. Biomes influence the economic systems of the humans that inhabit them; people who live near forests are often part of the wood industries; people who live in the Red River Valley of Minnesota are agricultural, growing sugar beets, wheat and sunflowers – crops that can thrive in a dryer prairie area. People living in areas where agriculture is not feasible often have a nomadic way of life such as the tundra-dwelling cultures in Siberia. They hunt and herd reindeer, moving in summer and winter with their portable technology and shelters. Human social systems, in turn, influence the biomes in which people live. In areas experiencing overpopulation and other social stresses, people are stretching natural resources beyond their capability to produce and depleting forests and grasslands. When this happens, the relationship between the green plants and soil fertility as well as rainfall is disrupted, and the land can become infertile. Thus the biome is profoundly changed. In Florida, parts of the Everglades have been drained for housing developments and agriculture, causing a change in the amount of freshwater in that system.

Concepts and their applications to natural and social systems

Concept **Biotic factors**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition Living organisms (plants and animals) located in a community. **Statement** Students demonstrate understanding that plants and animals interact and can exert influence on the environment and each other. **Discussion** Associated organisms having mutual relationships to each other and/or to their environment are recognized as a community. Each then is a part of the environment of every other organism there.	The biotic factors in an ecosystem are the living organisms in that system. Examples of biotic factors in a pond community include all the floating plants (i.e. duckweed), underwater rooted plants (e.g. lily pads), the plants that grow along the edge and are partially submerged in the pond (e.g. cattails), and the plants that grow on the banks of the pond (e.g. jewel weed). Biotic factors also include the animals such as muskrats, beaver, ducks, loons, herons, and so forth. Dominant species compete with each other and with subordinate species whenever some requirement of the organisms is available in amounts insufficient to supply all demands adequately, i.e. wolves kill foxes and coyotes who compete for the prey species. Dissimilar organisms form intimate relationships for their mutual advantage (symbiosis, mycorhizas, nodules, pollination, and epiphytes). Other organisms contribute to the community by soil aeration (worms, moles), return of nutrients to the soil (legumes), and herbivore control (wolves, hawks, owls).	Human beings are one of the living components in the ecosystem(s) in which they exist, and as such affect and are affected by the other factors, both living and nonliving. For instance, a person living in a Minneapolis suburb breaths air, drinks water from a local source, and eats foods that are grown in soil and watered by rainfall or irrigation. The quality of the air, the water, and the food, whether from a local source or farther away, depends on all the factors that affect those sources. It has been traditional in cultures with Western European histories to see humans as outside of, or somehow above the ecosystems that surround them, and therefore able to control those systems. This cultural belief is not often met, even with very familiar systems such as forests, primarily because the systems are often so highly complex that humans do not yet know or understand the effects of all of the variables.	Human settlement patterns and economic systems such as agriculture create major changes in the plants that exist in an area, and therefore create major changes in the other biotic factors that can exist in a given area. Animals that used to live in and on the prairie plants in central United States such as bison, antelope, a host of prairie birds and smaller mammals and reptiles, have been replaced by human settlements and farms. As the plants changed, so did many of the animals and birds. Mammals such as coyotes, deer and fox were largely replaced by introduced animals such as cattle, swine, sheep and turkeys. Human settlement patterns around lakes in central Minnesota often eliminate the plants around the edges of the lakes, so that the lakes lose their ability to support the food chain, including fish that eat both plants and smaller animals. Social ideologies or belief systems that find value in wildlife have led to the creation of organizations that actively work to maintain individual biotic factors (such as eagles, manatees, deer, wolves, walleye, etc.) or whole ecosystems (such as the work of the Land Trust and the Nature Conservancy).

Concepts and their applications to natural and social systems

Concept **Boundary**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition Something that indicates a border or limit. It is the area beyond which different conditions exist. **Statement** Students demonstrate understanding of the use of the concept of boundary to study both natural and social systems. **Discussion** Defining boundaries is one way to build understandings of social and natural systems. Boundaries that are seen and used to describe both nature and culture are a product of culture. A traditional Navaho, a Siberian reindeer herder, a Spanish merchant, and a Western European scientist will not see or use the same boundaries to deal with both natural and social systems. Boundaries, both social and natural, can seem to be quite sharp or quite gradual, going through a series of transitional stages from one state to another. They can also be selective in what comes through them. The concept of boundaries is one that people of Western European tradition use to separate the world we experience through our senses into categories or segments we can understand and work with.	The boundaries one chooses to use depend on the subject at hand. For instance, it is possible to speak of the earth and its atmosphere as one system with many subsystems. Or, if one is studying one of those subsystems, like a watershed or a prairie area, the investigator will speak of the watershed system or the prairie system as the entity for study. The boundaries to the watershed system or the prairie or any other natural system are the factors that are responsible for change, e.g. moisture, light, altitude, temperature. They, in turn, create the conditions that form the 12 major plant communities, with their particular animal components, that are found throughout the world. These systems are not often separated by sharp boundaries although they can be (tall cliffs bordering a watercourse). Most of the time, the edges of natural systems are diffuse, and may form their own systems, such as the oak savanna that occurs between the dense forested areas in Minnesota and the prairies. The oak savanna, made up of scattered trees with an understory of grasses, has some characteristics of both the prairie and the forests, but it is different from either and can provide habitat for some animals that can live in either, and some that can only live in the oak savanna. Therefore the animal component is both different and the same as the surrounding systems. Where each system begins and ends depends on the characteristics one chooses as important.	Cultures create boundaries to make sense out of the world so that individuals know what to expect and what is expected of them. They may define states, nations, latitude or longitude, parcels of land, or a hunting gathering territory. The term boundary may also be used to describe the sphere of influence of a social system, the extent of impact created by some social action, or the degree of tolerance a society expresses toward some social activity. Social systems take the boundaries they have created very seriously. ▪ Status and socioeconomic standing can determine who is most likely to marry whom. ▪ A nation controls who comes into the country and what they are allowed to bring through customs. ▪ The Roman Empire had a considerable geographic sphere of influence before its fall. ▪ Three-time criminal offenders receive much harsher treatment at the hands of the legal system than first-time offenders do. ▪ The number of wives a man can have is rigorously regulated in our country.	People acting for social objectives can create changes in natural systems; for instance building highways through wetlands to enhance transportation can create barriers that change the natural vegetation and water movement. Acting to improve our human economic well-being and quality of life, American culture has often ignored or misunderstood the natural systems. Now, recognizing the effects of those misunderstandings, legal, political and social limits are being set on what people can or cannot do in order to bring back the viability of the natural systems. Changes in natural system boundaries can affect social systems. If the earth's atmosphere is indeed warming, climatological boundaries to snowfall will have a major effect on the recreational patterns of people in Minnesota, and therefore on the economy in the areas of the state dependent on heavy snowfall to bring in tourists such as snowmobilers and skiers.

Concepts and their applications to natural and social systems

Concept **Cause and effect**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Cause:** a) That which produces an effect, result, or consequence; the person, event, or condition responsible for an action or result. b) A basis for an action or decision; grounds; reason; motive. **Effect:** a) Something brought about by a cause or agent; result. b) Way in which something acts upon or influences an object. **Statement** Students demonstrate understanding that inputs to social and natural systems can produce effects and that these effects are not always predictable. **Discussion** A system comprised of interacting parts generally produces predictable effects that have evolved over time. Inputs to these systems that contribute to these effects have coevolved with the system. New inputs that were not part of that co-evolution can change a system's interactions and also produce outputs that are different from the system's previous outputs. These changes may not be beneficial to the system.	Natural systems take time for the interacting parts to coevolve. New inputs of materials, forces, energy, or species affect ecosystems by changing the interactions among its interacting parts. ▪ The uplifting of the Colorado Plateau lifted parts of Utah several thousands of feet. This increased the run-off gradient of surface water to the sea, adding new strength to formerly sluggish streams. These streams carved most of Utah's national parks, changing the ecosystem in the process. ▪ Lightening strikes can cause vast fires that cause changes in the types of plants and animals that repopulate these areas. ▪ The appearance of a new predator species, i.e. sea lamprey in Lake Superior, changes interactions within the ecosystem, sometimes with devastating effects.	Education is structured in a way that causes students to learn. Parents develop chores for children, hoping they will cause them to be responsible. Practicing a sport, game, or a musical instrument should cause better performance. An effect is something that is produced by a cause. Learning is an effect of studying books, asking questions, and having experiences. Virtually everything societies do have some type of effect. One cause can have many effects. Not studying can have the effect of flunking a test. If this happens too often, the student may eventually drop out of school. This would have the effect of the student not being eligible for college.	In the past, environmental degradation caused by people has been largely unintended. Currently, we are aware of many of the effects of our choices, however we continue to make choices that degrade the environment. For instance, cars give people individual freedom and easy, affordable transportation but cars are a major cause of air and water pollution. Social systems have had a variety of effects on the natural systems. For example, people have cats as pets. If cats are allowed outside and not monitored, they can decrease the bird population quickly. Also, if cats are not neutered, they can reproduce quickly, having more detrimental effects on the various bird populations and overall wildlife.

Concepts and their applications to natural and social systems

Concept **Change & constancy**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Change:** To be different, alter or to give a completely different form or appearance. **Constancy:** An unchanging quality or state. **Statement** Students demonstrate understanding of the causes, processes, and results of change in environmental factors and plant and animal populations. **Discussion** It has been said that the only constant is change. The earth and its ecosystems are in a constant state of change. This can occur over very long periods of time or over a relatively short term. The introduction of chemicals or organisms into ecosystems that have evolved over long periods of time can cause irreversible changes that result in new environmental conditions, new plants and animals, or extinctions.	Communities of plants and animals can naturally appear in an orderly sequence in a particular area over a period of time (succession). A change in abiotic factors (e.g. climate, water) can change the composition of plants and animals that appear. Any succession under similar conditions of climate and abiotic factors will usually be comprised of the same series of communities in the same sequence. Succession communities can end in a plant and animal community that is self-renewing and self-sustaining if conditions in the area remain the same (climax). Invasion of new species can change the sequence of plant and animal communities in an area. Geologic and ocean current changes can cause climate changes that affect habitats.	Human social systems provide a set of understandings that make sense of our world and prescribe behavior that allows humans to function in their surroundings. Many mechanisms within these systems (e.g. inputs, outputs, and feedback loops) help keep the system stable enough to do these tasks. Without this programmed stability, systems would change erratically and frequently. Our surroundings, including other people and other people's cultures, however, do change all the time. Therefore, the systems also need some built-in ways of coping with change without totally destroying the original system. If the changes come slowly enough, the systems will change as little as necessary to preserve the greater part of the system. If the outside change is too rapid, the system may not be able to cope and may break down. The tension between change and stability is ongoing. This tension is clear, for instance, in the role of women in American society. The numerous articles that appear every year analyzing the conflicts and consequences of women who are trying to fulfill multiple demands of careers, (new role), home and children, (old roles), are a symptom of the changes that have been working themselves out since post-World War II. These changes in women's roles are all connected to other social system change, such as the evolving nature of the economy and the workplace.	People can restart the succession of plants and animals in a particular area by harvesting the dominant plant species. People can change the composition of plants and animals in an area by changing the biotic or abiotic factors (overgrazing, building dams, irrigation). People can cause changes in the environment by adding materials from their cultural activities. New ideas/technologies adopted by a culture can change the habitat from what it used to be into something different (agriculture).

Concepts and their applications to natural and social systems

Concept **Change over time**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The many processes by which things become different than they were before. **Statement** Students understand the causes, processes, and results of changes to biotic, abiotic, and behavioral factors **Discussion** Change is happening all the time in the universe to geologic, atmospheric, plant and animal (including human) structure, and animal (including human) behavior. These changes range from enormous to minute (scale), and from instantaneous to incredibly slow (rate). These changes interact with each other on many levels to produce further changes.	An example of a large, instantaneous change would be the effects of a large meteor hitting the earth. This has happened a few times in the past, causing the sudden extinction of much of the life on earth, allowing the surviving forms to flourish (e.g. the final extinction of the dinosaurs and the rise of the mammals. Examples of slow, small changes would be those that often happen in natural selection. As environment changes (such as when the glaciers receded at the end of the last ice age) those plants and animals with the genetic capabilities to withstand warmer temperatures became more numerous, while those better adapted to colder climates died out. The rise of the mammals after the extinction of the dinosaurs is an example of the interaction of a large sudden change with the process of natural selection (the process by which the mammals slowly changed over time to fill the niches previously occupied by the dinosaurs).	Social systems change in many ways and in response to many different environmental changes. Cultures borrow from each other, a conquering culture forces the defeated one to change; a conquering culture may find itself changing in order to rule the people they have defeated (e.g. the Mongols who ruled China eventually became more Chinese than Mongol); one subgroup within a society puts pressure on other subgroups to behave differently, (social movements such as the women's movement, the environmental movement, and the black power movement of two decades ago); a new invention allows new behaviors that were not possible before, (the industrial revolution, for instance); and people try to maintain a culture within another by changing only enough to live in the new culture (e.g. the Amish, Hmong, Hispanic, and Native American cultures.) In attempting to remain the same, these cultures are nonetheless changed.	Humans can create environmental changes, and respond both physically and socially to environmental changes. For instance, the automobile is the product of human social systems, including belief systems, and economic systems. The automobile produces emissions which can change the percentage of gases in the atmosphere. Humans respond physically with increased incidence of respiratory difficulties where emissions are concentrated. Over time, by means of natural selection, this might cause people who live in urban areas to develop an ability to tolerate these emissions, as those who have respiratory difficulties become debilitated and fail to produce as many offspring as those whose genes allow them to tolerate the gases better. The response of social systems to these environmental changes can include, among many possibilities, developing new technology that produces fewer emissions, providing medical and emotional care for those affected, and organizing groups to influence the makers of autos to produce emission-free cars.

Concepts and their applications to natural and social systems

Concept **Chaos**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Any condition or place of total disorder or confusion. b) The disordered state of unformed matter and infinite space supposed to have existed prior to the ordered universe. **Statement** Students demonstrate understanding that a state or condition of disorder in a system may represent chaos caused by the loss of one of its parts or a new input to the system that is disruptive. **Discussion** Systems can be characterized as having orderly interactions among their parts, some of which are processes. Disorder among these parts can be caused by damaging or deleting a part. Inputs to a system that have this effect bring disorder (chaos) to the system.	Earth's atmosphere appears chaotic. It is a very complex system of whirlpools and streams of air moving in response to many abiotic inputs. Its parts consist of water vapor, gases, particulate matter, electrical charges, and clouds. Scientists are employing chaos theory in an attempt to better understand how this very complex system functions. ▪ A hypothetical viral infection that destroyed all grasses, including corn, wheat, oats, etc., would destroy the base of Earth's terrestrial food web and throw the world's ecosystems into total disorder. ▪ Photosynthetic plankton in the oceans produce most of the oxygen on Earth. They are also a major part of the base of the marine food web. Any factor that would reduce the amount of sunlight that reaches the Earth, i.e. debris in the atmosphere from a meteor impact, would create chaos in the marine food web, drastically reduce the amount of oxygen in the atmosphere, and ultimately create chaos in terrestrial food webs. A drastic change in the acidity of the oceans would create the same effects.	One of the major functions of social systems is to make order of the world in which individuals live so they know how to react to situations and what to expect from other people. If everything an individual did brought a chaotic (unexpected and unpredictable) result from others, then there would be no way of deciding how to act in order to live with others. ▪ If you say hello to an individual, and that person responds one day by saying hello in return, the next day hits you, the third day walks by without looking at you, and the fourth day runs up and hugs you, you have no idea how to interact with that person, or even if you should. Social systems form patterns of interaction between people that are generally predictable within a range of behaviors. This enables individuals to make order of an otherwise chaotic world and live within it. One way of studying unfamiliar social systems that may look chaotic is to watch the interactions of others, to try to discern the patterns in the interactions. The test of our analysis is to try to predict how individuals will interact with each other in future encounters.	The actions of a social system can create chaos in natural systems, other social systems, and its own social system. ▪ Slaughter of the buffalo herds by American settlers brought chaos to the Plains Indian tribes who had built a whole lifestyle based on the buffalo as a food staple. They were unable to feed themselves through the winter, and the buffalo was reduced to near extinction. ▪ Placing the American Indians on reservations, restricting their hunting, and eliminating intertribal conflict brought chaos to a culture whose rights of passage to adulthood were based on a person's accomplishments in these activities. ▪ The practice of cities dumping raw sewage into river systems reduced the dissolved oxygen content of the water below four parts per million, which threw the aquatic system into chaos, killing all species that could not survive at that level of oxygen. ▪ Poor sanitation and overcrowding during the Middle Ages allowed for the spread of the Black Plague, which was carried by fleas living on rats. The death toll was enormous, disposal of the large number of dead became a problem, and the normal function of cities was thrown into chaos.

Concepts and their applications to natural and social systems

Concept **Climate**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The meteorological conditions, including temperature, precipitation, and wind that characteristically prevail in a particular region. b) Prevailing condition in human affairs. **Statement** Students demonstrate understanding of the physical and geographical conditions that produce varieties of climate. **Discussion** The existing climatic conditions on earth are created by latitude, altitude, mountain ranges, ocean currents, and availability of water in the form of precipitation. Earth's geologic record shows that major climate changes have occurred, some of which were caused by continental drift and changes in ocean currents.	Climatic conditions exert influence on wildlife. ▪ Mammals in arctic climates tend to have smaller ears and a reduced ratio of surface to body volume to conserve heat. ▪ The tropical elephant has large ears that it waves in the air to carry away excess body heat. ▪ Some species of animals are capable of burrowing into the mud as their ponds dry up and "sleep" through the dry season. (estivation) ▪ Many birds and some butterflies migrate to warmer climates to escape winter weather.	This term is not significantly useful to a discussion of social systems and is not a term that is commonly used in the analysis of social systems.	Human societies are affected by climate, and this is reflected in their lifestyles, agricultural practices, and sometimes their behavior. The growing season in Russia is so short that they often cannot get a wheat crop. Without international trade to import wheat, this has resulted in widespread famine. Persons living in tropical ecosystems develop housing that is far different from Minnesota housing. Behaviorally, they have adopted the custom of taking a siesta (nap) during the hottest part of the day, resuming their daily activities in the cooler hours of the evening. Societies living in the North American tundra have little or no access to wood. Much of their art therefore is found on ivory tusks and bone.

Concepts and their applications to natural and social systems

Concept **Communication**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A system for sending and receiving information. b) To make known; impart; have an interchange. **Statement** Students demonstrate understanding that communication is a systematic way that an individual or group exchanges information with another individual or group and this communication can assume many forms. **Discussion** Communication among organisms is an important survival adaptation. It imparts the ability to convey information among and within species. It can be used to protect the young, avoid conflict, share food sources, find mates, and coordinate activities. This communication can be auditory, chemical, or visual in form.	Communication in natural systems assumes many forms. It usually enhances the survival of the parts within an ecosystem. ▪ Some plants secrete chemicals that attract species that help them transfer their pollen to other plants, i.e. skunk cabbage and certain species of flies. ▪ Whales communicate over vast distances in the ocean by generating ultra-low frequency sound waves. ▪ Wolves use posturing to demonstrate their dominance in the pack hierarchy. ▪ Fireflies use luminescent abdomens to attract and locate mates. ▪ To avoid predators, the viceroy butterfly uses wing patterns to mimic the monarch butterfly, which is a bad-tasting species. ▪ Honey bees are famous for their figure-eight dance that relays information to other members of the hive about where and how far away a food source is located.	Communication is exchanging thoughts and/or information. It is the transfer of messages from one person to another. It is easier in small groups than in larger groups. It is done verbally, or by gestures with one's body, i.e. hands, face. ▪ Lack of communication and/or miscommunication can cause conflict among and within groups. For instance, some religious groups hate other religious groups and do not communicate. This lack of communication has led to war. ▪ Another example involves a family. If a parent tells a child to take out the garbage or do the dishes but does not set a deadline, the child may believe they can complete the chore at their leisure. Later the parent may become angry with the child because the chore is not done. The child may respond with anger and confusion because they were not told when they had to complete the chore.	Communication occurs between people and natural systems. Animals, plants, and the overall environment cannot communicate the way humans do, so people have to pay close attention in order to discover what the natural systems need. ▪ For example, by monitoring bird populations, people can determine if a habitat is healthy or needs help. ▪ By monitoring the types of aquatic insects in a stream, a biologist learns about water quality. Some species will be absent in polluted water.

Concepts and their applications to natural and social systems

Concept **Community**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A group of plants and animals living in a specific region under relatively similar conditions. b) A group of people living in the same locality and under the same government. **Statement** Students demonstrate understanding that plants and animals living in any natural area form an assemblage each finds environmentally tolerable and which provides at least minimal basic needs for the organism to survive and reproduce. **Discussion** In a community, the presence of many of the organisms is necessary for the continued life of other members of the group. Mutual tolerance and beneficial interaction bring about a degree of integration within the group.	In its most limited sense, a community may be represented by two species living together or in close proximity to one another. Interaction among and within species can influence community longevity and induce changes in the surrounding environmental conditions. Communities persist because over long periods of time, a system of checks and balances has evolved among the species living there. External factors that tend to change the character of a community are often physiographic factors involving geological and climatic events.	Human communities are characterized by having a variety of occupations, each of which contributes to the function of the community. They are not self-sustaining and are maintained by a complex series of inputs that allow numbers of people to live together in an area that cannot provide all the food, materials, energy, or services they require for survival. If parts of this logistical system are missing, damaged, mismatched, or misconnected, the community may not work as well. When one or more of the inhabitants' needs cannot be supplied by its community residents, those goods or services must be obtained elsewhere. This results in a net loss to the community's economy unless it can be matched by a community output that compensates for the loss. Inputs to human communities include items needed to provide food, energy, information, and shelter that the community cannot provide for itself. In communities that cannot provide the quantity or variety of occupations (niches) to support the new generation entering the workforce, people will immigrate to locations where these opportunities exist.	Urban sprawl, energy production, and agriculture needed to produce food and fiber required by human communities have impacts on natural systems. All of the aforementioned require space and reduce the capacity of an area to support the plants and animals that occupied the former habitat. ▪ In some nonindustrialized cultures, harvest of the forests for fuel or the clearing of the rain forests for agriculture to support villages have a negative impact on the existing ecosystem. ▪ Lawn fertilizers used in communities can get into area lakes and streams. These nutrients promote excessive plant growth, resulting in lower oxygen levels in the lakes and algae blooms.

Concepts and their applications to natural and social systems

Concept **Cycles**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A time interval in which a characteristic, especially a regularly repeated, event or sequence of events occurs. b) A single complete execution of a periodically repeated phenomenon. **Statement** Students demonstrate understanding of the importance of cycles in maintaining healthy ecosystems. **Discussion** Cycles are important factors in systems that can make materials available once again to a system's parts. This provides balance and stability in the systems.	Oxygen is generated by terrestrial, freshwater, and marine photosynthetic plants. They use carbon dioxide produced by burning, volcanism, and animal respiration to do this. These processes use the oxygen generated by photosynthetic plants. Living organisms are comprised of mostly water. They return water to the cycle through respiration, transpiration, and excretion. Evaporation puts water back into the atmosphere that is then returned to ecosystems in the form of precipitation. ▪ The seasons are a good example of a cycle that has profound effects on plants and animals that live in temperate climates.	**Life cycles:** Stages most of us proceed through in life. For example, we begin as infants, move into childhood, adolescence, adulthood, and become elderly. Each of these stages has different social aspects to them. It is similar to the seasons. **Social movement cycles:** This is the idea that each social movement goes through stages. The first stage is usually emotionally charged reactions to some injustice in the world (e.g. environmental movement). When social movements have been around for a while, they tend to lose their momentum and at times radically change their focus or dissolve.	Cycles in natural systems affect the activities of social systems. ▪ The seasons are cycles. During winter, shipping on Lake Superior stops until the ice breaks up in the spring. ▪ Tides are a phenomenon created by the moon's cycle around the earth. Many shipping activities are regulated by the tides. ▪ Seasonal cycles are not the same length in all locations on earth. Far northern and southern latitudes with short growing seasons do not have the same agricultural opportunities as Minnesota's farmers do. ▪ Migrations of some birds and animals are linked to the seasonal cycles. Hunting for these species usually takes place during this time. ▪ Many human physiological responses are linked to the cycle of day and night as well as to the moon.

Concepts and their applications to natural and social systems

Concept **Diversity**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The fact or quality of being diverse: difference. b) The point or respect in which things differ. c) Variety; multiformity. **Statement** Students demonstrate understanding that diversity in natural and social systems can promote a more stable system by providing extra opportunities for a variety of interactions. **Discussion** Systems are comprised of interacting parts that, in combination, can do things that the parts themselves cannot do. In these systems, it is not uncommon to have two or more parts performing the same function when interacting with other parts. Loss of one part, therefore, does not entirely eliminate that interaction from the system. Additionally, two or more parts may be performing the same function in the system, but in slightly different ways. This leads to new opportunities for system interactions that could benefit the system.	In natural systems, diverse communities tend to be more stable. Over time, these communities have evolved a system of checks and balances that involves interactions among the producers, consumers, and decomposers of that system. Overgrazing of plants (producers) by herbivores (consumers) is usually prevented by carnivore (consumer) species. If two or more carnivore species are present, elimination of one of those species will not result in an overpopulation of herbivores. Competition for the remaining predator species is removed and their populations tend to increase. Biodiversity can be defined three ways: species, genetic, and ecosystem.	Diversity in social systems typically involves cultural diversity. Cultural diversity is having people from various cultures reside together in one place like a city. The level of cultural diversity varies from place to place and time to time. For example, large cities generally have more cultural diversity than rural areas. Cultural diversity may involve discrimination and conflict due to perceived differences, low tolerance, and inequality. However, for the most part, diversity is valued for two reasons: • Some groups want to maintain their cultural traditions because they value them. • Diversity brings new insights and alternative ways of looking at issues and offers more answers to problems.	Diversity in the natural system helps maintain a high quality of human life. Cultures can teach and learn from each other so they can take care of the delicate natural systems that affect everyone globally. For instance, some cultures attempt to control and dominate natural systems causing degradation. These cultures could learn from culturesthat believe people are part of the earth's system and need to care for it like they would care for themselves.

Concepts and their applications to natural and social systems

Concept **Economics**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Of or pertaining to the necessities of life; utilitarian. b) Of or pertaining to the production, development, and management of material wealth, as of a country, household, or business enterprise. **Statement** Students demonstrate understanding that social systems create a wide variety of systems of exchange that include barter, (i.e. the exchange of goods or services) and currency systems to obtain food, water, shelter, or services. Students will also understand that these systems are based on a value set by the culture in question. **Discussion** Cultures develop a variety of specialized roles as a means of contributing to the common good of the community. These roles or subsystems of activity divide the labor of group living. Methods of exchange are used to acquire the necessities of life, objects, and services that individuals cannot easily provide for themselves. Economic systems can be global or very localized, but all change over time.	This term is not significantly useful to this discussion of natural systems. It is not a term that is commonly used in the analysis of natural systems.	Systems of exchange are essential to group living. In hunter gatherer societies, there are hunters; gatherers; those who prepare hides, wool, or plant material for clothing; and providers of spiritual guidance and leadership. The invention of currencies of agreed upon value reduced the need to transport objects for barter or to pay for services received in goods. The first currencies appeared in the Middle East as clay tokens with hieroglyphs representing a garment, bushel of grain, livestock, etc. Economic systems can be very localized or global. If a part of an economic system is broken or malfunctioning, it affects the whole community. It can alter exchange values, and the effect of this change can either hinder or enhance the function of the system. This produces instability in the community.	Exchange values in social systems can have a direct effect on natural systems. ▪ When the value of walnut trees became substantial, most of the walnut trees in southern Minnesota were harvested and not replaced. ▪ Minerals such as coal, copper, and iron have social value. Their extraction from vast open pit mines devastated local ecosystems until social environmental values became great enough to require restoration of these habitats once extraction was completed. ▪ Oak has high value in our society as a building material. Forest managers are concerned about the oak trees in southern Minnesota, which are being harvested faster than they are currently being replaced. ▪ Waterfowl and passenger pigeons were valued as food by the early settlers in Minnesota. Waterfowl populations were devastated by market hunters, and the passenger pigeon was driven into extinction.

Concepts and their applications to natural and social systems

Concept **Ecosystem**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition An ecological community together with its physical environment, considered as a unit. **Statement** Students demonstrate understanding that ecosystems are comprised of all living things and their environment in an area of any size, all linked together by energy and nutrient flow. **Discussion** As opposed to communities that only contain living organisms, ecosystems are comprised of living and nonliving parts. Organisms living in an ecosystem must meet the requirements of the nonliving parts. This condition produces a stable system of material exchange between the living and nonliving parts.	Organisms living in terrestrial, freshwater, or marine ecosystems have adapted to the nonliving parts of their ecosystems. Sometimes these organisms show special physical, behavioral, or physiologic modifications in response to their ecosystems ▪ Many aquatic cave-dwelling species display no colors and have no eyes. ▪ Marine and estuary species have special physiological adaptations that permit them to tolerate high salt concentrations. ▪ Microbial species living in hot springs and volcanic vents on the ocean floor have physiologically adapted to temperatures that would cook other organisms. ▪ Many species of birds and some species of animals migrate from their summer ranges as winter approaches.	This term is not significantly useful to a discussion of social systems and is not a term that is commonly used in the analysis of social systems.	Social systems affect and are affected by the ecosystems in which they live. ▪ Plants and animals that humans use as food are either products of the ecosystem in which they live or have adapted to the ecosystem. Some domestic animal species have to be helped to survive by supplementing their diets with food they cannot obtain from the ecosystem. Human habitation, depending on the society, can change an ecosystem drastically by building communities or practicing agriculture. People living near marine ecosystems turn to the oceans and develop technologies to harvest food for personal use and to export to other locations. Many nonindustrialized societies have evolved religions that recognize the potential of souls in the phenomena, and animate and inanimate objects of the local ecosystem.

Concepts and their applications to natural and social systems

Concept **Energy and energy flow**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The work that a physical system is capable of doing in changing from its actual state to a specified reference state, the total including contributions of potential energy, kinetic energy, and rest energy. **Statement** Students demonstrate understanding that natural and social systems use energy to accomplish work and some energy is lost to the environment as heat. **Discussion** Energy passes through social and natural systems and is used to accomplish work. In both systems, energy is lost as heat when energy is transformed to do work or is changed into other forms of energy. This heat energy can also be used for other purposes in a system and/or lost as waste heat.	Sunlight is the single most important energy source in natural systems. In addition to warming the earth, the food chains of the majority of terrestrial, aquatic, and marine species depend, directly or indirectly, on sun energy captured by green plants in the process of photosynthesis. Green plants are able to use sunlight as an energy source to combine carbon dioxide from the air with water and minerals from the soil to build carbohydrates that become the building blocks of other plant materials. These plants become the foundation upon which food chains and food webs are created. Consumers, both herbivores and carnivores, pass this stored energy along the food chain. Some of this stored energy is used to do the work of building and maintaining the organism. Some is converted to heat.	Social systems in industrialized societies use great quantities of energy for climate control, fabrication of products, processing food, agriculture, transportation, and transforming energy from one form to another. The parts of the social subsystem that guide the acquisition, transfer, transformation, and household consumption are numerous and their interactions complex. If parts of this system are missing, damaged, mismatched, or misconnected, the social system as a whole can be affected. Coal is mined, transported long distances, and used to generate electrical energy which is then distributed to the community. A lengthy breakdown in any link in this system, particularly in winter, has serious consequences for the community. Most energy in the United States is provided by fossil fuels, i.e. coal, petroleum. Depletion of these resources would have profound effects on society as we know it today. Nonindustrialized societies demand less energy than industrialized societies because more work is done by humans and animals. They do, however, have energy requirements for heating, cooking, or fabricating artifacts.	Natural systems are affected by the demands of social systems for energy. ▪ Electrical generating facilities often use water from rivers or lakes to cool equipment. The waste heat from the plant is transferred to the water, which is returned to the aquatic ecosystem from which it was drawn. Under some conditions, the increase in temperature of the water in the natural ecosystem can have a negative effect on the organisms living there. ▪ In regions where wood is the main source of fuel, deforestation of the area surrounding the village or community can occur if trees are harvested faster than they are replaced by natural regeneration. ▪ Crude oil is transported over long distances from where it is pumped from wells to where it is refined. Larger and larger transports are being used. The risk of accidental oil spills increases. Oil spills are a good example of part of this system malfunctioning. Coal with a high sulfur content generates sulfur oxides when burned. These are exhausted into the atmosphere where they dissolve in rainwater and are returned to the earth as acid rain.

Concepts and their applications to natural and social systems

Concept **Evolution**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition A change in the gene pool of a population from generation to generation by such processes as mutation and natural selection. **Statement** Students demonstrate understanding of the causes, processes, and results of mutation and natural selection. **Discussion** Natural selection and mutation interact to cause changes in species of living organisms over time. Mutations are changes within an individual's genes, which often result in different physical and/or behavioral characteristics in the next generation. Natural selection is the process by which particular characteristics become more or less adaptive to the environment, resulting in those characteristics being or not being passed on to the next generation. Natural selection is a process that results in some members of a population having a greater success in perpetuating their genetic traits.	▪ An example of mutation and natural selection working together is a moth population that lives in the fields surrounding London. When the country was largely agricultural, most of these moths were white, like many of the wildflowers in the area. They blended in well with their environment and were able to escape their predators by means of camouflage. As London became more industrialized, factory smoke began to fill the air, and soot covered the areas around London. The white moths stood out against the dark background, making them easy prey for their predators. Some of the white moths had some brown spots. These spots were produced by mutations in the moth genes that programmed their color. The moths with the brown spots were less visible to predators than the all white ones, so they were able to escape being eaten more often. Therefore, the brown spotted ones became more numerous, and were able to pass along these genes for brown spots to the next generation. The ones with the biggest brown spots were able to survive longer and produce more offspring, so the big brown spots became more numerous in the population. Eventually, over several years time, the once white moth population was almost completely changed to brown.	Mutation and natural selection are the processes that have produced the large brain in the human species. It is the selective advantage of the large brain capable of complex thought that has enabled a relatively weak creature to survive and spread over the planet. The human brain is a specialized adaptive mechanism in the same sense as a double fur coat on a polar bear or gills on fish. The advantage it gives humans is the ability to generate social systems that produce behavior patterns and tools that allow humans to live in and adapt to their environment. Culture (social life) is a series of interacting systems that helps the species to survive in many types of environments.	It is easy to assume that the cultural systems within which humans live and the technologies that are products of those systems have erased any effect that natural selection might have on humans. The current crop of "superbugs" causing outbreaks of diseases for which there is no or only ineffective treatment are good examples of why this assumption is misleading. Human social systems have enabled the creation of antibiotics that were quite effective against earlier generations of disease-causing bacteria. However, as these antibiotics were used and overused, the bacteria with mutations that enabled them to withstand the onslaught of the antibiotic survived and because of the short life span of the bacteria, reproduced at a rate much faster than it is possible for humans to generate new antibiotics. By using our own technology, humans have contributed to new and more virulent forms of disease. And with worldwide transportation systems (themselves the product of humans social systems), the diseases can now be spread planetwide in a very short period of time.

Concepts and their applications to natural and social systems

Concept **Extinction**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition Condition of having been removed from existence. **Statement** Students demonstrate understanding of the causes, processes, and results of the extinction of plants and animals. **Discussion** The most probable fate of any group of plants or animals in the course of time is extinction. In fact, many organisms leave no descendants at all — their species dies out. Groups of organisms that are dying out are replaced not only by surviving ones, but also eventually by quite new organisms that may exploit the environment in new and novel ways. This has contributed to the diversity of nature, which has become greater and greater over the course of time. Species may disappear when environmental conditions no longer meet their requirements for survival. This may be due to climate changes, the disruption of ocean currents, excessive predation, or certain catastrophic events.	The geologic record shows that massive global extinctions have occurred throughout earth's history. The extinction of the dinosaurs has been attributed to an asteroid that hit the earth 65 million years ago, creating fires and dust clouds that hid the sun and changed earth's climate for millions of years. Fossil records show that many species simply disappeared and left no traceable lineage to related species (the North American horse).	Although some cultures no longer exist and may be said to be extinct, this term is not significantly useful to this discussion of social systems. It is not a term that is commonly used in the analysis of social systems.	▪ The dodo bird that lived on Madagascar was hunted to extinction when people came to that island. ▪ American settlers hunted the passenger pigeon to extinction. ▪ Many scholars attribute the extinction of the large ice age mammals to the hunting pressure of prehistoric humans. ▪ Amphibians around the world are seriously decreasing in numbers, and some attribute this decline to chemicals that human societies have put into the environment.

Concept **Family and kinship**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Family:** a) A taxonomic category ranking below an order and above genus. b) The most instinctive, fundamental social or mating group in humans and animals, especially the union of man and woman through marriage and their offspring; parents and their children. **Kinship:** a) One's relatives collectively; family. b) The state of being related by blood. **Statement** Students demonstrate understanding that the family (parents and offspring) in natural and social systems is a basic unit of organization (part) of those systems but that the term family can also have different connotations when applied to either a natural or social system in different perspectives. **Discussion** Family units are important parts of natural and social systems. Their primary function is to promote the survival of the young that will become the next generation of the species.	The term kinship is not significantly useful to this discussion of natural systems. It is a not term that is commonly used in the analysis of natural systems. Family units do exist in natural systems but they lack the elaborate cultural extensions of "relatedness" found in social systems. Animal family units consist of the parents and their offspring. Another use of the term family is to designate a group of similar species on the basis of their similarities; e.g. all ducks and geese belong to the family *Anatidae* in the taxonomic system of classification.	Kinship systems are characteristic of social systems and there are many cultural variations of how this "relationship" is structured. Kinship bonding is not as important to the survival of the group of related individuals in technological societies as it is in more traditional cultures.	In nonindustrialized societies, when the group becomes too large to be supported by the local ecosystem, smaller groups splinter off and establish communities of their own. ▪ Land ownership patterns in Ireland at the turn of the century allocated portions of a farm among a family's children and their families. Holdings became smaller, and it was more difficult to raise enough crops for food and barter. When the potato blight reduced production even more drastically, many Irish immigrated to North America.

Concepts and their applications to natural and social systems

Concept **Feedback**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The return of a portion of the output of any process or system to the input. **Statement** Students demonstrate understanding that systems are comprised of interacting parts and that one part of a system can produce an output that serves as input for a different part of the system and affect the operation of that part. **Discussion** Any system comprised of interacting parts produces outputs. These sometimes help regulate some portion of the system's activity. Feedback outputs from one part of the system may become feedback *input* to a totally different part of the same system or a different system.	Ecosystems contain numerous feedback mechanisms that have evolved over time to help regulate the ecosystem in a fashion that tends to balance the operation of its parts. Feedback mechanisms also exist within individual organisms. ▪ When aspen buds are overbrowsed by a high population of ruffed grouse, they produce a distasteful chemical that inhibits browsing. This is a factor in the well-known 10-year population cycles of rough grouse. ▪ Bats vocalize ultrasonic sound waves that bounce off objects and return to the bats' ears. This feedback is used by bats to locate food and navigate in their environment.	In the American political system, the answers people give to opinion polls can influence the way politicians speak or vote. The output of the polls influences the input politicians give to their speech writing or voting. Their speeches and voting can then influence the polls. In the American economic system, the products that manufacturers make are the ones they think people want to buy. What people actually buy will influence what products continue to be produced.	Human populations create complex food webs that can be seriously disrupted by environmental changes, the feedback from which can cause starvation or human migrations. Products from human activities can cause changes in the environment. ▪ Chemicals released to the atmosphere have created decreases in the ozone layer and have increased levels of ultraviolet radiation that can lead to skin cancer. ▪ DDT pesticide accumulated in the food chain, made eagles' eggs brittle enough to break during incubation, and endangered the bald eagle with extinction.

Concept **Formal and nonformal**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Formal:** Following or adhering to accepted forms, conventions, or rules. Done in proper or regular form. **Nonformal:** Done in other than recognized formal forms, conventions, or regulations. **Statement** Students demonstrate understanding that social systems develop formal procedures to help regulate orderly and standardized activities in society to promote stability and predictable responses. **Discussion** It is a common property of all human societies that they establish formalized procedures and codes of behavior. These codes and procedures remove uncertainty from daily activities and reduce conflict among groups of people living together. There are however, exceptions to the "ideal." Formal procedures describe the ritual to be followed to accomplish some end. Although this ritual may be followed in form, it is often preceded by informal social action. For example, a certain action may be arrived at by appearing before the city council, but the outcome is usually preceded by informal interaction with the decision-making people involved.	This term is not significantly useful to this discussion of natural systems. It is not a term that is commonly used in the analysis of natural systems.	Formal usually implies procedure. Formal organizations use organized procedures to run smoothly. Applying to college, filling out emergency health forms, having parents sign permission slips, and getting a driver's license are all formal procedures. Laws are part of the formal procedures created by social structures. Laws are intended to help society. For instance, there are laws that apply to driving. If everyone drove a different way, there would be more accidents and more people injured or killed. Nonformal usually refers to the lack of formal procedure. Spending time with family and friends is an example of a nonformal situation.	Formal laws and regulations have been developed by society to protect wildlife. These laws determine how many fish, deer, etc. people are allowed to harvest. If society was allowed to take as many fish or deer as they wanted, there may be none left, as in the case of the passenger pigeon. The nonformal interaction of people with natural systems varies. When people want to enjoy the outdoors, they may take a boat out fishing, water-skiing, and/or tubing. The effect on the environment is dependent on what type of boat is used and how it is used. High speeds and motors have an adverse impact on natural systems, while paddles and oars have little impact.

Concepts and their applications to natural and social systems

Concept **Function**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The natural or proper action for which a person, office, mechanism, or organ is fitted or employed. **Statement** Students demonstrate understanding that a system's parts interact and give it a different property than its individual parts. **Discussion** The parts of a system interact to give a system its characteristics. These properties are different from its individual parts. If parts are missing, damaged, mismatched, or misconnected, the system may not function as well or not at all.	An ecosystem demonstrates properties that are the result of the interaction of its parts — biotic and abiotic factors. The function of each of its parts contributes to the character of the ecosystem. If a part of an ecosystem is missing, the parts of the ecosystem interacting with the missing part are also affected. Precipitation is an abiotic factor. If the annual precipitation is 10 or fewer inches per year, the biome is a desert and the plants and animals (biotic "parts") found there will only be those species that have evolved the behavior and physiology required to compensate for this abiotic factor. ▪ If bees were removed from an ecosystem, all the flowering plants that depend on them for pollination are affected. ▪ Removal of all the predators of herbivores in an ecosystem will seriously effect its plant species interacting with the herbivores.	A function is something that has or serves a purpose. Each person in a group performs a function. For instance, parents protect and support their children. Each group also performs a function. Families socialize children. Schools educate people. Each individual and group is interdependent; each plays a role in the functioning of society. For example, people work in supermarkets that provide food and other needs/wants of society.	The functions of natural systems are determined by social systems. Each function in society has consequences. For example, agriculture provides much needed food to people by way of the grocery store. However, agriculture may have unintended consequences, dependent on the manner in which it is done. The use of pesticides, herbicides, and fertilizers can increase crop production, while negatively impacting natural systems.

Concepts and their applications to natural and social systems

Concept **Geomorphism**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The change over time of the earth's surface configuration and land forms. **Statement** Students demonstrate understanding that the earth is a dynamic, interacting system, and that its surface configuration changes continually through plate tectonics, volcanism, mountain building, and erosion. **Discussion** The earth's surface configuration changes over time as a result of forces and processes that move continents and raise mountain ranges. Erosion reduces these mountains to their roots, sculpts the landscape, and fills basins. Portions of continents are uplifted and stretched, faulting huge areas of the continent upward and downward. Portions of continental land masses can split away, creating rifts. Drifting continents collide, raising volcanic mountains and pushing layers of rock many miles. Oceanic volcanoes create volcanic islands.	Changes in the configuration of earth's surface can take place over very long periods of time or occur in a much shorter time interval. These changes always affect the ecosystems where they occur. ▪ When Mount St. Helen explosively erupted in the state of Washington, forests were leveled, lakes were filled, and streams were loaded with mud. Hundreds of square miles were covered with ash. The plants and animals living in ecosystems included in the event were affected by the changes. ▪ As continents drift northward or southward from the equator, major climate changes occur that affect existing ecosystems. When mountain ranges rise, most of the precipitation that falls in the area is on the side of the range facing the prevailing winds. The other side of the range now lies in a "rain shadow," receiving less precipitation than before the range was created. The biomes there generally change into desert biomes.	This term is not significantly useful to a discussion of social systems and is not a term that is commonly used in the analysis of social systems.	These processes affect the natural and social systems that can survive in an area affected by these changes. ▪ Japan experiences frequent earthquakes. In response, Japanese society constructs its buildings to withstand the earthquakes. ▪ Mountain ranges create "rain shadows" on the opposite side of the range from the prevailing winds. This creates desert conditions that dictate the types of plant and animal species that can survive there. Human populations either move or modify their lifestyles to fit the physical conditions created by the mountains.

Concepts and their applications to natural and social systems

Concept **Group**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A geological stratigraphic unit, especially a unit consisting of two or more units. b) A number of individuals or things considered together because of certain similarities. **Statement** Students demonstrate understanding that the parts and objects of social and natural systems can be grouped or separated by their similarities and differences and that making systematic groupings helps build understandings about the environment. **Discussion** Similarities and differences among the parts, objects, and processes of social and natural systems can be useful ways of grouping these systems and their components. The grouping allows for imposing a hierarchy of perspectives that can be useful in describing or studying natural and social systems.	In natural systems, the term group has two very different meanings. In geology, it refers to a series of sedimentary layers of rock, called formations, that were deposited during the same approximate time period. The deposition may have occurred over a very long span of time. When used in describing the plants and animals in an ecosystem, the term refers to collections of individuals or species that possess similar characteristics. However, the term group is not usually applicable. People have created a system of naming that describes groups of individuals or species. Some of these are scientific and some are not. ▪ A large group of deer is referred to as a herd. ▪ A group of ducks is referred to as a flock. ▪ All red breasted robins are referred to as a species. ▪ All robin-like birds are referred to as a family. ▪ All animals with a backbone are referred to as a subphylum.	Groups are collectives of individuals who interact and form social relationships. Groups vary in size from two people to thousands. The complexity of a group increases as the size increases. Groups also vary in importance, with primary groups (family, friends) being most significant and secondary groups (work, school), being less. The pressure to conform is present in any group.	Groups utilize the environment for air, water, food, energy, space, and a place to put their wastes. Groups can have both a negative and positive impact on the environment. Many family groups are aware of environmental issues, yet their lifestyles may still contribute to degradation of natural systems. ▪ For example, the U.S. produces more garbage than most countries even though it is among the most educated about environmental issues. Groups also form to protect and restore natural systems and promote activities and lifestyle choices that have less of an impact on the environment.

Concepts and their applications to natural and social systems

Concept **Habitat**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The area or type of environment in which an organism or biological population normally lives or occurs. b) The place where a person or thing is most likely to be found. **Statement** Students demonstrate understanding that habitat is the arrangement of a natural area containing the food, water, space, and shelter that an organism needs to survive and raise its young. **Discussion** Habitats influence the plants and animals that live there. Wildlife species seek out certain types of plant communities because they suit their evolved behavior as well as their physiological needs. The term habitat is useful in referring to species' preferences for one type of plant community over another.	Habitats consist of populations of plants and animals that include producers, consumers, and decomposers whose interactions, over long periods of time, have evolved into a system of checks and balances that keeps populations relatively stable. Major abiotic changes within a given habitat influence all the organisms directly or indirectly interacting with the altered conditions. ▪ Eradication of milkweed in agricultural areas results in the elimination of monarch butterflies in the same habitat. ▪ Forest fires kill trees that are used by many species and the new habitat usually draws new species into the area. ▪ Overpopulation of snowshoe hares in northern Minnesota overbrowse the forest's brush cover during the winter months, killing hazel bushes that provide nuts for squirrels and catkins for ruffed grouse.	This term is not significantly useful to a discussion of social systems and is not a term that is commonly used in the analysis of social systems.	Social systems directly and indirectly affect wildlife habitats. ▪ The zebra mussel was brought to Minnesota by ships carrying water as ballast. This water contained the mussels. In Lake Superior, the ships dumped the water to take on cargoes of grain and iron ore. This mussel invades freshwater habitats and so drastically changes them that the species who lived there before are displaced. ▪ The English sparrow was imported to the United States from Europe. The sparrow expanded into new habitats and has now displaced many native species of sparrows from their former habitats. ▪ Golf courses often alter existing habitat, displacing many of the species that were living there, while attracting new ones. ▪ Overgrazing of western short grass prairies by the Spaniards and early American ranchers reduced the grass cover causing the depleted habitats to become more arid. This dramatically increased soil erosion, which increased gully formation and promoted the invasion of the creosote bush.

Concepts and their applications to natural and social systems

Concept **Ideal and real**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Ideal:** A concept of something in its absolute perfection. Pertaining to or consisting of ideals or mental images. **Real:** Being or occurring in fact or actuality; having verifiable existence. **Statement** Students demonstrate understanding that natural and social systems are often described in terms of the ideal, but in fact, the actual (real) functioning of those systems might be significantly different from the ideal. **Discussion** The concepts of ideal and real pertain to the discrepancy between what is perceived to be the way something ought to be as opposed to how it actually works in real life.	This term is not significantly useful to this discussion of natural systems. It is a not term that is commonly used in their analysis. The term most often used in referring to natural systems is "model." This is based on a theoretical estimation (hypothesis) of what the parts of a natural system, or its processes, might be after scientific observation. This model constitutes the deduced "ideal" whereas discrepancies between scientific observation and the model suggest that the model may not be a "real" approximation of the system's parts or processes. Further testing and observation may then lead to refinement of the model to increase its accuracy in testing.	These terms are most appropriately applied to the stated ideals of a social system as opposed to what its people or institutions actually do. All cultures have formal and informal codes (rules) whose purpose is to provide orderly interpersonal interactions within the group and to punish those who transgress against these policies. These social codes may be formalized laws, religious imperatives, or informal group expectations known as mores. ▪ Laws govern Minnesota's political process and formal procedures designed to provide a process of orderly group decision making. In real life however, much of the decision making does not take place as a result of a public hearing. Individuals and friends of the policymakers have already had one-on-one conversations with their legislators to lobby for their position on the issue. ▪ Members of formal religions strive to follow their religious laws (the ideal), yet members may also choose to occasionally "bend" the laws. ▪ Minnesota's speed laws are clearly stated and signed along its 55-mph highways. Many agree that such a limit is necessary to provide for public safety, however average speeds often reach 65 mph.	Minnesotans generally drive about 10 mph above the speed limit. It was clearly demonstrated during the gas crisis in the 1970s that the higher speeds are less fuel efficient and the best compromise was 55 mph. Driving faster than the liberal speed limits we now have puts more oxides of nitrogen and sulfur into the atmosphere to form acid rain. Additionally, more carbon dioxide is emitted, increasing the already growing concentration of this greenhouse gas, which contributes to global climate change.

Concepts and their applications to natural and social systems

Concept **Ideas and concepts**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Idea:** a) That which exists in the mind, potentially or actually, as a product of mental activity, such as thought or opinion, conviction, or principle. b) A plan, scheme, or method. **Concept:** a) A general idea or understanding, especially one derived from specific instances or occurrences. b) A thought or notion. **Statement** Students demonstrate understanding that ideas and concepts are the product of observation, experience, and learning from others that result in perspectives that are determined by the culture in which people live. **Discussion** Ideas and concepts are influenced by the environment in which people live as well as by the formal and nonformal procedures established by cultures to promote order in community living. They are also influenced by religion. Different cultures relate differently to the environment as a result of this. North Americans want to preserve the rain forests and have difficulty understanding why the people who live there want to cut and burn. We forget that we did the same thing when we settled here and that economics and desired improvement of lifestyle are central to this issue.	This term is not significantly useful to this discussion of natural systems. It is a not term that is commonly used in the analysis of natural systems.	People share ideas continuously. Ideas usually grow out of people sharing in social situations. Ideas are often culturally determined. When people share ideas about what they want to do for the evening, there are cultural boundaries. Learned understandings (ideas or concepts) form the basis for human social systems and perhaps (recent research shows) social systems of some other animals. The way we see the world and therefore how we act is based on these understandings. In most societies, the definition of who is a family member carries with it rights and responsibilities — for instance, the responsibility of caring for other family members or the right to inherit. When analyzing social systems of any type, whether they are economic, political, legal, religious, social stratification, etc., it is necessary to discover the ideas and concepts that lie at the foundation of that system. These ideas and concepts are important inputs to social systems. In western European-based cultures, for instance, a family includes all people who are biologically related and some that are related by marriage, though these are distinguished. Generally, people think about and behave towards those they consider family members differently than they do towards friends or strangers. In other societies, families are defined differently. In Navajo society, only the mother's line is considered "true" family.	When groups have ideas about how to conserve the environment they want to share that with other groups. International agencies struggle to implement what they consider "good" ideas about conserving the earth. These agencies go into less developed countries and may build a dam or try to build up tourism. When the agency leaves the country, the local people may not take care of what the agency developed because they did not share in the idea process. Using their own ideas would give them more control and ownership and may increase the success of some projects.

Concepts and their applications to natural and social systems

Concept **Individual**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition Something that exists as a distinct, indivisible entity; also, a single human being, as distinguished from a group. **Statement** Students demonstrate understanding that systems can include individual organisms as some of the component parts, and that these organisms can be humans. **Discussion** While most people understand that material objects can be parts of a system, (e.g. the parts of a clock), it is less common for us to understand that living beings, including ourselves, are parts of systems as well.	Systems are made up of individual parts that are related in some manner or by some process. In a wetland, for example, the individuals can include the animals and the plants that live and function together so that each survives and the whole system survives. Even though each individual is an entity unto itself, each has a role to play in the functioning of the whole. In a marsh, the muskrat feeds on the cattails. In doing so, it can help the plant to spread. When the muskrat uproots the plants, they then float away and re-root elsewhere. The muskrat's small scale harvesting of cattails also helps waterfowl by creating little areas of open water where the birds can rest.	Individual humans are among the major component parts of human social systems. These can range from small, as in a nuclear family (husband, wife, and children) to very large as in a nation or a multinational corporation. In each of the many social systems of which an individual is a part, that individual has a role to play and a relationship to the others in the system. ▪ For instance, a football team is a system. It is a group of individuals, each of whom has a set role to play. Each interacts in ways spelled out by rules, expectations, and strategies in order to achieve a goal, i.e. getting the football over the goal line enough times to win the game. Anyone who watches a football game long enough can eventually determine the role of each of these individuals.	Individual humans make decisions that are often very dependent on the social systems of which they are a part. These decisions can affect individuals in natural systems. ▪ For instance, homeowners often choose to surround their homes with large expanses of lawn. This decision is influenced by the status system in North American culture that equates large expanses of trimmed and manicured lawns with upper socioeconomic status. As many homeowners continue this practice, natural ecosystems are disrupted, and individuals in those ecosystems lose their food, shelter, and reproductive space.

Concept **Innovation and invention**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Innovation:** a) To begin or introduce something new. b) That which is newly introduced; a change. **Invention:** A new device or process developed from study and experimentation. **Statement** Students demonstrate understanding that species in natural and social systems are capable of discovering new behaviors or concepts and that this can have high survival value for the species. **Discussion** Not all innovations or inventions have value to the species or to the natural and social systems within which they occur. The ability to retain and use an innovation that has value to the system, however, has high survival value for the system. An innovation or invention may also change the system significantly.	Although these terms are generally reserved for describing the outputs of social systems, there is some application to wildlife behavior that seems to be the result of (probably accidental) discovery that is learned through observation by others. It is unlikely that the following behaviors are genetically inherited. ▪ Sea otters of the Pacific West Coast float on their backs in the ocean and use rocks to break open the shells of mollusks they have placed on their stomachs. ▪ Sea gulls will pick up mollusks and drop them from heights to break open the shells on the rocks. They do not drop them onto the sand. ▪ Some African primates will pull the leaves and side branches off a twig, insert it into a termite mound, and lick off the termites. Field observations by scientists have recorded the young observing and copying the act.	These concepts refer to an original product, idea, thing, or method. They can affect the majority of people, e.g. electricity, telephone, and computer. Innovations/inventions develop out of social situations. Computers are the result of many people working hard and trying new things. They can also change society as the computer has.	Innovations/inventions have historically been used to benefit social systems without regard to natural systems. However, there have been some inventions/innovations developed to support natural and social systems. For instance, societies use energy in a variety of ways. Although many are still degrading natural systems, there have been some inventions such as the solar cell that supplies energy without causing environmental harm. Likewise, pollution controls have been required for automobiles to reduce pollution.

Concepts and their applications to natural and social systems

Concept **Inputs and outputs**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Input:** Anything put into a system or expended in its operation to achieve a result or output. **Output:** The amount of something produced or manufactured during a given span of time. **Statement** Students demonstrate understanding that social and natural systems are affected by things put into the systems and their subsequent outputs can serve as inputs to other systems. **Discussion** Social and natural systems use natural resources in their operation. The activity of these systems results in the production of materials, behavior, ideas, waste, or artifacts.	▪ Waste material generated by animal metabolism becomes a nutrient for plants or organisms at lower trophic levels. ▪ Ammonia is formed from nitrogen being acted upon by lightening in the atmosphere and is carried to the earth in rain to become a plant nutrient. ▪ Photosynthetic plants use sunlight to combine water, carbon dioxide, and other nutrients to produce plant material and release oxygen into the atmosphere. ▪ Bacteria in nodules in the roots of some plants convert nitrogen from the atmosphere into materials that are used by these plants to grow. ▪ Chemicals released by moths attract moths of the opposite sex for purposes of reproduction. ▪ Openings in the leaves of plants close when sunlight is removed at night to reduce the loss of moisture.	Social system inputs and outputs can consist of information (or misinformation), technology, religion, materials, energy, ideas, cultural practices, language, people, or waste. Their effect can be either positive or negative to natural systems or other social systems. A large portion of inputs to industrialized cultures, particularly Japan, comes in the form of materials or forms of energy obtained from third world countries. The output of these industries enters into a worldwide economic network. When you change a system, it is difficult to predict the results. The advent of the computer and the Internet has radically increased the rate of exchange of information, technology, and ideas. It is difficult to predict how this increased input-output rate of information exchange is going to affect earth's social systems.	▪ People spread manure and other nutrients on the soil to increase plant growth. ▪ Excess nutrients collect in moving and standing bodies of water, increasing the amount of plant growth in the water. ▪ Windmills are used to generate electricity in areas where there are adequate prevailing winds. ▪ Industrialized nations generate large quantities of solid waste, most of which is not easily recyclable by natural systems. Solid waste landfills result in habitat loss. ▪ Prior to World War II, Minnesota farmers sold walnut tree stumps, which they considered to be waste (output), to Germany, which, in turn, used this input to manufacture rifle stocks. The ultimate output from this activity had devastating effects on both social and natural systems.

Concepts and their applications to natural and social systems

Concept **Instruction**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The act, practice, or profession of education. b) An imparted or acquired item of knowledge; a lesson. **Statement** Students demonstrate understanding that instruction is a system of conveying information to others. **Discussion** The output of information during instruction provides the input to others. The purpose of instruction is to control what goes on in the system as a whole. This output-input process is accomplished by seeing, listening, and imitating.	Wildlife species instruct their young and each other. ▪ Predators must often be taught to hunt. This is accomplished by the young accompanying the adults while hunting and subsequently trying to hunt for themselves. ▪ Some species of chimpanzees teach their young to gather termites by inserting a stick into a termite mound, removing it, and licking the angry termites off the stick while the young watch.	Humans and some other animals pass on information to others by means of instruction. Human social systems are, for the most part, learned systems. One learns who family members are and why they are considered so, for instance, and how the political, legal, economic, religious, and other systems within which we exist, work. Because of this, people have created a great variety of social systems. When studying the social systems of others, it is wise to begin with an open mind, without expecting the systems to be the same as or similar to one's own. Generally, it's the ideal systems that are taught. We are instructed on how the systems are ideally supposed to work. We are often left to find out by trial and error how those systems work in everyday life and what exceptions there are to the rules.	▪ Colonial hunters noticed that the game was declining from over-hunting. They demanded that regulations be set to control the harvest of wildlife. This created the concept of conservation, which is taught in schools today. The result is increased wildlife populations and improved habitat. ▪ Instruction based on past lessons learned has increased social awareness about the need to protect our water, air, soil, plant, and animal resources. The end result is cleaner water, reduced soil erosion, sustained forests, preserved prairies, and healthy wildlife populations.

Concepts and their applications to natural and social systems

Concept **Interactions and relationships**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Interaction:** To act on each other. **Relationship:** a) A logical or natural association between two or more things; relevance of one to another; connection. b) The mode in which a person or thing is connected with another. **Statement** Students demonstrate understanding that the causes and effects of interactions and relationships among and within the parts of social and natural systems are not always predictable when a part (or parts) of those systems is changed. **Discussion** Systems are collections of things, processes, or people that interact to perform some function. Although most interactions relate to survival of the organism, they may also convey information, be spiritual in nature, or have no identified purpose.	▪ Predator populations are directly dependent upon the number of prey species available and will be lower when prey species populations are low. ▪ Some plants depend on other taller plants to shade them from direct sunlight. ▪ Some plants release chemicals into the soil that kill or retard the growth of other plants to reduce competition for moisture or nutrients. ▪ Lichens found growing on rocks and tree trunks are fungi containing photosynthetic algae that produce food for the fungus, which in turn provides support for the algae. ▪ Some birds perform very elaborate rituals to attract a mate. ▪ The shorter hours of daylight in the fall causes chlorophyll in tree leaves to die, showing the other colors of pigments formerly hidden by the chlorophyll.	Interactions and relationships among social systems or within a social system may take many forms and serve many purposes. This interplay may or may not be beneficial to some or all of the individuals or societies involved. ▪ Children's relationships and the way they interact with the members (parts) of their families are different from their interactions with people encountered in school. ▪ Local communities have varying types of work opportunities that are completed by individuals who have specialized in a particular type of work. The combined result of work completed (interaction) benefits the community as a whole. ▪ In addition to goods and services, trade with another culture also results in an exchange of ideas and information. ▪ Warfare between two or more nations always produces chaos in the societies involved. ▪ All societies have restrictive mores governing the interaction of males and females who have reached puberty.	▪ Wildlife managers will sometimes reduce the number of predators in an area to allow more of the predator's prey species to survive, e.g. reducing raccoon populations to increase waterfowl nesting success. ▪ People have domesticated and protect some species to provide a continuing and abundant supply of food, i.e. cattle, chickens, pigs, sheep. ▪ The way of life of the American Plains Indian was forever changed when the buffalo were hunted to near extinction. ▪ The application of pesticides and herbicides to promote higher crop yields also affects other plants and animals in the ecosystem.

Concepts and their applications to natural and social systems

Concept **Knowledge**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Familiarity, awareness, or understanding gained through experience or study. b) That which is known; the sum or range of what has been perceived, discovered, or inferred. **Statement** Student demonstrates understanding that humans and wildlife accumulate information from experience and that this information is retained to be used to compete for survival in natural and social systems. **Discussion** Knowledge is accumulated information gained by observation and experience. The ability to retain knowledge has high survival value for the species. The longer and greater the retention, the more successful the species will be.	Wildlife accumulate and retain information they gain from experience. This can be equated to knowledge, but the term is usually applied to humankind. ▪ Prey species learn to know when a predator is hunting and when it is not. Although prey species keep a cautious eye on nearby predators, their behavior toward adjacent predators becomes quite casual when they sense that the predators are not hunting. ▪ Many predators are taught to hunt by their parents. As they gain experience, they retain this information and become more efficient at acquiring prey.	Knowledge is facts or information gained through experience, such as studying a book, doing hands-on activities, or daily life lessons. Knowledge is a building process and is culturally determined, constructed, and controlled. ▪ For instance, what students learn in school is determined by many people besides their teacher. ▪ The information offered on TV is determined by the executives, producer, and the owner of the network.	People gather and use knowledge to get what they need from the environment. In the past, knowledge was used to attempt to control the environment. More recently, some groups have focused on gathering knowledge that natural systems have to offer. This knowledge has been used to protect the wildlife. ▪ For example, when people realized the bald eagle was becoming extinct, they gathered knowledge on why it was in danger and how to save it. Now the bald eagle has been taken off the endangered species list.

Concepts and their applications to natural and social systems

Concept **Language**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The transmission of meaning, feeling, or intent by significance of act or manner. b) Any method of communicating ideas, as by a system of signs, symbols, gestures, or the like. c) The aspect of human behavior that involves the use of vocal sounds in meaningful patterns and, when they exist, corresponding written symbols to form, express, and communicate thoughts and feelings. **Statement** Students demonstrate understanding that although communication is common in both natural and social systems, social systems have developed formalized language structures that allow for detailed exchange of information and abstractions. **Discussion** The ability of members of a species to communicate among themselves has high survival value to that species. As far as scientific observation at this time has been able to determine however, language is unique to humankind.	This term is not significantly useful to this discussion of natural systems. The term "communication" is more commonly used in the analysis of natural systems. ▪ The honey bee communicates the location of a pollen source to other members of its hive by means of an elaborate figure-eight dance that includes abdominal and wing movements. ▪ Animals communicate within and among species by means of sound, smell, and body language to locate one another, express dominance or subservience, warn of potential aggression, demonstrate readiness to mate, or express play and affection. ▪ Although it is suspected that whales and dolphins demonstrate very complex communications, it has not been demonstrated that they "converse" in the human sense of the word or are capable of communicating abstractions.	The invention of language, spoken and written, is one of humankind's most significant inventions in its long journey of change over time. It allows exchange of ideas, emotions, abstractions, and information among members of a social group. Most significantly, it allows for the sharing of the concepts of past, present, or future and putting the aforementioned into their context. The further invention of written languages allowed for histories to be documented in terms of their original recording by eyewitnesses rather than be passed from generation to generation through oral histories. Languages are an extension of the culture and embedded within a language are meanings imparted by the perceptions of the culture. A language, therefore, also includes cultural perceptions, philosophy, biases, prejudices, elements of its religion, and its misconceptions. ▪ The term "medicine" means one thing to an American Indian and quite another to a Minnesotan of Swedish descent.	Within every culture, there are subcultures. In Minnesota, it might be said that we have urban, suburban, rural, and agricultural subcultures. Because of their significant contribution to society, our agricultural constituency has always represented a strong lobby in policymaking. In a culture's language, words can convey emotional prejudice. Before the time of chemical cultivation, plants that invaded crop fields were removed by hand and later by cultivators drawn by horses or tractors. These invading plants became known as "weeds." Native plants and wildflowers that fell into this category became "noxious weeds." Every county that had any significant amount of agriculture also had a county "weed" inspector, and there were regulations on the books that mandated their removal. Other words created to imply undesirability were "pest," such as a pocket gopher and "varmint" such as a woodchuck. All hawks were categorically lumped under the term "chicken hawk" and killed.

Concepts and their applications to natural and social systems

Concept **Member**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition A distinct part of a whole. **Statement** Students demonstrate understanding that natural and social systems are entities and contain parts that are members of those systems. **Discussion** Interacting members (parts) of a system are the elements that give the system its properties. The addition or deletion of any of these members may change the function and properties of the system.	The members of an ecosystem are equal to its biotic parts. If any member of a particular ecosystem is eliminated or altered, the interactions of that member with other members may disappear or be altered. This introduces a change in the properties of the ecosystem. ▪ Snowy owls of the North American tundra feed primarily on lemmings. When the lemming population is very low, the owls migrate southward to different ecosystems in search of alternative prey species. ▪ One type of edible oyster mushroom grows only on dead aspen trees during early summer. Without disturbance to this forest, aspen will eventually be replaced by maple and birch in a normal succession. Two members (the mushroom and the aspen) have been removed, and the ecosystem will have different properties.	Everyone is a member of various groups, ranging from family and friends to the global community. Membership can be formal like joining a sport team or a club. It can also be informal such as family and friends. Each member of a group has a role to play. A parent's role is to raise children. A teacher's role is to teach students.	All humans and animals are members of the earth's natural systems. Human membership can affect natural membership by degrading habitat. For instance, dumping waste into an area can kill the habitat of plants and animals. Members of society affect each other's membership as well. One member may use more water or eat more food than he or she needs. This may affect another member's ability to get enough food and water to survive.

Concept **Migration**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) To move from one region to another by chance, instinct or plan. b) Direct movement from one locality to another, with a periodic return to the original locality. **Statement** Students demonstrate understanding of the processes and results of the migration of living organisms, e.g. plants, invertebrates, insects, reptiles, amphibians, birds, mammals, and humans. **Discussion** Most people associate migration with the movement of birds southward in the fall for the winter months. This movement, however, is also found in insects, fish, reptiles, and mammals. Most migration is associated with climate factors or reproduction. It may also take place because of poor habitat or pressures caused by overpopulation.	▪ Invertebrate populations drift in ocean currents. Whales and fish follow them for food. Their predators, in turn, follow them. ▪ Wildlife populations migrate in relation to the seasons and for purposes of reproduction, e.g. geese, ducks, songbirds, and caribou. ▪ Wildlife species can be introduced into new areas by other wildlife species, e.g. fish eggs attached to birds brought into new lakes or streams. ▪ Wildlife species will migrate, adapt, or die if their existing habitat no longer meets their survival needs.	Humans migrate in response to population pressure, e.g. settlement of the New World and the Irish response to the potato famine. Humans also migrate in response to cultural pressures such as war or persecution or in the desire to better their lives or obtain advantages for themselves and their children. Hunting and gathering cultures migrate to follow their food source. This creates circumstances to which the culture must adapt, e.g. shelter and technology must be portable. Examples of this are the buffalo hunting tribes of the American west and the nomadic reindeer herders of Siberia. Migration often brings people in contact with others and other cultures they have not met before. In the process, people learn new ways of doing things or thinking about things that they have not adopted before. They may borrow new ideas, technologies, and words. In turn, they carry their own patterns into new areas. Migration may contribute significantly to change in culture.	When, where, and how many people migrate affects the natural environment. If an area becomes overpopulated, environmental degradation usually follows. Where people live and how they treat habitat can affect the migration of animals. For example, buffalo were migratory but no longer exist in their natural state. Many bird and butterfly populations are low due to the loss of habitat throughout their migratory areas. ▪ The Irish settlement of the New World came in response to population pressure and the potato famine caused by the potato blight.

Concepts and their applications to natural and social systems

Concept **Mutation**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The act or process of being altered or changed. **Statement** Students demonstrate understanding of the process, results, and factors that can cause genetic changes in organisms. **Discussion** Mutations are accidents of gene reproduction that yield chance versions of genotypes. If the mutant survives to reproduce the altered structure, it will pass the change on to subsequent generations until new mutations intervene. All organisms, from the simplest to the most complex, build their bodies and those of their offspring from the environment. An organism that could exist in only a single environment would not remain alive for long because the environment is always changing. A species is concerned not only with the prevailing environment at any given moment, but also with the whole sequence of environments which the mutant meets during its existence. In the last analysis, evolution is a long-term sequence of changes in the genes.	▪ Fossil records show that many plants and animals have changed over long periods of time. ▪ Many disease-causing micro-organisms have mutated and are now resistant to antibiotics. ▪ Some organisms that live under-ground have lost the function of their eyes and, in some cases, the eyes themselves. ▪ Birds of the same genus have evolved specialized bill structures that help them take advantage of different food sources. ▪ Some plants have evolved colored flowers to attract insects for pollination.	This term is not significantly useful to this discussion of social systems. It is not a term that is commonly used in the analysis of social systems.	▪ Scientists have purposely guided mutations to produce new varieties of plants and animals (corn, dogs). ▪ Some species of insects have developed immunity to insecticides. ▪ Some substances introduced into the environment by people cause mutations.

Concepts and their applications to natural and social systems

Concept **Niche**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The functional role an organism plays within a community or ecosystem. **Statement** Students demonstrate understanding of how organisms function in relation to the food and energy levels of an ecosystem and how that relationship might cause physiological and anatomical modifications. **Discussion** This concept focuses on how an organisms "fits" into its habitat — what it eats, who eats it, where it lives, and reciprocal relationships between the organism and the community's environment or other organisms.	A number of widely separated regions of similar ecological makeup may have different species occupying the same niche (ecological equivalents, producer, consumer, decomposer, herbivore, and carnivore). Specialized activities necessary for survival by a species in a particular niche may ultimately lead to physiological, behavioral, or physical changes in that species (birds' bills, wings and legs, nocturnal, diurnal).	This term is not significantly useful to a discussion of social systems and is not a term that is commonly used in the analysis of social systems. However, human cultures have developed many alternative methods of meeting the same basic survival needs. Societies have specialized occupations, all of which contribute to the survival of the social system. Individual jobs in a social system can be thought of as being roughly analogous to niches in natural communities.	Cultures living at the same latitude meet their basic requirements for food, water, shelter, and space differently.

Concepts and their applications to natural and social systems

Concept **Parts and objects**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Part:** a) A portion, division, or segment of a whole. b) A component that can be separated from a system. **Object:** a) Anything perceptible by one or more of the senses, especially something that can be seen and felt; a material thing. b) A person or thing serving as a focus of attention, curiosity, discussion, feeling, thought, or action. **Statement** Students demonstrate understanding that natural and social systems are composed of components or parts that can be used to define or understand those systems, and collectively influence system structure and function. **Discussion** To understand natural and social systems, it is important to think about the whole in terms of its parts and how they relate to one another. Describing the components comprising a given system helps to define and begin to understand that system.	Plants and animals can be described in terms of their parts. These properties can be used to describe groups of organisms in terms of like and not alike. This is the basis of the taxonomic system of classification. Organisms living in an area can be described as being parts of that ecosystem. Ecosystems comprised of the same or very similar abiotic conditions tend to contain the same or similar plant and animal parts performing the same functions in the food web. There may be a variation in species in widely separated geographic regions, but the producer, consumer, and decomposer relationships will be nearly the same. The parts of multicellular organisms may vary in shape and relative location, but they all provide for the functions of locomotion, ingestion, digestion, excretion, elimination, coordination, and reproduction.	The parts of a social system may consist of its people, institutions, economy, form of government, religion, way of life, mores, relationship with other social systems, rituals, language, modes of transportation, etc. By careful observation of the interaction of these parts, it is possible to build an understanding of how that social system probably works. Objects in a social system may be the artifacts it creates, such as its buildings, art, waste, tools, monuments, manufactured goods, etc. Scientific study of these objects from ancient cultures helps us better understand how these people lived and, sometimes, the environments in which they lived and the foods they ate. ▪ Mummies have revealed to pathologists some of the diseases and parasites that plagued these ancient people.	▪ Bees and flowers are parts of several kinds of ecosystems. The relationship between bees and flowers produces honey that people harvest for their own use. ▪ Human communities are usually established in locations where the parts of an ecosystem, or its objects, meet their needs, i.e. a river for water and transportation. ▪ Industrialized societies generate non-recyclable waste (parts), which accumulates in dumps and landfills that are created by modifying habitat.

Concepts and their applications to natural and social systems

Concept **Patterns**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A design of natural or accidental origin. b) A composite of traits or characteristic features. **Statement** Students demonstrate understanding that systems consist of patterns that may reflect parts, processes, and properties. **Discussion** Patterns are always present in natural and social systems. These patterns are the result of interactions among the biotic and abiotic parts. If a system's parts become mismatched, misconnected, damaged, or missing, a pattern that is the property of a system may be altered or disappear.	Patterns are very visible in ecosystems. They are the result of interactions of the biotic and abiotic parts of the ecosystem. Sometimes they are the result of abiotic-biotic factor interactions and other times the result of biotic-biotic part interactions. There are also process patterns represented in these systems. ▪ In northern Minnesota, a floating bog is created by sphagnum moss mats growing outward from the shoreline at an undisturbed rate of about one inch per year. As the dead plant material accumulates, the mat becomes connected to the bottom of the pond. When this happens, different types of plants will grow on it. ▪ Bulrushes only grow on firm sand bottoms in shallow water. Their presence along a shoreline represents a pattern of bottom properties. In northern Minnesota, a meadow left undisturbed will usually be replaced by aspen. The aspen, in turn, will be replaced by birch and maple unless invaded by balsam fir. This pattern (process) of replacement is referred to as "succession."	Social groups demonstrate patterns: • **Establish hierarchies** for purposes of providing an orderly, systematic process of group decision making. Although these hierarchies, historically and at present, represent a wide variety of alternatives, their basic purpose remains the same. • **Create systems of exchange.** This common trait of exchange may be simple barter of objects or services, small clay disks with hieroglyphs representing objects of exchange, or currency. The shared purpose of these systems is to allow the members of a society to obtain objects or services they need or want. • **Invent a verbal system of communication** that increases the groups' survival potential, provides a means of sharing information or ideas, and allows information to be passed on to the next generation. In most, but not all societies, a written language follows the sophistication of the oral language. • **Provide systematic education** for their young, which helps prepare the next generation by giving them the skills and knowledge to function successfully in the group. This process may be provided by elders or relatives, through apprenticeships, or formal school programs.	Ecosystems affect the social groups that live in them. Methods of obtaining food, water, and shelter from the elements follow patterns that generally reflect the group's adjustment to the local environment: ▪ Before the introduction of fossil fuels, Eskimos in the arctic did not have fuel for heating and cooking. Food was eaten raw or dried, heat in winter was provided by whale or seal oil lamps, and shelters were igloos made of blocks of snow. ▪ Social groups living in desert ecosystems tend to congregate around water sources or migrate between water sources to obtain food. These groups tend to have portable technologies and shelters. ▪ A pattern demonstrated by social groups living adjacent to marine, river, or lake ecosystems is the development of technologies to extract food from them.

Concepts and their applications to natural and social systems

Concept **Politics**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Using, displaying, or proceeding from policy. b) Pertaining to or dealing with the study, structure, or affairs of government, politics, or the state. **Statement** Student demonstrates understanding that social systems create policies, procedures, and hierarchies to provide order in the operation of the system and that any given cultural system has both formal and informal subsystems of policymaking, decision making, enforcement etc. **Discussion** Political systems are inventions of social groups established for the purpose of maintaining an orderly decision-making process and coordinating the activities of the group. The elimination of chaos in group behavior reduces conflict and has high survival value for the group.	Although leadership and the formation of alliances have been observed in the social interactions in natural systems, this term is not significantly useful to this discussion of natural systems. It is not a term that is commonly used in the analysis of natural systems. Hierarchies and order in groups of animals is a function of dominance, e.g. the alpha male and female in a wolf pack are the only breeders (controlling the population) and the rest of the pack follow their lead in activities (group orderliness).	Group living requires conflict management, clearly defined expectations regarding behavioral patterns, and a source of authority from which decisions affecting the group come in an orderly fashion to avoid chaos. A social group's political systems are idealized models of how to do this and appear in many forms in different cultures. Although the political system represents an ideal and does provide order in group decision making, behavior regulating, etc., social systems always have an informal aspect to this process. Interactions within this subsystem of the process usually take place informally and prior to the ritualized decision-making process. ▪ Monarchies have either a king or queen that serves as the source of all authority. They are usually supported by advisors who help them in their decisions. On a smaller scale, a chieftain of a tribe, a religious leader, or a village elder may serve this function. ▪ Representative political systems usually have elected or regional leaders who participate in governing as a representative of the people who live in their regions, states, etc.	Sportsmen's groups (informal) lobbied their legislators (law making formal) to have a national tax on the sale of sporting goods (Pittman Robertson Act) to generate money for fish and wildlife habitat management that would supplement federal budget allocations for this purpose. Big business (informal) lobbies legislators to try to get legislation passed that favors the operation of their businesses. Persons of wealth or of a celebratory stature often promote causes and recruit constituencies (informal) for that cause to contact their legislators about the issue or cause.

Concepts and their applications to natural and social systems

Concept **Population**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) All the organisms that constitute a specific group or occur in a specified habitat. b) Designating or pertaining to the species that is most characteristic of a habitat that may determine the presence or type of others. **Statement** Students demonstrate understanding that populations of plants, animals and humans are parts of ecosystems and that one or more species may be dominant to the extent that they influence the size or presence of other populations. **Discussion** The size of a population of living things is influenced by abiotic factors, available food, competition for food and space by other species, disease, and predation. An association of plants in an area is known as a plant community. These communities are named after the most numerous (dominant) plants, e.g. spruce-fir, aspen-birch.	Plant populations compete for sunlight. Taller plants reduce sunlight available to shorter plants, limiting them to species that can grow in shade. Some plant species can gradually change the abiotic factors in an area, changing the plant populations that can live there. The dominant plant species in an area will change over time when the area is invaded by tall, more shade-resistant plants (succession). A long-term change in abiotic factors can favor some plants that then become more numerous than the former plants, which may even disappear from the area. A change in the dominant producer plant population can change the dominant population of consumer species. Wildlife populations can become so numerous that they deplete their habitat of food and shelter. Depletion of a habitat can result in migration of wildlife that makes them more susceptible to predation. Large populations of animals in a limited habitat are more susceptible to disease.	Population is the number of people living in an area. It can range from global to township to classroom. It is studied by looking at birth rates, death rates, and migration. Population determines what happens in social structure. For instance, how many jobs are available in various areas of the world, how much food and water is available, and how much space is available for people to live largely depends on the number of people that must be provided for. For example, the length of time one has to wait in line is partially determined by how many people are ahead of you. If there were 20 people waiting in line for the bathroom, number 21 would understand the frustration of population pressures.	The size and lifestyle of the population are the two most important factors to consider when discussing the environment. Since humans rely on the environment for virtually everything, more people translates into more being taken from the environment. Having too many people take from these systems without letting them regenerate may cause permanent damage. The consumption lifestyle of a population is important to understand. How much food and water does one person need versus how much water does one person use? Can the earth provide for all of us if the population keeps growing? If it cannot, who will be provided for and who will not? ▪ For example, when it comes to dishing out a dessert like cake, everyone usually gets a piece. It is not fair if one person gets three pieces while two people are deprived.

Concept **Predation**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The act or practice of plundering or marauding. b) The capture of prey as a means of maintaining life. **Statement** Students demonstrate understanding of the causes, processes, and results of plant, invertebrate, insect, reptile, amphibian, bird, mammal, and human predation. **Discussion** Although predation has a detrimental effect on an individual organism, there are long-term benefits in preventing overpopulation of an ecosystem that could lead to habitat destruction. Most animals in any ecosystem will have one or more predators that will hold the population in check. Prey species also tend to change over time by acquiring behavior, physiological, and physical modifications that help them cope with predators in their ecosystem. New predators and parasites introduced into an ecosystem, however, bring a whole new set of population pressures that the ecosystem has not evolved to cope with.	In all types of living things, there are some species that kill other species for food. The abundance of prey species controls the number of predators that can survive. Unchecked predation may completely depopulate an area of a particular species. There are no major groups of plants or animals that are not parasitized. Parasites are usually highly specialized (reproduction, body parts), and this usually prevents parasitism from reaching disastrous proportions in ecosystems where they have evolved. In addition, parasites can be infested with parasites.	Humans are predators. They historically and presently rely on other animals for food. In the agricultural revolution 7,000 to 9,000 years ago, humans learned to domesticate their prey so the animals would be easier to obtain and less dangerous to use. The agricultural revolution was a cultural adaptation that occurred in response to population pressure — the earth could not support the growing numbers of humans through hunting and gathering. Human predation is posed as one reason for the disappearance of some of the large ice age mammals.	▪ Natural resources and habitat inadequacy represent causes for human conflict even today, e.g. access to petroleum. ▪ Hunting and fishing are forms of modern human predation but laws have been created by the social legal systems as methods of regulating wildlife harvest. ▪ People can create physical change in the environment that introduces new predators into ecosystems that haven't evolved to cope with it, e.g. the sea lamprey in Lake Superior.

Concept **Probability**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Likely to happen or to be true. b) The likelihood of occurrence of a specific event. **Statement** Students demonstrate understanding that some phenomena in social and natural systems are subject to variables that may change their parts or processes under certain conditions and that forecasting the function of these systems is not a matter of certainty. **Discussion** The function of social and natural systems is a product of many interactions among their parts and other systems. They are also influenced by inputs from outside systems. When we speak of forecasting interactions in or between natural and social systems, we can only speak in terms of possible (probable) outcomes. The reliability of this forecasting increases with increased information about how these systems work.	Natural systems are comprised of interacting parts and processes that, if not interfered with, are very (probably) likely to continue functioning as before. The species may change with the geography, but the specie's function () will probably remain the same. This general stability of natural systems allows scientists to predict the general probability of finding similar parts and processes in other ecosystems of the same type. It is not, however, always easy to predict the result of changing some part, process, or connection in natural systems. One might predict the probable population increase of a particular prey species if there were fewer predators. But there are other variables involved: • Another prey species may have a greater reproductive potential and rapidly increase in numbers, crowding out other prey species. • The prey species may become so numerous that they exhaust their food supply faster than it can be replaced. This results in starvation and habitat degradation.	In social systems as well as natural systems, any predictions made about how a system will react in the future is a matter of probability, not of certainty. No matter how much is known about a social system, there may still be variables, both internal and external, that will influence that system and that are unknown or unaccounted for by the analyst. For instance, even though companies spend a huge amount of their budgets trying to find out and predict what products will appeal to people by analyzing their age, economic status, sex, where they are from, what culture or lifestyle they have, and many other characteristics, companies still have many product failures as well as successes. They have to measure their success by the percentage of successes that they have, which indicates to them the probability of any one product becoming a success or a failure.	Social systems try to predict how the natural system will probably respond, but other variables in the natural system are often not thoroughly understood. ▪ Sparrows and starlings were brought to the U.S. as biological control agents by people in Europe who had observed that they were competitors. However, the birds expanded into new habitats in America, displacing native species through competition for food, shelter, and places to raise their young. ▪ Early wildlife managers observed that forests maintained in smaller tracts produced more edge effect and supported more breeding pairs of ruffed grouse. However, this brought nesting songbirds closer to the edge of the woodland where their nests were more often parasitized by cuckoos and cowbirds. This practice resulted in more grouse but fewer songbirds. Development of technology that enabled the paper industry to use aspen added value to this type of hardwood forest. Clear-cut harvesting of aspen allows aspen to regenerate from runners under the soil, producing another potential harvest in 50 years. In many areas, a forest's natural succession to basswood and maple trees was interrupted and the species associated with those types of forests declined.

Concepts and their applications to natural and social systems

Concept **Products**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Anything produced by human or mechanical effort or by a natural process. b) A direct result; consequence. **Statement** Students demonstrate understanding that interactions of the parts of systems can include processes that result in outputs that can encourage what is going on in a system, discourage it, or provide something that the system or another system can use. **Discussion** Systems can be connected to one another and to larger and smaller systems. The output of one system can become the input for another system or other systems. It is not always easy to predict how the output of one system will affect others.	Outputs (products) of a biotic system can benefit the system that produces it, be used by another biotic system, have a negative effect on another biotic system, or become part of an abiotic system. ▪ Green plants use carbon dioxide from the atmosphere to create a carbohydrate molecule that serves as the building block for all the plant's parts. ▪ In their reproductive process, flowering plants produce pollen that is converted by bees into honey that serves as food for the hive. ▪ Venomous species have evolved in many ecosystems. The toxin they produce is used to discourage other species from messing with them. It can be lethal, cause sickness, or merely be painful to the other organism. ▪ Tiny plankton living in the oceans at times reached enormous numbers. They secreted a carbonate covering for the cell parts. When they died, they settled on the ocean floor, forming a carbonate layer. The White Cliffs of Dover in England are a product of these tiny organisms.	Products of social systems are artifacts generated by the interaction of its parts. These products may be used within a social system or be passed on to one or more other social systems. This interaction may be local, regional, continental, or international in scale: ▪ Stone that was used by American Indians to make pipes was quarried in southwestern Minnesota and has been found in all parts of the United States. ▪ Following World War II, the United States helped Japan build a manufacturing economy. Today, the United States is one of the largest importers of Japanese automobiles. ▪ Minnesota's Cargill Corporation has one of the largest private fleets of ships in the world, and they ship grain worldwide. ▪ Some products produced by social systems are waste and, depending on the scale of its production, may become a problem for the social system, e.g. smog produced by automobile exhaust.	▪ Solid waste generated by social systems poses disposal problems. Landfills must be created at the expense of habitat. Some of the waste is toxic and gets into groundwater supplies. ▪ Nuclear waste is a product of atomic generating plants. This waste is highly toxic, and its toxicity may last as long as 50,000 years. Ways must be found to safely store these wastes in a manner that protects the environment and the social systems that generated it. ▪ Synthetic chemicals invented by social technologies are not always recyclable by natural processes nor in a timely fashion. Many of these compounds are harmful to the environment and people. ▪ Commercial food processing uses a lot of water. Wastewater coming from this process contains phosphates, nitrates, and other chemicals that must be removed before returning the water to the environment. New technologies are being invented to do this.

Concepts and their applications to natural and social systems

Concept **Properties**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Qualities serving to define or describe an object. b) Characteristic attributes possessed by all members of a class. **Statement** Students demonstrate understanding that the properties of social and natural systems can be used to define and describe them for purposes of creating hierarchies of relationships that help build understandings of these systems. **Discussion** When natural and social systems are put together, the interaction can create properties that they would not otherwise have. Some of these properties can be beneficial to both systems; others can cause parts of a system to disappear, become damaged, mismatched, or misconnected. In this event, the system may not function as well or not at all.	Objects in natural systems have observable properties, e.g. size, weight, color, shape, or existence in different states. These properties can also be used to describe the objects in terms of the materials from which they are constructed, or used to sort a group of objects in a natural system. ▪ The scientific classification system uses properties to separate groups of living organisms, fossils, and minerals. ▪ Taxonomic keys based on similar and differing properties are used to identify or catalog objects under study. ▪ The periodic table of elements is based on slight changes in the properties of atoms that make up our universe. Natural systems also demonstrate properties; e.g. a food web will ultimately demonstrate the properties of producer, consumer, and decomposer relationships. These relationships are based on the energy provided by the sun or some chemical source of energy.	Properties of social systems are essential or distinctive attributes of those systems. This term is much more commonly used for analyzing natural systems. However, it can be used in analyzing social systems. For instance, in analyzing the similarities and differences between a student and a teacher, both are human (an essential attribute) but the student is defined by his or her rights and responsibilities, such as the right to receive teaching and the responsibility to follow the teacher's directions. Though both the student and teacher may be either male or female, this attribute is not essential to defining the teacher-student interrelationship, so it would not be considered a property of these particular social roles.	One property of the technology of social systems is the production of artifacts. This may be as simple as an obsidian knife or as complex as a hydroelectric dam or a nuclear generating plant for electricity. The impact of the properties of these artifacts varies greatly in significance to the continued, "normal" function of natural systems. For instance: • The volcanic glass of an obsidian knife crafted by a stone age culture can become part of the geologic strata without significant interaction with natural systems. • A hydroelectric dam interrupts the amount of water that used to be available to other living organisms downstream while the reservoir fills, interrupts sedimentation patterns, and stops the normal migration of aquatic species that live in the river. • Properties of the waste materials produced by a nuclear generating plant are harmful to living organisms and may last as long as 50,000 years. Natural systems have coevolved over long periods of time and this has allowed for the evolution of recycling systems of materials in the environment. The properties of some of the substances produced by social technology have no recycling counterpart in natural systems.

Concepts and their applications to natural and social systems

Concept **Rate**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition A measured quantity that occurs or is attained within the limits of a fixed quantity of something else, usually time, e.g. a rate of sixty miles an hour. **Statement** Students demonstrate understanding that rate at which a phenomenon or element affects social and natural systems can either encourage or discourage their function and that both types of systems are the result of change over long periods of time, making them less tolerant of rapid change. **Discussion** Social and natural systems are sensitive to rate of change. Rapid rates of change often do not accommodate the modification of a system's parts or processes. These systems may not function as well or not at all following a change of this type. However, not all rapid changes in social systems are harmful.	The parts and processes of natural systems can change over time. This is usually in response to biotic or abiotic inputs to the system from outside the system or from within due to a change in one of the parts of the system. If this happens over a long period of time, some parts of natural systems have the potential to adjust. If this change is abrupt, the system's parts may become damaged, mismatched, misconnected, or disappear. ▪ A large meteor struck the earth about 65 million years ago. The tremendous energy of this event caused extensive fires and placed a huge amount of debris into the atmosphere. Scientists theorize that the suddenness of this event and the length of time that its aftereffects lasted resulted in the extinction of the dinosaurs and a majority of species living at that time. Other species may have adjusted and formed new communities in the changed ecosystem. ▪ The human body maintains a temperature of about 98.6 degrees Fahrenheit. This is due to the rate of heat production by chemical reactions in the body being matched by the body's ability to get rid of the excess heat.	The rate at which change takes place is one of the key factors in the ability of a social system to respond to that change without breaking down. Social systems can often adapt to major changes, given enough time. ▪ The Spanish conquest of the Aztecs was very rapid because the Aztecs confused Cortez with their religion's white god, Quetzalcoatl whose legend stated that he would return to the Aztecs. They were aggressively converted to Christianity by the clergy traveling with the Spanish army. When the Spanish left, the Aztec never reverted to their former religion and highly developed sciences. The Aztec today do not build their ornate pyramids and cities. They are a mixture of two cultures. ▪ Invention of the computer caused a rapid evolution in the way social systems handle and process information. This improved system of information management and communication has benefited social systems.	Urban centers are rapidly growing because there is a wide variety of jobs available that are not provided by the economy in smaller communities. These centers are expanding into suburbs whose creation causes the destruction of natural plant and animal communities. The rate and scale of this growth is endangering some species by reducing their numbers to a point where there is not a viable gene pool. ▪ Technological social systems generate an enormous amount of waste. This waste must be disposed of in natural areas. Even if all the waste generated were biodegradable, the rate of its accumulation far exceeds the ability of natural systems to recycle it.

Concept	Applications to natural	Applications to social systems	Examples of interactions

Reciprocity	systems		between natural and social systems
Definition a) A mutual or cooperative condition or relationship interchange of favors or privileges. b) To give and receive one thing for another. **Statement** Students demonstrate understanding of the causes/motivation, processes, and results of cooperative relationships of interchange in natural systems and human interrelationships in regard to the environment. **Discussion** Ecosystems and cultures depend upon relationships of sharing and exchange. In natural systems nearly everything that is produced by plants and animals becomes a food source for something else. Other relationships are connected to survival. Social systems form mutual relationships to acquire natural resources not available in their area or not available in enough abundance in their area, to exchange technologies with other cultures, and for mutual protection.	Some members of different species are found together in habitats and one member of the association benefits from this relationship (commensalism), e.g. pilot fish and sharks. In some situations, two species must remain together in order to survive (obligatory mutualism), e.g. algae and fungi as lichens. Sometimes a relation exists between two species in which each benefits from the other, but neither must remain with the other in order to survive (nonobligatory mutualism), e.g. buffalo birds and water buffalo.	Social systems are based on the exchange of everything from goods and services to communications. Exchange relationships in a social system are often complex and subtle, which makes analyzing them, let alone manipulating or predicting the future of the system, so difficult. It is often necessary to examine the nature of the exchanges to determine the structure and function of a social system. As with natural ecosystems, social systems are studied by observing or otherwise tracing exchanges that take place and analyzing them. For instance, an analysis of a conversation between two people can indicate their relationship to each other. If someone is listening more than talking, agreeing more than disagreeing, accepting tasks to do rather than suggesting tasks for the other, his or her position probably is, in some way, subordinate to the other.	Throughout history, societies have taken from the environment without giving back. This taking without regarding how it affects the earth has been detrimental. Recently, groups have realized this and are now attempting to make the exchange even. ▪ For example, many groups plant trees to replace the ones that have been cut. ▪ Also, recycling is being done to reuse material rather than taking more from the earth.

Concepts and their applications to natural and social systems

Concept **Redundancy**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition Exceeding what is necessary or natural. **Statement** Students demonstrate understanding that social and natural systems usually contain subsystems that carry on essentially the same functions and that this condition acts as a safeguard to the continued operation of the system should one or more of these subsystems malfunction or cease to function. **Discussion** Natural and social systems may not function as well, or not at all, if parts are missing, damaged, mismatched, or misconnected. This can happen as a result of the disappearance of an input required by the system or the introduction of a new input which is harmful to the system. When a system contains subsystems that perform a similar function, the impact of damage to one of the subsystems performing that function is lessened by virtue of having backup subsystems that continue to function.	▪ Minnesota forests contain foxes, coyotes, and several species of hawks and owls that prey on rabbits. If one of these species were eradicated, the other predator species would keep the rabbit population from growing beyond the replacement capacity of the plant species it uses for food. ▪ In like fashion, these predators also have alternate (redundant) prey species, i.e. rodents. When rabbit populations become very low, the predators turn to these alternate prey species. ▪ The human body has paired kidneys, lungs, and gonads. If one of these is lost to disease or accident, the human organism can still respire, excrete waste from the blood, and reproduce.	This term is not significantly useful to this discussion of social systems. It is not a term that is commonly used in the analysis of social systems. Redundancy, however, does exist in social systems. ▪ Most communities will have businesses that provide the same or similar services. If, for instance, a plumbing business goes out of business, there is usually another to take over the services. The service, therefore, is not lost because another of the "parts" of this social system takes over the function. ▪ Many businesses, hospitals, etc. have a back-up generator in the event that electrical power is lost for a period of time. This allows the output of these systems to continue. ▪ NASA's shuttle flight equipment is always backed up by a duplicate system in the event that an essential part ceases to function during a mission. ▪ Specialized knowledge or skill is never restricted to a single individual and is usually backed up in some sort of records. Loss of one individual does not represent loss of the skill or knowledge to the social system.	Conservation is a major enterprise in Minnesota. Multiple agencies have been created and citizen groups have been formed that have overlapping or shared environmental concerns. ▪ County Soil and Water District, Federal Soil Conservation Service, and Minnesota's Department of Natural Resources-Division of Soil and Minerals personnel have shared concerns about soil conservation. Reduction of the activities of one of these agencies does not mean that soil conservation efforts will end. ▪ In the Minnesota Department of Natural Resources, the Divisions of Forestry, Wildlife, Waters, and Trails and Recreation have shared management concerns for our forest resources, their wildlife, and provision for their multiple use. ▪ There are many national, state, and local sportsmen's groups who provide money and manpower to conserve natural resources. The loss of one or more of these groups does not mean the loss of organized volunteer citizen support for conservation.

Concepts and their applications to natural and social systems

Concept **Religion**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The expression of humankind's belief in and reverence for a superhuman power recognized as the creator and governor of the universe. **Statement** Students demonstrate understanding that the religious subsystems of differing cultural systems may vary greatly in their theologies, practices, and relationship to the environment. **Discussion** Belief in a supreme being as creator and custodian of the universe is unique to social systems. It is a property of all cultures. Religions characteristically proscribe how one relates to the creator, personal codes of behavior, manner of relationship to others, and include a concept of life after death. Some, but not all religions embrace the belief that one must pass through several reincarnations before one is admitted to heaven.	This term is not useful to this discussion of natural systems because it is a phenomenon that does not exist in natural systems.	All cultures practice a religion of some kind. Although religious beliefs vary greatly among the cultures of the world, all possess the elements of a theology describing a deity and its relationship to humankind, codes of interpersonal interaction, and provide a spiritual leader for each social group. Religion is closely meshed with other interactions within a social system and may influence non-religious interactions within that social group.	Among low technology cultural groups that live in close association with the environment, religious beliefs tend to be animistic, i.e. natural phenomena and things both animate and inanimate are held to possess an innate soul. It was tradition for American Indians to ask the prey they killed for forgiveness because they took its life for the good of the tribe. These cultures recognize their oneness with the ecosystem in which they live because of their closeness to its interactions and vagaries. Industrialized societies have mostly lost this awareness due to the technologies they employ to control their environments. This perspective is a limiting factor in making sound environmental decisions, particularly when political interests are involved in the process.

Concepts and their applications to natural and social systems

Concept **Resources**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) An available supply that can be drawn upon when needed. b) Something that can be turned to for support or help. **Statement** Students demonstrate understanding that natural and social systems contain human, artifact, and natural resources that can be either renewable or non-renewable. **Discussion** A system must have access to resources that are essential to the operation of its parts. This is especially essential to those parts of systems that are processes. As a system's resources become fewer, it may not function as well or, at some minimal tolerance, not at all.	Ecosystems contain biotic and abiotic resources that are used by its biotic parts. These may be renewable or non-renewable resources. If a resource is missing that is essential to a part of an ecosystem, it may not function as well or not at all, affecting those parts of the ecosystem with which it interacts. ▪ Sumac stands grow old, fail to reproduce, and disappear. This has been attributed to the depletion of a non-renewable trace mineral resources essential to the sumac. ▪ "Fairy rings" are circles of mushrooms that can reach large diameters. This movement is attributed to the mushrooms moving outward from the original growth as they deplete the soil of the nutrients that they need. ▪ Prey species may be considered a renewable resource to their predators. As long as the predator's harvest of prey does not exceed the ability of the prey species to maintain a viable population, the resource remains available unless the prey species' food supply is depleted.	In addition to the biotic and abiotic resources available to natural systems, social systems also include human resources that provide the system with skills, experience, knowledge, invention, technology, etc. ▪ Minerals, such as iron, copper, bauxite, etc., are extracted from the earth to provide the raw materials for society's manufacturing industries. ▪ The glaciers and large glacial lakes formed during their retreat from Minnesota left fertile soils behind that supports a large agricultural industry. ▪ Minnesota's forests provide lumber and fiber that supports our forest products industry that supplies building materials, paper, and employment for many people. ▪ Highly trained and skilled people provide medical services, research new ideas, guide successful businesses, fabricate products, process food, construct homes, etc.	▪ When essential minerals are depleted to a point where crop production diminishes, farmers rotate to crops that replenish those minerals or they add them to the fields in the form of chemical compounds. ▪ Fire is essential to maintain native prairie areas and the wildlife populations that make prairies their home. Historically, this was done by wildfires of natural causes and uncontrolled burns by American Indians. Settlement of the land has made wildfires potentially too costly in terms of property damage and the safety of the people who live in these areas. Wildlife managers conduct controlled burns in prairie areas every three to five years to maintain the habitat. ▪ The harvest of Minnesota's fish and game species is carefully regulated by resource managers to prevent excessive depletion of these species. ▪ Forests are being managed so that no more trees are harvested in any given year than are being planted or regenerated. This provides a sustained yield of wood fiber for our forest products industry.

Concepts and their applications to natural and social systems

Concept **Scale**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition A progressive classification, as of size, amount, importance, or rank. **Statement** Students demonstrate understanding that the size or extent of a phenomenon manifesting itself in social and natural systems can either encourage or discourage the usual function of those systems, even to the point of destruction of the system as it once was. **Discussion** Although the phenomenon of scale in social and natural systems can be very large or very small, it is a property of the successful functioning of the system. The scale of inputs to systems and outputs from systems that affect other systems usually has a tolerance or range within which the effect on a system is not damaging. Once that tolerance range is exceeded, however, the parts and processes of a system may not function as well or not at all. The outcomes of this effect on the system and other systems it interacts with are not easy to predict.	Scale (size, amount) is an important concept in natural systems. A system may not function as well or gradually cease to exist when its parts become damaged, mismatched, misconnected, or disappear altogether because the system itself, or input to the system, has become too small or too large. Ecosystems demonstrate their greatest ability to endure over long periods of time when there are many member species of plants and animals in the community. This diversity of interdependent species imparts stability to the ecosystem because of the duplication (redundancy) of roles they play in moving energy through the food web. This requires space. A reduction of scale in an ecosystem will result in loss of the diversity of species that can be supported by the system. This can make the ecosystem vulnerable to drastic, short-term abiotic change agents. ▪ High winds in north central Minnesota blew down several million acres of trees. This reduced the scale of habitat available, reducing the biodiversity of the area. This posed a “die, adapt, or move” situation for the wildlife there. Natural regeneration replaces the trees and increases the scale of habitat available. This reestablishes the potential for biodiversity but doesn’t guarantee it will return to the ecosystem.	The size of a social group can have many consequences for the social system or other social and natural systems with which it interacts: ▪ Hunter gatherer groups must be moderately small and mobile. As the game and plant forage in an area becomes scarce, the group must pack up and move to another more bountiful area. When the group becomes too large to support this lifestyle, it must adopt agriculture and become sedentary or splinter off small groups from the main group to hunt and forage on their own. ▪ Large urban areas have more job opportunities (niches) than smaller communities to accommodate the next generation of workers. Smaller communities, therefore, tend to loose their younger generation to urban areas. Conversely, the logistics of urban areas are so complicated that they are more vulnerable to natural disasters.	In all species, there appears to be a minimum population needed to avoid extinction. ▪ Wild populations in natural systems are large enough that genetic inbreeding does not normally occur. In the zoos of the world, however, the size of the captive species population is small enough that it will not support many generations of breeding, even with international cooperation for breeding programs. Scientists are concerned about some of the rarer species, e.g. pandas, becoming extinct. ▪ Urban sprawl into the suburbs consumes vast acreages of habit each year. The maintenance of genetic diversity among wild populations will decrease at that point where the habitat is not sufficient to support the numbers of individuals in a species to maintain it.

Concepts and their applications to natural and social systems

Concept **Similarities and differences**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition **Similarities:** Showing some resemblance; related in appearance or nature; alike though not identical. **Differences:** The condition or degree of being unlike, dissimilar, or diverse; disparity; variation. **Statement** Students demonstrate understanding that similarities and differences of the properties of the parts and processes of natural and social systems can be used for the purpose of comparing and learning about how these systems work. **Discussion** Similarities and differences that appear to be constant are useful in building understandings about the parts of natural and social systems and how these systems work and interact. Careful observation allows the observer to make predictions, to identify processes, inputs and outputs, and to define boundaries of the systems being observed. Making a change in a system, however, can produce unpredictable results.	Similarities and differences of the properties of the parts of natural systems form the basis of the taxonomic system of classification used to characterize species and their relationships to other groups of organisms. For example, the bills of woodpeckers have the property of being elongated and chisel-shaped. Taxonomists place all these species in the Family *Picidae*. Terrestrial communities of plants and animals demonstrate similar properties of producer, consumer, and decomposer relationships. The species that participate in these similar relationships may, however, differ greatly in their structure or behavior due to special conditions within their habitats, e.g. desert plants and animals compared to prairie plants and animals.	In analyzing and describing the parts of a social system, it is necessary to define the similarities and differences among and within parts in order to understand that system and how those parts interrelate. For instance, if one is analyzing the social system of a school, many of the parts are human and although there are other parts like rules and regulations, there are differences in the humans and the roles that they play. Some are students with particular rights and are administrators with still other rights and responsibilities. One can only understand that school system if those roles are known. It is also necessary to analyze the similarities and differences between two social systems or a social and natural system that are interrelating or might interrelate in order to predict the results (consequences) of that interrelationship. For instance, when people of different cultures immigrate to the United States, how well they fare in this culture has much to do with how similar their traditional cultures are with the ones into which they are moving.	▪ Cultures who live in non-mountainous ecosystems that make travel difficult typically use rivers and streams as their main routes of travel, communication, and trade. ▪ Medicine uses the similarities of an immune response in people to an infectious agent to create vaccines to develop immunity prior to actual infection by disease agents. ▪ The trade routes of cultures not using cars and airplanes for travel across arid areas were all related to the availability of water between marches.

Concepts and their applications to natural and social systems

Concept **Species**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A fundamental category of taxonomic classification, ranking after a genus, and consisting of organisms capable of interbreeding. b) An organism belonging to such a category, represented in taxonomic nomenclature by a Latin adjective or epithet following a genus name. **Statement** Students demonstrate understanding that a species is a population of individuals, including humans, that have the same characteristics and are able to breed and have fertile offspring. **Discussion** Although there may be small variations within a species, called races, their characteristics can be reliably used to identify them as a group. These groups of individuals can also be related directly to preferred habitats wherein they occupy characteristic locations in the habitat's food web.	Earth's geologic record shows that species have both disappeared and changed over time. The basic structure of food webs of terrestrial, aquatic, and marine habitats, however, has changed little. They are comprised of producers, consumers, and decomposers. Species of populations evolve to occupy various positions in the food webs founded on this basic design, cycling minerals, carbon, gases, energy, and water through the ecosystem. Sometimes, when two species compete directly for the same food source, behavioral changes can reduce the competition, e.g. hawks hunt rodents and rabbits during the day, owls do so at night. Some species of consumers evolve into the role of scavengers and feed on the already dead remains of other species, i.e. vultures. Over long periods of time, species isolated on islands have evolved characteristics different from their ancestors on the continents. Other species show a tendency to be darker in moist climates and lighter colored in dry climates.	This term is not significantly useful to this discussion of social systems. It is not a term that is commonly used in the analysis of social systems.	Over time, species living in the same ecosystem develop a dynamic balance in species population numbers. Human societies growing in population change their ecosystem by creating farm land or by building and expanding their cities, towns, and suburbs. The species that were living there must die, adapt, or move to an alternate suitable habitat that is occupied by the same or other species. This produces competition for food, water, shelter, and living space. Some species may disappear from an area as a result of this. ▪ Human hunting has overharvested some species causing them to become extinct, e.g. the passenger pigeon. ▪ Human manipulation of the reproduction of some species has changed them drastically, e.g. dogs, cats, cattle, and horses.

Concepts and their applications to natural and social systems

Concept **Stratification**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) To form, arrange, or deposit in layers. b) To develop different levels of caste, class, privilege, or status. **Statement** Students demonstrate understanding that the processes and/or products of systems may be layered as a result of the interaction of its parts. **Discussion** One of the properties of social and natural systems may be the output of layering produced by the interaction of its parts. These layers become part of the system's environment. The production of layers may or may not alter the properties of the system.	The interaction of a natural system's parts can produce layers. These layers are usually the result of interactions among the system's biotic and abiotic parts. The output of one part becomes the input for another part, forming the layer. These interactions can be abiotic-abiotic, abiotic-biotic, or biotic-biotic: ▪ Rock weathers into mineral particles. These particles are washed away by precipitation. The water velocity sorts these particles by weight and size, depositing them in deltas, basins, and flood plains. The result is a sorted and layered sedimentary deposit. ▪ Soils consist of mineral materials and humus formed from dead plant material. These layers in soils are known as "horizons." ▪ The human body is covered with skin that protects the body's internal organs. It is layered in structure and formed by chemical interactions within the body guided by genes. ▪ Undisturbed Minnesota hardwood forests contain three layers, i.e. groundcover, understory, and canopy. Some species living in the forest have specialized into these layers.	Social systems also demonstrate stratification of the people that are part of the system: In India, people are assigned to one of four "castes" within their society by heredity. People within a caste are assigned certain duties that only they can perform and may marry only within their caste. Stratification may also reflect wealth. In the United States, we recognize the categories of upper, middle, and lower income families. Caste systems may also be based on authority. In the military, generals tell colonels what to do. Colonels tell majors who tell captains who tell lieutenants what to do. Religious orders have authority layers that include the leader of the sect, regional leaders, and their subordinates. Caste systems can be based on sex. At one time in the United States, women could not control their own money or vote. In many of the third world countries, women still do not have the same status as men in their societies.	▪ In Germany, foresters manage their woodlands in three layers: very tall trees, understory shade tolerant trees, and forest replacement trees. All harvest is done selectively as the timber is ready. This is different from the aspen, birch, and oak clear-cut practices in the United States. ▪ During the warm summer months, lakes in Minnesota form thermal layers. The warmer surface water is separated from the lower cooler water by a transition layer called the thermocline. The invertebrates and algae that concentrate in this layer attract minnows. Predators that feed on the minnows suspend just below this layer in the cooler water, rising up to feed in the thermocline when hungry. Fishermen use this information to increase their success during the summer months. ▪ Oceans have currents that flow at various depths beneath the surface. The depth of the current is a function of the temperature of the water and the amount of dissolved salt that it contains. These layers will deflect sonar, and submariners use this information to hide from ships searching for them.

Concepts and their applications to natural and social systems

Concept **Structure**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The configuration of elements, parts, or constituents in an entity. b) The interrelation of parts or the principle of organization in a complex entity. **Statement** Students demonstrate understanding that systems are comprised of parts that are organized in a manner that allows them to do things that they could not do by themselves. **Discussion** The structure of a system is a result of the interaction of its parts. If parts are missing, damaged, mismatched, or misconnected, the structure may not function as well or not at all.	In natural systems, structure and its properties form the basis for systems of classification used by scientists to differentiate species, ecosystems, and phenomena. Altering the parts of a natural system alters its structure and potentially the interaction of its parts. ▪ A taxonomic system of classification was created to differentiate species and place them into related groups. This structure-based system includes fossils as well as living species. ▪ The structure of an ecosystem is based on its interacting biotic and abiotic parts. Producer, consumer, and decomposer are dependent upon green plants that, in turn, are dependent upon certain abiotic factors. Changes in an ecosystem's structure influences its other parts. ▪ Atmospheric abiotic factors, such as wind, water, temperature, and electrical charges, create a variety of cloud structures that are characteristic of certain kinds of weather conditions. As the abiotic factors change, the cloud structure changes.	Social structure is any reoccurring pattern of social behavior. Individuals create and participate in a variety of social structures such as family, education, government, and religion. Each structure has rules to behavior. For example, in the social structure of education, teachers teach, students learn, and the lunchroom staff feeds everyone. When rules are broken, there are usually consequences. For instance, students that misbehave may get detention, a note sent to their parents, and/or sent to the principal's office. You can figure out the structure of a social system, e.g. a family, by observing and inquiring how members (the parts) relate to one another. For example, who in the family does what kind of activity? Who makes what kind of decisions? What does each provide for the others? Do they provide these services or things for all others, or just for some? What must the others do in return? How does each describe his/her relationship to each of the others? This structure differs from one culture to the next, e.g. a white middle class family structure compared to a Navajo family structure. If some members of the family are missing, the role that they play, the decisions that they make, and the resources they provide are also missing; and the other members must make up for this in some way.	Social structures dictate much of human behavior; therefore, they also determine how natural systems are treated. ▪ For example, the education structure dictates how trees are used by relying on them for paper. Paper is used for exams, taking notes, and writing memos. When the loss of trees became a concern, the structure changed and now attempts to use less and recycle more are taking place.

Concepts and their applications to natural and social systems

Concept **Subsystems**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) A group of interacting, interrelated elements forming or regarded as forming a collective entity within a larger system. b) A set of interrelated ideas, principles, rules, procedures, laws, or the like within a larger system. **Statement** Students demonstrate understanding that all social and natural systems are subsystems within larger systems, may themselves be comprised of subsystems and that interaction among subsystems occurs internally as well as externally. **Discussion** The human organism is comprised of many interacting subsystems, e.g. digestive, nervous, etc. Subsystems in society and nature can be described as food webs, various habitats, beliefs, associations, etc.	▪ Small temporary ponds and wetlands in an ecosystem contain interacting organisms that use the temporary habitat for feeding and reproduction. ▪ Forest ecosystems are layered vertically into three general zones and each contains interacting populations of organisms characteristic of that zone. ▪ An ecosystem may contain several types of habitats, each of which contains interacting sets of producer-consumer relationships. ▪ A tree is a subsystem of a forest. The leaf of a tree is a subsystem of the tree that, in turn, contains structural subsystems that address the functions of photosynthesis, water and food transport, and the import and export of gases. ▪ The soil of a forest floor is a subsystem of interacting organisms that fertilize, circulate, and make burrows that aerate the soil.	Social systems are all part of larger systems and are comprised of smaller subsystems. ▪ A family is a basic subsystem of a community. Its parts consist of the parents, children, and home. ▪ A community, i.e. Brainerd, Minnesota, is comprised of subsystems that include occupations, economic status, city ordinances, commercial inputs and outputs, religion, race, age, sex, education, legal, communication, political, etc. ▪ Brainerd is a social system that is a subsystem of Crow Wing County, which is a subsystem of the state of Minnesota. Our state, in turn, is a subsystem of the United States of America. Our nation is a subsystem of all the nations of the world, which are subsystems of the world's population.	▪ Conservation organizations are subsystems of society that direct their activities toward improving, restoring, or maintaining a quality environment. ▪ The Division of Forestry is a subsystem of the Department of Natural Resources whose mission is to conserve Minnesota's forest resources. ▪ The Brainerd Chapter of the Minnesota Deer Hunters' Association is a subsystem of the state organization that focuses its conservation activities on conserving the whitetail deer. ▪ The Minnesota Izaac Walton League is a subsystem of the national organization. Its subsystems are comprised of local chapters that collectively work to get state and national conservation legislation passed.

Concept **Synergy**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition The action of two or more substances, organs, or organisms to achieve an effect of which it is individually incapable. **Statement** Students demonstrate understanding that the interaction of two or more substances, organs, or organisms can achieve an effect that the interacting parts individually could not produce. **Discussion** The interaction of two or more parts of a system or several systems often produces a new system of relationships that is sustained by the interaction. It will persist as long as the systems benefit from the interaction. The outputs of this new system can affect other systems coexisting in its environment. It is not always easy to predict the results of this new interaction.	Many synergistic relationships can be found in natural systems whose parts have coevolved together: ▪ Cattle have bacteria in their stomachs that secrete an enzyme that breaks down plant cellulose, enabling the cattle to digest the plant material. ▪ Lichens are comprised of a supporting fungus upon which live green algae. The photosynthetic algae produce food material used by the fungus and the fungus provides support for the algae, while making minerals from the rock available to the algae. ▪ The organ systems that comprise the human body cannot exist by themselves, but their combined interaction results in a functional, healthy organism when all the parts are functioning properly. Widely varying combinations of plants and animals coexist in the different habitats of the world. Certain species live together in mutual adjustment, creating a self-sustaining natural community of interacting species dependent upon each other in the food web. Scientists who study these natural communities call this relationship "synecology" or community ecology.	This term is not significantly useful to this discussion of social systems. It is not a term that is commonly used in the analysis of social systems.	Conservation groups use the knowledge about the synergistic relationship between bacteria and ruminants and introduce deer herds to certain foods prior to starvation periods in winter. This helps guarantee that adequate populations of bacteria are present in the deer's stomachs when their normal diet needs to be supplemented

Concepts and their applications to natural and social systems

Concept **Technology**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The application of science, especially to industrial or commercial objectives. b) The entire body of methods and materials used to achieve such objectives. **Statement** Students demonstrate understanding that technology is the use of tools by humans or animals to perform a task. **Discussion** Technology is any tool that humans or other animals use to perform a task. It can range from a simple stick stripped of its leaves and stuck into an insect mound to the most complex of space stations. Once a technology is created, it can have its own effect on social and natural systems. It feeds back into the system.	▪ Some species of birds in South America use twigs to extract insects from borings in trees. ▪ Sea otters off the west coast of North America use stones to break open abalone shells while floating on their backs and pounding the shell as it rests on their stomachs. ▪ Some species of monkeys in Africa use sticks to poke into termite mounds to provoke the termites into attacking the stick. They then remove the stick from the mound and lick off the termites.	The particular technologies that humans create and use are related to and products of social systems. The form of transportation one uses, for example: • Can be strongly influenced by place occupied in the socioeconomic system, (what one can afford or the image one wishes to project). • Place occupied in the system of social stratification, (higher ups often ride or are driven when others walk or drive themselves). • Whether one's religion allows certain forms of transportation, (the Amish people drive horses and buggies). • What the economic system is based upon, (If one is a fisherman, one probably drives a boat of some kind). The success of modern medicine in keeping people alive, for instance, has led to the creation of whole industries that care for people with disabilities. Access to computers is changing the way the world works and does business. Several thousand years ago, the invention of agriculture allowed people to settle down and live in larger groups rather than hunting and gathering in small, mobile groups.	Human technologies can often have a negative effect on natural systems: • Chemicals placed on agricultural land or in landfills find their way into the groundwater supplies that we rely upon for drinking water. • Automobile exhaust into the atmosphere creates harmful smog and falls back to the earth as acid rain, affecting the life in lakes. • Large volumes of packaging materials and discarded manufactured items accumulate in landfills whose creation destroyed the local ecosystem. Human technologies can also have a positive effect on natural systems. • Computers and other equipment have assisted us in understanding natural systems and the impacts we have on them, enabling resource managers and citizens to reduce impacts and/or restore ecosystems.

Concepts and their applications to natural and social systems

Concept **Threshold**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) The outset; verge; beginning. b) The intensity below which a mental or physical stimulus cannot be perceived and can produce no response. **Statement** Students demonstrate understanding that systems are comprised of interacting parts and that many of these interactions are governed by outputs within the system or inputs to the system that have to be present at some critical level before interaction occurs. **Discussion** The interacting parts of a system influence one another and allow systems to do things that the parts alone could not do. Inputs to the parts of a system must usually meet some critical level (threshold) before the system responds. The system's response to this input can be either good or bad for the system.	Both positive and negative thresholds exist in natural systems. On the one hand, they can stimulate and help maintain a healthy ecosystem, but they can also result in the degradation of an ecosystem. Phosphorus is a plant nutrient that is carried into lakes by streams, groundwater, and shoreline runoff supplied by rain. ▪ A positive threshold is reached when there is enough phosphorus present to support green plants, which produce oxygen, provide food for aquatic herbivores, shelter for small fish from aquatic predators, and nesting sites for adult fish. ▪ A negative phosphorus threshold is reached when there is so much phosphorus present that the lake supports enormous plant populations and very large algae "blooms." The decay of all this plant material reduces the amount of oxygen in the lake available for oxygen requiring aquatic species. It also reduces the extent to which sunlight can penetrate below the lake's surface. The ecosystem degrades from its former balance as parts of the ecosystem begin to die.	Positive thresholds in social systems can be reached when inputs to a society from social subsystems within that society become strong enough to attract a membership large enough to cause change that results in a better society ▪ Although Copernicus didn't fare too well when he postulated that earth revolved around the sun, enough people eventually believed in his theory that the science of astronomy changed radically. ▪ When Newton postulated his theories of physics, a phenomenal advance in science method and understanding of the universe took place. ▪ Einstein's theory of relativity provided a new science perspective that resulted in entirely new fields of science and technology. A negative threshold in a social system is reached when the population of that group exceeds the capacity of the local ecosystem or the groups' technologies to feed its membership. Famine or migration must follow.	▪ In the past, it was common practice to dump raw sewage into river systems because the popular observation was that they "cleaned themselves" through natural processes. Increased populations eventually exceeded this threshold—oxygen levels dropped below 4 parts per million killing aquatic organisms and disease organisms became so concentrated that using the water almost guaranteed infection. ▪ Harvest of forests is now carefully regulated so that the amount of trees taken does not exceed the number of trees reaching a harvestable age. This provides a sustained annual yield of timber for paper and building materials. This practice also maintains a sustained volume of forest habitat for wildlife.

Concepts and their applications to natural and social systems

Concept **Trophic level**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Of or pertaining to nutrition or the nutritive process. b) Where an organisms is located in an aquatic or terrestrial food chain. **Statement** Students demonstrate understanding that trophic levels indicate an organism's relation to the food web in any natural environment in terms of producers, consumers, and decomposers. **Discussion** Producers are photosynthetic and chemosynthetic organisms that can use nonliving materials, sunlight, or an alternate energy source to grow and reproduce. Plants, for instance, are consumed by herbivores who are, in turn, preyed upon by carnivores. Remains of dead organisms are consumed by carnivorous scavengers or reduced to raw materials by decomposers, i.e. bacteria and fungi.	Food webs are interacting food chains. A food chain is the transfer of food energy from the producer source through a series of organisms. A single species may be a member of several food chains. ▪ Aquatic plants are eaten by snails who, in turn, are eaten by other species of organisms, such as kingfishers. ▪ Producer bacteria living in volcanic vents on the ocean bottom are consumed by tubeworms who in turn are eaten by fish and crabs. ▪ Prairie plants are eaten by insects who are eaten by birds who are eaten by hawks.	The concept of trophic level is most commonly used to describe the nutritional steps in a food chain. Humans, at the top of the food chain, and therefore predators, (animals that eat other animals), have set up elaborate social systems for gathering, producing, protecting, and distributing food. These social systems, e.g. agriculture, fish harvesting, merchandising, transportation, government testing, and regulation, interact with natural systems and with other social systems in a huge variety of ways.	Humans domesticated and genetically improved plant and animal species creating agriculture. This changed some societies from wandering hunters and gatherers to more stationary societies while still maintaining their producer-consumer and consumer-consumer position in the food chain. In many instances, the local ecosystem and its plant and animal inhabitants dictate the human inhabitants' position in the food web and the trophic level at which they obtain nutrition, e.g. Eskimos are primarily hunters and gatherers because of the climate.

Concepts and their applications to natural and social systems

Concept **Waste**	Applications to natural systems	Applications to social systems	Examples of interactions between natural and social systems
Definition a) Any useless or worthless byproduct of a process or the like; refuse or excess material. b) Regarded or discarded as worthless or useless. c) The undigested residue of food eliminated from the body. **Statement** Students demonstrate understanding that waste in social and natural systems becomes a detriment to the normal functioning of the ecosystem if it is incapable of recycling through those systems or if the rate of recycling cannot keep pace with its production. **Discussion** All natural and social systems produce waste. These materials are usually recyclable through the ecosystem if the rate of accumulation does not exceed its recycling. Social artifacts may have different properties, however, and may have to be dealt with through technology or by avoiding their production altogether.	In addition to metabolic waste, natural systems demonstrate other forms of waste. ▪ Full utilization of available food in a natural area is seldom, if ever realized if the area's trophic levels are in balance and all abiotic factors remain constant. ▪ An overabundance of prey species usually results in predators killing more prey than they can eat before the organism deteriorates. ▪ Consumers dependent upon vegetation tend to eat only the tastier parts of plants when they are in abundance. ▪ In times of food abundance, organisms that characteristically store food to survive winter conditions tend to store more food than will be utilized and thereby deprive other populations of adequate food.	The activities of social systems, particularly their technologies, produce wastes other than metabolic waste. Cultural waste takes many forms: ▪ Exhaust from internal combustion engines burning fossil fuels produce harmful smog in urban areas and contribute to acid rain, which has damaged trees, monuments, and ancient ruins. ▪ Parts of plants and animals that are not used for food that accumulate as garbage, which is taken to landfills. ▪ Carbon dioxide produced by burning and industrial processes accumulates in the atmosphere faster than it can be used by green plants in photosynthesis. These molecules capture and hold heat from the sun, warming the atmosphere more than under the influence of natural systems only. ▪ Fabricated materials such as stoves, refrigerators, automobiles, cans, clothing, etc. are not recycled at the rate they are being produced and therefore accumulate in the environment.	Some waste artifacts created by social systems can disrupt the normal function of natural systems. ▪ Chlorofluorocarbon waste from refrigeration and air conditioners which gets into the atmosphere and reduces the amount of ozone that protects us from ultraviolet radiation. ▪ Much of the packaging material produced by western social systems becomes solid waste and is discarded in landfills. This requires that the ecosystem in the area selected for the landfill is destroyed and may not be restored to its former state. The parts, and therefore the processes, of natural systems coevolve over long periods of time. This coevolution includes processes for recycling materials through the systems. Many of the chemicals produced by our social systems are new to the environment and no method of breaking them down (decomposing) exists in the natural systems. Many of these chemicals have negative effects on plants, animals, and people.

Applications

This section of the document deals with five applications of the *Environmental Literacy Scope and Sequence* that you may find useful. First, application to state and national standards. Second, the relationships between natural and social systems from the social systems perspective. Third, the Environmental Literacy Benchmarks and their correlation with the Minnesota Graduation Standards. Fourth, examples of how to apply the Scope and Sequence in classroom learning, including a sample concept map. And fifth, sample lesson plans for familiarizing yourself and others with the *Environmental Literacy Scope and Sequence.*

Application to state and national standards

The developers of the *Environmental Literacy Scope and Sequence,* researched a wide array of resources in their work to create this document. From the beginning, it was recognized that with the resources in existence it would be a terrible error to disregard the work already accomplished. The Scope and Sequence incorporates standards from other states and national organizations which include:

- American Association for the Advancement of Science (AAAS): *Benchmarks for Science Literacy*
- North American Association for Environmental Education: *Guidelines for Learning*
- Hungerford's Environmental Literacy Components
- National Research Council: National Science Education Standards
- Independent Commission on Environmental Education: *Are We Building Environmental Literacy?*
- Pew Charitable Trust: State Education and Environment Roundtable Literacy Models
- President's Council on Sustainable Development: *Education for Sustainability: An Agenda for Action*
- Minnesota Graduation Standards
- Minnesota Science and Math Standards
- Minnesota Environmental Education Advisory Board: *A GreenPrint for Minnesota: State Plan for Environmental Education*
- Wisconsin Environmental Education Standards
- Florida Graduation Standards
- Izaac Walton League of America: *Community Sustainability*
- California Guide to Environmental Literacy
- Environmental Texas Essential Knowledge and Skills
- GreenPrint Council: Environmental Literacy Understandings

- Pennsylvania Proposed Academic Standards for Environment and Ecology
- Other works pertaining to ecology and social interaction with the environment

The foundation of the Environmental Literacy Scope and Sequence

A study completed by the Independent Commission on Environmental Education made two major points that reinforce the notion of needed reform in our environmental education methodology:[5]

- Environmental problems of the day will change over time, but the environmental literacy gained in schools will last a lifetime.
- Environmental education materials often do not provide a framework for progressive building of knowledge.

The President's Council on Sustainable Development believes that understanding the principles of sustainability and the interdependence of the environment, the economy and social systems will help us learn to make changes necessary to become effective stewards of natural resources and the environment. This, in turn, would support development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[6]

According to Edward T. Clark, Jr., author of *Designing andImplementing an Integrated Curriculum,* before we can design a new structure for education, it is necessary to identify those alternative assumptions that can guide and shape educational transformation. He suggests that this means adopting an assumption of "wholeness," everything being connected to everything else, i.e. systems thinking. However, in order to build social and environmental systems thinking into environmental education, the process must be based on a solid understanding of the scope and sequence of concepts needed for a thorough understanding of systems and how to work with a systems perspective.[7]

Also, the California Guide for Environmental Literacy Project suggests that since problems of the world are based in relationships, systems thinking can be useful to redirect attention toward connections and the networks they form. This means that, to better promote environmental literacy, educators should increase their attention to:[8]

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[5] Independent Commission on Environmental Education (ICEE). 1997. *Are We Building Environmental Literacy?* ICEE. 1730 K St. NW, Suite 905. Washington D.C.

[6] President's Council on Sustainable Development. 1994. *Education for Sustainability: An Agenda for Action.* U.S. Government Printing Office. Washington, DC.

[7] Clark, Edward T. Jr. 1997. *Designing and Implementing an Integrated Curriculum.* Holistic Education Press. Brandon, VT.

[8] Smith, Gary C. 1996. *Environmental Education: A Systems Approach.* California Guide for Environmental Literacy Project.

Wholeness by shifting from:

- Parts to the whole. The whole of a system better represents the system than the sum of its parts.
- Objects to relationships. Relationships are responsible for the sum being greater than the parts.
- Objective knowledge to contextual knowledge. Contextual knowledge includes the parts, relationships, and environment.
- Content to pattern. Patterns are configurations of relationships that appear repeatedly. They provide new insights into both the connections and the relationships.
- Quantity to quality. Mapping patterns is qualitative and can illuminate causes and distant effects.
- Hierarchies to networks. Complex systems, such as environmental systems, are always organized into networks. Social systems also reflect networking in decision making and other activities that are not reflected in the usually visible hierarchical structure of their organizations.

Process by shifting from:

- Structure to process. Understanding structures requires understanding the linkages and continuing events that underlie them.

AAAS and the benchmarks

Using the wealth of knowledge at hand, the Development Team chose the American Association for the Advancement of Science's (AAAS) Systems Benchmarks listed in their publication, *Benchmarks for Science Literacy* as its foundation upon which to build the *Environmental Literacy Scope and Sequence.* AAAS has developed a carefully thought out conceptual scope and sequence for teaching the science of systems. It serves as a cornerstone for the development of a content scope and sequence for any approach to environmental education that is systems-based because it:[9]

- Incorporates a "both/and" logic
- Assumes a living universe
- Values ecological thinking
- Is at the same time both local and global
- Honors the long-range view
- Promotes contextual thinking

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

Furthermore, the team decided that these benchmarks were to be rewritten to meet two criteria: be expressed in a simplified manner in language easily understood by non-science educators and school children; and emphasize social systems and natural systems equally to emphasize their dual importance in environmental education activities.

The AAAS Benchmarks were reviewed and seven major systems concepts were identified that appeared to be key to understanding systems. It was later determined some of these concepts are taught by the Benchmarks themselves and that the seven could be reduced in number to five for the *Environmental Literacy Scope and Sequence.* The five major concepts could then be used as a guide to be used by students to formulate questions about social and natural systems they were examining. These Key Systems Concepts are *parts and objects, interactions and relationships, subsystems, inputs and outputs,* and *change over time*.

The following table highlights the original AAAS Benchmarks and the Environmental Literacy Benchmarks that evolved from them. The benchmarks are the indicators of the knowledge that should be achieved at each level. In understanding the benchmarks, consider the phrase, "By the end of the 2nd grade; 5th grade; 8th grade; and 12th grade, students should know that… "

The master concept to be understood from the AAAS benchmarks is vital to any and all environmental education. "Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis."[10]

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

Grades	AAAS *Benchmarks for Science Literacy*	*Environmental Literacy Scope and Sequence* Benchmarks
K-2 (preK)	• Most things are made of parts. • Something may not work if some of its parts are missing. • When parts are put together, they can do things that they couldn't do by themselves.	• Social and natural systems are made of parts. • Social and natural systems may not continue to function if some of their parts are missing. • When the parts of social and natural systems are put together, they can do things they couldn't do by themselves.
3-5	• In something that consists of many parts, the parts usually influence one another. • Something may not work as well (or at all) if a part is missing, broken, worn out, mismatched, or misconnected.	• In social and natural systems that consist of many parts, the parts usually influence one another. • Social and natural systems may not function as well if parts are missing, damaged, mismatched or misconnected.
6-8	• A system can include processes as well as things. • Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole. • Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem of a larger system.	• Social systems and natural systems may include processes as well as things. • The output from a social or natural system can become the input to other parts of social and natural systems. • Social and natural systems are connected to each other and to other larger and smaller systems.
9-12 (adult)	• A system usually has some properties that are different from its parts, but appear because of the interaction of those parts. • Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis. In defining a system, it is important to specify its boundaries and subsystems, indicate its relation to other systems, and identify what its input and its output are expected to be. • The successful operation of a designed system usually involves feedback. The feedback of output from some parts of a system to input for other parts can be used to encourage what is going on in a system, discourage it, or reduce its discrepancy from some desired value. The stability of a system can be greater when it includes appropriate feedback mechanisms. • Even in some very simple systems, it may not always be possible to predict accurately the result of changing some part or connection.	• The interaction of social and natural systems can create properties that are different from either individual system. • Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs. • Feedback of output from some parts of a managed social or natural system can be used to bring it closer to desired results. • It is not always possible to predict accurately the result of changing some part or connection between social and natural systems.

The social systems point of view

As we confront the task of creating an ecologically sustainable lifestyle, we need to have a clearer and deeper understanding of the social systems that constrain and guide almost all of our actions. We are so imbedded in our own social systems and the beliefs that underlie them that we are often unable to make them visible for analysis. In addition, we are often unaware of and unfamiliar with social systems in other cultures that might provide options for social organization that are more ecologically sustainable. Examining other ways of life can clarify which behavior is learned as opposed to what we may have assumed is inherent in the human creature.

What are social systems?

Homo sapiens is an animal species subject to the same biological realities and mechanisms as other animals. We humans differ in degree from other animals but not in absolutes. Despite popular misconceptions, humans are an integral part of the ecosystem (speaking globally), we are also integral parts of local ecosystems. We are subject to the same conditions as other species. For example, the earth has a carrying capacity for humans as well as other species; humans benefit from biodiversity; we are subject to natural population controls; we are subject to natural selection; etc.

The human brain is a specialized adaptive mechanism in the same sense as a double fur coat on a polar bear or gills on a fish. The advantage our human brain gives us is the ability to generate social systems that produce behavior patterns and tools that allow us to live in and adapt to our environment. Any kind of technology, from digging sticks to houses to highway systems to computers, is a product of those social systems.

Technology can only be understood in the context of the social system which produces it. Using a concept like the "built environment" as if it existed somehow in isolation from the hands and minds that built it and the natural systems that make it possible and within which it exists does not seem very useful; in fact, it can be counterproductive.

Culture (social life) is a series of interacting systems that helps the species survive in many types of environments. It may or may not be adaptive in the long term. Humans have only been around a few million years, and our own adaptations are already threatening our survival. The dinosaurs were around for 168 million. Humans have no reason to be arrogant about the survival value of human cultural systems.

These brain-generated systems help the species perform functions that other species may perform in other ways—getting and allocating food, finding shelter, keeping order, reproducing, and raising offspring. The systems are identified in various ways depending on the schools of thought, but they seem to include:

- **Economic organization** pertains to food getting or production and the allocation and distribution of resources. The economic system includes subsystems such as transportation.
- **Political organization** determines how order is kept and decisions are made. The political system includes subsystems such as the legal system.
- **Communications system** allows communication between individuals and groups. Products of this and other systems combined are technologies such as computers. This system includes subsystems such as language and arts.
- **Religious organization** explains and controls the otherwise unexplainable and uncontrollable.
- **Kinship systems** encompass all the rules surrounding reproduction and relationship.
- **Ideological systems** are the systems of belief that underlie the other systems.

Here are some examples of how the Environmental Literacy Benchmarks and the Key Systems Concepts and Supporting Concepts relate to the previously mentioned social systems:

- The **parts** of these systems are individuals, groups, ideas or beliefs, and products.
- These broad systems each encompass numerous **subsystems**, which vary widely, to the point that one society may not even recognize systems in another. The whole focus of anthropology for many years was identifying the systems in other cultures and how those systems functioned and were interconnected.
- Each of these systems in a society interacts intimately with the others to form a **coherent interrelated whole** for the society's participants.
- The **structure** of a social system is composed of the parts of the systems and the ways these parts interact. The **function** of the system is what it does.
- Technology is not something apart, but is a product or **output** of these systems. To understand the total impact of a technology, it is necessary to understand the system **inputs** underlying it.
- Social systems **change over time** in response to many variables. This change is not always predictable.
- If there is **change** in one system, there will be change in others.

Some basic ideas in understanding the relationship of natural and social systems

One must be careful about tight analogies between natural and social systems. As Dr. Luther Gerlach, an anthropologist specializing in the relationship of culture and ecology, states, "Humans interact with nature most significantly through culture, in symbolic ways not comprehended by biological or physical ecosystem models. In other words, humans can generate wants and capabilities of meeting these wants that are far removed from feedback from the biophysical environment."[11]

In knowing the relationship of natural and social systems, students need to understand that:

1. Humans are subject to natural laws (see above).
    a. Humans are part of ecosystems.
    b. Human diversity strengthens biological and cultural systems.
    c. Humans use natural resources.
    d. Humans are subject to the same processes as other animals. For instance, concepts such as carrying capacity also apply to humans.
2. Social systems allow the human species to survive and adapt to environments.
    a. Beliefs and values form the basis for social systems.
    b. Examples of social systems include economic, political, communications, religious, kinship, and ideological systems.
3. Social systems affect and are affected by natural systems. Social systems affect natural systems, e.g. products and byproducts of our economic system pollute rivers and streams. This in turn affects our economic systems because taxpayers must pay to clean the river water before it can be used again. Social systems are affected by natural systems, e.g. shortages of water near large desert cities create the need for political and economic problem-solving and/or changes in values.
    a. Humans create complex systems to solve problems.
    b. Solutions to complex problems can have unforeseen consequences.
    c. Implementation of solutions can create additional problems.
    d. There are basically three kinds of action on environmental issues: technological, individual, and systemic.

[11] "If Ecosystem Management Is the Solution, What's the Problem?" *Journal of Forestry,* Vol. 92, No. 8, Aug. 1994, p. 20.

How to study social systems

If understanding social systems is so important, how does one go about making them visible and analyzing them? Children who grow up in any society learn its systems early on, because they must in order to function. For example, every child knows what it can expect from various members of its household in its first few years—who mother is, what she does, how she treats the child—the same with brother, sister, father, etc. We all learn to speak a language that is made up of a series of complex interrelationships of sounds and meanings. However, few of us are able to articulate very well the many systems that we learn. Therefore, we do not have a good understanding of how systems interrelate in our own culture.

Anthropologists use participant observation to make visible and analyze systems in societies they are not familiar with. They live in the society, learn what they can and can't do, and what they are expected to do. Anthropologists watch people to see what they do, who they talk to, who they live with, how they make their living, and so on. They record daily life meticulously to see if they can establish the patterns that are the social systems. It is important to document and analyze the exchanges that take place between people—of words, things, services, actions. This helps to establish the nature of the patterns of relationships between people. These same techniques can be used in our own culture to determine, for instance, the decision-making system in a school district.

In societies with systems of recordkeeping, it is also possible to use documents, art, voice and video records, etc. to analyze patterns of interrelationship. Sociologists have specialized in studying complex industrialized societies. Because these societies were and are often large and complex, sociologists are more likely to gather data from existing documents and use techniques such as surveys.

Human geography is the analysis of spatial patterns that are evidence of and formed by both the natural systems in which they exist and the social systems by which people's lives are organized. Analyzing these spatial patterns contributes greatly to our understanding of social systems and the surrounding natural systems. Demographic history and population dynamics contribute to an understanding of how these social and natural systems have evolved and changed.

It will become apparent, as one starts to do these social analyses, that there are two levels of understanding in most systems. There is the ideal—the way things are supposed to work, often formalized, documented, and articulated by members of the society, such as the rules for bringing something before an elected body. And there is the real system—the way things really happen. Most of us in our own cultures learn the ideal systems; indeed, we are overtly taught these. We are often left to learn the real systems on our own.

For instance, if someone asks us how to go about getting a matter put before our county commissioners, we will tell them to see the city clerk and try to be put on the agenda. That is the ideal system. However, people who spend time working with elected bodies will be more likely to go to the official they know or someone who knows the commissioner and talk to him/her about the issue, get an idea of where that person stands, and try to

persuade that person before the meeting. Then they ask to be put on the agenda when it is more likely that a) they will get on the agenda, and b) that the matter will be resolved favorably. That is the real system.

There is nothing subversive about this. In every culture there are the ideal systems and the real ones. The real systems are built on the understanding that ideal systems are necessary to define the ideals of a society, but that reality often must take into account the contingencies and vagaries of everyday life and the impinging of other systems. In order to understand why things happen as they do in social systems, it is necessary to acknowledge and understand *both* the ideal and the real.

To study social systems, one must usually use a combination of the techniques and methodology of all of the social sciences.

Environmental literacy and the Minnesota graduation standards

The following pages demonstrate: 1) the "environment" in the Graduation Standards and 2) the Environmental Literacy Benchmarks correlated with the Minnesota Graduation Standards. These are standards that can be achieved by examining the interaction between social and natural systems. The Scope and Sequence is correlated to the Minnesota Graduation Standards to provide an alternative means of using environmental education to achieve the standards.

Environment in the graduation standards

Listed below are the High Standards and Primary, Intermediate, and Middle level standards in which there is direct reference to connections to the environment or in which some of the concepts taught are identical to those in environmental literacy definitions.

Standards	Inquiry (Learning Area 5)	Scientific Applications (Learning Area 6)	Social Studies (Learning Area 7)	Decision Making (Learning Area 8)	Resource Management (Learning Area 9)
High Standards	History of Science Research and Create a Business Plan New Product Development	Concepts in Biology Concepts in Chemistry Earth and Space Systems Concepts in Physics Environmental Systems	Human Geography		Economic Systems Natural and Managed Systems Personal and Family Resource Management Business Management Technical Systems
Primary		Direct Science Experience	Family, School and Community		
Intermediate		Living and Nonliving Systems	Geography and Citizenship		
Middle		Living Systems Earth and Space Systems	Geography and Culture	Personal Health	Informed Consumerism

Environmental Literacy Benchmarks correlated with the Minnesota Graduation Standards

The following tables provide information on the Minnesota Graduation Standards that apply to the Environmental Literacy Concepts being introduced. Each table represents the corresponding grade level divisions: primary (preK-2), intermediate (3-5), middle (6-8), and high (9-12). Note, the Graduation Standards divide the primary grades somewhat differently: primary (K-3) and intermediate (4-5).

Students should be introduced to examples of natural and social systems, and learn to identify the different parts and objects of social and natural systems. discussion of how one part affects another encourages students to explore interactions and relationships between the parts of a natural or social system. experiences should include a variety of systems, and involve questions on how well a system works or doesn't work, when parts are missing or broken. The focus in the elementary grades should be on **single** systems and their parts and relationships.

At the secondary level, students should begin to look at interactions and relationships between **multiple** systems. In their study of natural and social systems, students should begin manipulating and observing systems to identify subsystems, the relationship of inputs and outputs to systems function, and learn to recognize how systems change over time. In the higher grades students should be able to apply systems thinking to many diverse interactions between natural and social systems.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Correlation to Minnesota Graduation Standards
Grades **preK – 2** **Social systems and natural systems are made of parts.** **Social systems and natural systems may not continue to function if some of their parts are missing.** **When the parts of social systems and natural systems are put together, they can do things they couldn't do by themselves.**	**Parts and objects** individuals, groups, ideas and concepts, biotic factors, abiotic factors, similarities and differences, properties **Interactions and relationships** structure, function **(See individual concept sheets.)**	**Scientific Applications** **Direct Science Experience**: Understand basic science concepts through direct experience. **Social Studies** **Family, School and Community**: Understand the interaction of location, family, school, and community.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Correlation to Minnesota Graduation Standards
Grades **3 – 5** **In social and natural systems that consist of many parts, the parts usually influence one another.** **Social and natural systems may not function as well if parts are missing, damaged, mismatched, or misconnected.**	**Parts and objects** similarities and differences **Interactions and relationships** structure, function, patterns, trophic level, cycles, change and constancy, migration, predation, feedback, communication **(See individual concept sheets.)**	**Scientific Applications** **Living and Nonliving Systems:** Understand interactions and interdependence of living systems. **Social Studies** **Geography and Citizenship:** Understand the interaction of people, places, and locations.

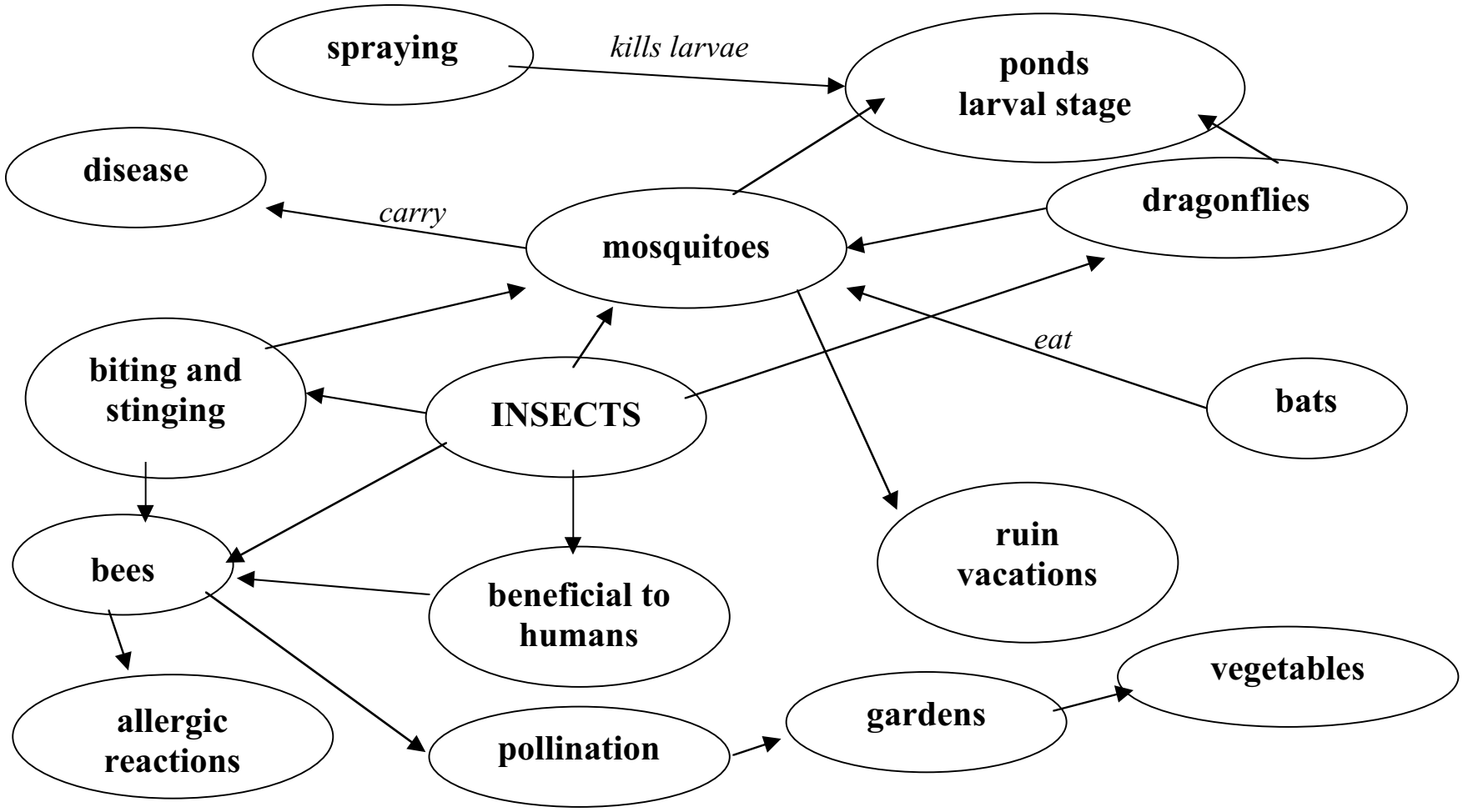
Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Correlation to Minnesota Graduation Standards
Grades 6 – 8 **Social and natural systems can include processes as well as things.** **The output from a social or natural system can become the input to other parts of social and natural systems.** **Social and natural systems are connected to each other and to other larger or smaller systems.**	**Interactions and relationships** population, structure, function, change and constancy, cycles, ideal and real, formal and nonformal, trophic level, feedback, reciprocity, predation, migration, communication **Subsystems** habitat, biome, boundary, scale, family and kinship, stratification, politics, economic, religion, language, niche, communities **Inputs and outputs** artifact, waste, technology, instruction **Change over time** diversity, rate, ideas and concepts, geomorphism, accumulation, threshold, mutation, evolution, extinction, knowledge, innovation and invention, species (group) **(See individual concept sheets.)**	**Applied Scientific Methods** **Living Systems:** Demonstrate knowledge of interactions and interdependence of living systems by understanding: • The human body including heredity, reproduction, regulation, and behavior. • Plants, animals, and microorganisms including diversity, adaptation, populations, and ecosystems. • The dynamic effect of humans interacting with the environment. **Earth Systems:** Demonstrate understanding of: • The structure of earth systems, including the geosphere, hydrosphere, and atmosphere. • Concepts of change and constancy in the earth's history including theories of origin through evidence found in fossils, rocks, rock layers, landforms, and natural events. **Physical Systems:** Demonstrate understanding of the fundamental laws and concepts of the physical world including: • Properties of matter. • Physical and chemical changes. • Transfer of energy. • Force and motion. **Social Studies** **Current Issue Analysis:** Defend a position concerning a current event or issue by demonstrating understanding of: • Specific events or situations illustrating the impact of the issue. • Selection and defense of a position based on information. • Description of the responsibilities of citizens involved with the issue(s). • Summarizing findings in written, oral, or role-play presentation. **Geography and Culture:** Demonstrate knowledge of: • How regions of the world are defined in terms of location, resources, people/culture, and physical features. • How global systems are interconnected. **History and Citizenship:** Demonstrate knowledge of: • The facts and sequences of historical events. • The origin and shaping influences of various points of view. • Historical events in relationship to themes of change and migration.

Environmental Literacy Benchmarks	Key Systems Concepts and Supporting Concepts	Correlation to Minnesota Graduation Standards
Grades **9 – 12 (adult)** **The interaction of social and natural systems can create properties that are different from either individual system.** **Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs.** **Feedback of output from some parts of a managed social or natural system can be used to bring it closer to desired results.** **It is not always possible to predict accurately the result of changing some part or connection between social and natural systems.**	**Parts and objects (all)** individual, biotic factors, abiotic factors, similarities and differences, properties, member, ideas and concepts, group **Interaction & relationships (all)** trophic level, structure, function, change and constancy, patterns, cycles, feedback, migration, predation, population, reciprocity, communication, synergy, cause and effect, probability, chaos, ecosystem, ideal and real, formal and nonformal **Subsystems (all)** habitat, niche, biome, ecosystem, boundary, scale, communication, community, population, family and kinship, stratification, politics, economics, religion, language **Inputs and outputs (all)** energy and energy flow, resources, products, communication, waste, innovation/invention, artifact, instruction, technology **Change over time (all)** climate, geomorphism, probability, diversity, species, cycles, scale, rate, accumulation, threshold, migration, population, mutation, extinction, ideas and concepts, knowledge, innovation/invention **(See individual concept sheets.)**	**Scientific Applications** **Environmental Systems:** Demonstrate understanding of: • The use of decision-making models and scientific investigation and issues involving relationships among the individual, society, economy, and the environment by investigating and analyzing the scientific concepts, principles, laws, or theories that affect and are affected by environmental changes. • The components of social systems that affect and are affected by environmental changes. • The interactions between social and natural systems. • Local, regional, or global implications of short- and long-term environmental changes. • Methods for citizenship action. **Social Studies** **United States Citizenship:** Demonstrate understanding of: • Analyzing how citizens can affect public policy. • Observing, analyzing, and interacting with an actual or simulated governmental process. **Human Geography:** Demonstrate understanding by: • Identifying the location of major places and geographic features on the earth's surface, the physical and cultural characteristics of places, the physical processes that shape patterns on the earth's surface, how movement of cultural characteristics interconnects various places, and how the physical environment is modified by and modifies human activities. • Interpreting and communicating geographic information through maps and other forms of graphic tools and geographic information systems. • Analyzing the effects of alterations on cultural landscapes, physical landscapes, or both. • Analyzing the relationship between geography and a dispute about land use versus ownership or political control. • Analyzing the relationship between geography and culture. **Community Interaction:** Demonstrate an understanding of: • The relationships between organizations and the communities the organizations serve. • Assessing and evaluating the impact of an issue, event, or service on a target population. • Suggesting, applying, and evaluating strategies designed to improve the community through direct service or other authentic experience.

Applications in the classroom

Concept mapping

Concept mapping allows you to see connections and understand relationships between ideas through the creation of a visual map. Below is one example of a concept map. For a more thorough understanding of the technique and its connection to learning, we recommend that you consult additional resources.



Sample unit of study

One of the benefits of the *Environmental Literacy Scope and Sequence* is that it can be used in traditional programs where the students engage in environmental lessons developed by other curriculum sources, or it can be used to develop curriculum. Both are presented here.

In traditional programs, using existing curriculum sources, teachers and environmental educators need to:

- Review the lessons and identify what the students are learning.
- Identify the Key Systems Concepts and Supporting Concepts that are involved in that learning.
- Describe how the Environmental Literacy Benchmarks apply to the lesson.
- Decide how to teach lessons so students understand how Benchmarks and Concepts relate to what they learned.
- Formulate a plan that uses the Benchmarks and Concepts to assess student learning.

An example of the non-traditional programs is the work of the State Education and Environment Roundtable and their education reform model called Using the Environment as an Integrating Context for Learning. This reform model uses community-based multidisciplinary units of study, developed at the local level, for improving student performance and achievement.

During a trial test of the Scope and Sequence, teams of teachers from two middle schools in Bemidji and East Grand Forks developed the following procedures for designing study units which met both the goal of interdisciplinary instruction and met the Minnesota Graduation Standards for at least two separate disciplines.

Investigating Your Own Backyard: Plan Outline

1. Select a topic that focuses on your community.
2. Establish the time context: past, present, or future.
3. Identify parts and objects, interactions and relationships, subsystems, inputs and outputs, and change over time applications to the social and natural systems you are examining.
4. Use the first six Environmental Literacy Benchmarks to determine how they apply (or might apply) to the system(s) you are studying.
5. Use the next six Benchmarks to help define the actual (or potential) relationship of these Benchmarks to the social and natural systems you are examining.
6. Use the Graduation Standards to clarify specific student tasks.
7. Assess student understanding of the environmental unit lessons using the Environmental Literacy Benchmarks, Concepts, and concept mapping at the appropriate grade level.

Setting the context

Mission: To create active lifelong learners by using the environment as an integrating context (EIC).

Description: This middle level project implements a community-based environmental curriculum that engages students in observing, investigating, and analyzing the interaction between natural and social systems.

Standards: Upon completion of all tasks, students will meet the criteria for:

- Scientific Applications: Living Systems
- Social Studies: Current Issue Analysis

Unit outcomes

- Gain knowledge and awareness of the role of resources in our area.
- Understand historical development of the land and its people.
- Understand the impact of our area on personal beliefs and values.
- Appreciate the diversity of the many ethnic groups that combine to give our community its identity.
- Provide opportunities for community and student interaction.
- Understand impact of our area in the world.

Standard tasks for assessment

1. Journaling
- Compare and contrast the human body with other natural systems.
- Demonstrate understanding of natural systems.
- Record historical development.

2. Investigating
- Participate in a field study.
- Frame a researchable question.
- Design and conduct an investigation.

3. Analyzing issue
- Examine data and viewpoints.
- Analyze the implications of the social and natural interactions.
- Compare findings to other qualified sources.

4. Defending a position

Scientific Applications

Living Systems Task List

1. Maintain a journal to record observations which compare and contrast the human body with other natural systems.
2. Demonstrate a conceptual understanding of a natural system.
3. Investigate an ecosystem specific to your area through field study.
4. Frame a researchable question based on your field study which reflects human and/or natural interaction with that ecosystem.
5. Design and conduct an investigation and compare your results with other qualified sources.
6. Describe and defend a premise based on your investigation.

Social Studies

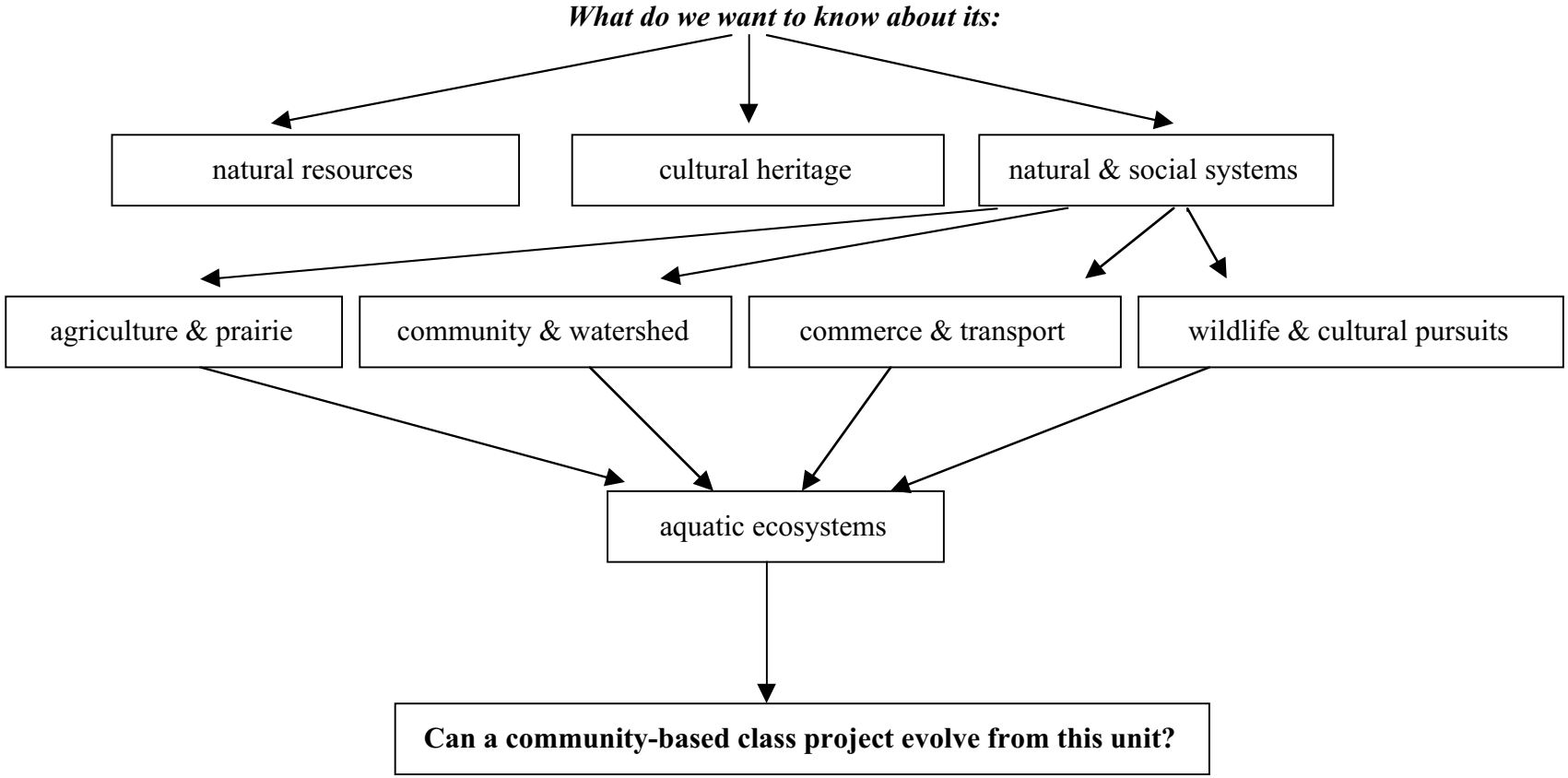
Current Issue Analysis Task List

1. Maintain a journal of the historic development of your area and its people.
2. Examine a range of historical and current viewpoints on a chosen issue impacting your area.
3. Analyze the roles of the players and their values, positions, responsibilities and rights relevant to the issue.
4. Select and defend a position.

Unit planning process

Unit study options can be determined by the teacher team, or in a more student-centered program, cooperatively by the teachers and students. This process is facilitated/guided by asking open-ended questions. Once the natural and social systems are identified, the graduation standard tasks can be developed. Following this, the *Environmental Literacy Scope and Sequence* can then be used to guide student inquiry.

Investigating Your Own Backyard: My Community and Its Environment



Sample activity lesson plans

Presented in this section are sample lesson plans for activities designed to familiarize participants with systems thinking and natural and social systems interactions. These lesson plans were developed for teacher in-service workshops that introduced educators to the *Environmental Literacy Scope and Sequence.* Use them for your own understanding of the Scope and Sequence or to help others understand it.

Workshop lessons covered four separate systems awareness-building categories:

1. Personal: Systems are an important part of my life.

- I am a system comprised of smaller systems.
- I am a part of larger natural systems.
- I am a part of larger social systems.

2. Contexts: Systems are universal.

- Social and natural system food webs are subsystems of the universe.
- Solutions to environmental problems may not be the same in differing cultures.
- Both formal and nonformal processes are factors in social system solutions to environmental problems.

3. Curriculum: Existing curricula have applications for the *Environmental Literacy Scope and Sequence*.

- The *Environmental Literacy Scope and Sequence* can be used with national and state curricula currently in use.
- The *Environmental Literacy Scope and Sequence* can be used with curricula that teachers are currently using.

4. Environment as an Integrating Context: Student-centered study units that focus on the community and its environs provide a rich opportunity to examine the interaction of social and natural systems that use the *Environmental Literacy Scope and Sequence.*

Lesson plans, arranged in the order of introduction for systems development thinking, include:

1. I am comprised of smaller systems and am a part of larger systems.
2. How are cows and cars alike?
3. How is a hamburger hooked to the stars?
4. I can find interactions between natural and social systems.
5. I can find applications for the Scope and Sequence in EE lessons.

Environmental Literacy Benchmark Cards

Throughout the following activities, there are references to the Environmental Literacy Benchmark Cards. These are the individual Benchmarks placed on note cards for use in the activities.

PreK-2	3-5	6-8	9-12 (adult)
Social systems and natural systems are made of parts. Single systems	In social and natural systems that consist of many parts, the parts usually influence one another. Single systems	Social and natural systems can include processes as well as things. Single systems	The interaction of social and natural systems can create properties that are different from either individual system. Multiple systems
Social systems and natural systems may not continue to function if some of their parts are missing. Single systems	Social and natural systems may not function as well if parts are missing, damaged, mismatched, or misconnected. Single systems	The output from a social or natural system can become the input to other parts of social and natural systems. Multiple systems	Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs. Multiple systems
When the parts of social systems and natural systems are put together, they can do things they couldn't do by themselves. Single systems		Social and natural systems are connected to each other and to other larger or smaller systems. Multiple systems	Feedback of output from some parts of a managed social or natural system can be used to bring it closer to desired results. Multiple systems
			It is not always possible to predict accurately the result of changing some part or connection between social and natural systems. Multiple systems

I am comprised of smaller systems and am a part of larger systems.

Time required: 45 minutes

Outcome: Learners will understand that they are comprised of smaller natural systems, that they are members of larger natural and social systems, and that all these systems interact.

Assessment:

1. Learners can draw a concept map of the relationship of themselves to smaller or larger natural and social systems.
2. Learners can verbally convey to the rest of the class how a specific Environmental Literacy Benchmark relates to their concept map and give examples.

Materials:

- 1 nontoxic marker per team
- 2 poster tablet sheets per team
- 1 roll of masking tape
- Environmental Literacy Benchmark Cards
- 1 tablet post-it notes per group

Note: Exercises 1 and 2 are best run concurrently using three small groups after the "most important organ system in my body" discussion.

Exercise 1. I am a system comprised of many smaller interacting systems.

The Environmental Literacy Scope and Sequence Project is based on building understandings about social and natural systems—how they work and how they interact. You live in a universe of interacting systems. In fact, you are comprised of interacting systems. Let's explore some of those systems.

- Ask participants to think about: "What is the most important organ system of my body."
- Participants write their decision on a post-it and paste on wall. Post different organ systems side by side. Post same organ systems under one another.
- Read the decisions—ask why they selected a particular system as "most important."
- Introduce idea that if one system is missing, you are not the same organism (system) and perhaps not able to continue to function.

- Divide workshop participants into work groups. (Preferably 2 to 4 groups, depending on the number of workshop participants in the session.)
- Start lesson by asking workshop participants to identify some of their organ systems. List on board or tablet.
- Make exercise assignment: On one of the poster sheets on your table, draw a circle in the middle of the sheet and write "me" in it.
- Draw circles around "me" and list the organ systems your group can identify. Connect these organ systems to "me" with lines.
- Mix the Benchmark cards and give one card to each of the groups in the session. Do not refer to the cards as "Benchmarks." Inform them that they are receiving a "statement" about systems.
- Groups write their statement at the top of the poster paper. They should discuss what it means. After discussion, the group should discuss one relationship between "me" and one of the organ systems. How does the statement relate to the system they chose? What does this mean to "me"? What might this mean to "we" as a species? (Give examples.)
- Groups post their worksheets on the wall. Each group elects a spokesperson who reports to the whole group.
- Ask if anyone in the whole group has questions that they want to ask of the work group or make additions to what they have mapped.
- Groups keep their Benchmark card for the rest of the introductory exercises.

Exercise 2: I am a part of larger natural and social interacting systems.

Each of us is a part of larger systems. These systems can be either natural or social systems. We affect them and they affect us. Let's see if we can identify some of them.

- Assign each of the work groups one of two topics: natural systems or social systems.
- Ask groups to list examples of the kinds of larger natural and social systems to which they belong. Give an example, such as "family" for social and "habitat" for natural, to help the workshop participants get a general idea of what they should map during this exercise.
- Each group maps systems and chooses one of the natural or social systems of which they are a part. Give a new Benchmark card to each of the groups. Describe how the "statement" might relate to the system they chose. Give an example.
- Groups post their work and each spokesperson reports to rest of participants in terms of their selected Benchmark.
- Discuss with the group and suggest additions where appropriate.
- Groups keep their new Benchmark card for the rest of the introductory exercises.

How are cows and cars alike?

This lesson is designed to help people analyze the social and natural systems in which they live and function. This is often difficult, because even though we have learned these systems and can act on them, we do not normally bring them to a level at which we can consciously see all the parts and interrelationships. Often, we try out solutions that are only based on part of the system, and we often find that these solutions do not work very well. When these systems are analyzed, the analysis can lead us to solutions that may have a much better chance of success.

Time required: 45 minutes

Outcome: Learners will understand that social and natural systems are interrelated in many ways.

Assessment:

1. Learners can draw a concept map of the relationship of cars to both social and natural systems.
2. Learners can verbally convey to the rest of the class how a specific Environmental Literacy Benchmark relates to their concept map and give examples.

Materials:

- 1 poster tablet sheet per team
- 1 nontoxic marker per team
- 1 roll masking tape

Note: This lesson is generally done as a concurrent task with two other exercises to avoid repetition of the points being made about the Environmental Literacy Benchmarks.

Tell the participants:

Let's look at an example of interacting social and natural systems on another continent and see what we can learn from it about ourselves.

The Duruma are a cattle-raising people in east central Africa. When the British colonized their country, the British noticed that the Duruma cattle seemed to have a major problem with an insect-borne disease. To be helpful, the British introduced the Duruma to veterinary medicine. The medical help worked so well that the cattle multiplied to the point that they stripped the land and destroyed their pasturage. The British suggested—to them, a simple

solution—sell or slaughter some of the cattle. What the British had not learned were that the cattle were much more than an economic commodity to the Duruma.

List these on an easel pad:

Time: 5 minutes

To the Duruma, the cattle were important because:

- Cattle were part of a girl's dowry when she was married and therefore a symbol of family solidarity, linking lineages in the kinship system.
- Cattle were used as gifts between political entities to symbolize friendship and agreements. They were therefore symbols of political strength in the political system.
- Cattle were important markers of social status—the more cattle, the higher the status in the social stratification system.
- Cattle were important parts of religious rituals and therefore important to the religious system.
- Cattle were closely connected in a complicated system of real estate privileges.
- Cattle produced milk, which was sold in the marketplace, and thus the living cattle were important to the economic system.
- Because of all these intertwined systems, the Duruma could not voluntarily give up numbers of cattle, even though they were obviously destroying the land. The Duruma and the westerners could not come to a mutually agreeable solution.
- The Duruma's solution to the problem was to ask the government to open up the national park nearby for cattle grazing.
- The cattle, the Duruma culture, and their central African environment had come to exist as a viable set of interacting systems, of which the insect-borne disease was one factor and the cow, another.

Exercise 1. How is a car like a cow?

Time: 15 minutes

So what have the Duruma got to do with us? We could also ask, "How is a cow like a car?"

We have an issue in this country that many people, including many land use planners, think is a major problem—urban sprawl. Many people blame the rapid growth of sprawl on the car as a convenient method of individual transportation. The apparently simple solution is to convince people to give up driving their cars and build mass transportation systems instead, or convince people to live in central urban areas and walk to work,

play, and the grocery store. However, in 20 years of promoting these solutions, they really have not worked very well. Urban sprawl is worse rather than better.

Why is this so? What are we missing? Let's see if we can analyze the systems in our culture in which the car plays a major role.

Lead a group discussion on the systems in which the car is involved.

Time: 10 minutes

Write the group's answers on the easel pad as they talk.

What natural systems does the car impact? Soil, water, air, land use, etc.

In which social systems does it play a role? Answers can be wide-ranging. People will tend to start out with small surface systems, then move to larger ones as the implications begin to dawn on them. They should begin to see the massive intertwining of the car with ideological, political, legal, economic, social stratification systems, and even systems of courtship, rites of passage, and definitions of gender.

When people begin to notice that the car is both a symbol of, and provides access to, freedom and independence, help them look back at the ideologies on which this country was founded to see why the simple solution to urban sprawl is very far from simple.

Exercise 2. Creating a concept map.

Divide the group into smaller groups of 3 to 5 people.

Time: 15 minutes

Ask them to create a concept map of the interacting social and natural systems in which the car is involved.

These can be collected and evaluated or the small groups can summarize their maps for the class.

What they should all conclude is that all of these systems are related, not just to the car, but to each other.

How is a hamburger hooked to the stars?

Time required: 45 minutes

Outcome: Learners will understand that their food items are related to larger interacting natural and social systems.

Assessment:

1. Learners can draw a concept map of the relationship of one part of a hamburger to larger natural and social systems.
2. Learners can verbally convey to the rest of the class how a specific Environmental Literacy Benchmark relates to their concept map and give examples.

Materials:

- 1 nontoxic marker per team
- 1 poster tablet sheet per team
- 1 roll of masking tape
- Environmental Literacy Benchmark Cards. (Keep your Benchmark Cards for the next exercise.)

Tell the participants that the purpose of this exercise is to show how a hamburger is hooked to the stars.

- Divide the class into the same work groups formed for previous exercises. (Preferably two to four groups of four to six persons per group.)
- Start lesson by asking groups to write hamburger in center of poster paper and draw a circle around it.
- Ask students to list the parts of a hamburger in a circle around the center circle containing the word hamburger.
- Review their work. Assign a different part of the hamburger to each of the groups.
- Ask the groups to map the natural and social systems related to the part of the hamburger that they were assigned. Be sure to show how their part is "hooked to the stars." They should make the connection that each of the parts is directly or indirectly dependent upon the sun.
- Give each group a third Benchmark card. Instruct them to write the statement on their concept map. Ask them to be prepared to report to the class how this statement relates to their concept map and give examples.
- Each group elects a spokesperson to report to the class. Groups report. Solicit comments and observations from the class.

Briefly summarize: You have been working with 12 Environmental Literacy Benchmarks evolved from NAAEE and AAAS national standards. These Benchmarks represent an age-appropriate method of creating a systems perspective in learners by teaching them to use the Benchmarks to examine/ask questions about environmental and social systems.

I can find interactions between natural and social systems.

Time required: 90 minutes

Outcome: Learners understand that natural and social systems are comprised of interacting parts and that social systems can exert a significant influence on natural systems.

Assessment:

1. Learners can draw a concept map of a natural and a social system and the relationship between these systems.
2. Learners can verbally convey to the rest of the class how a specific Environmental Literacy Benchmark relates to their concept map and give examples.

Materials:

- 1 nontoxic marker per team
- 2 poster tablet sheets per team
- 1 roll of masking tape
- Environmental Literacy Benchmark Cards

The operative definition of environmental education that we use in the *Environmental Literacy Scope and Sequence* is "studies focused on the interaction between natural and social systems." *A GreenPrint for Minnesota: State Plan for Environmental Education* promotes using the school, community, and regional resources to identify opportunities for environmental studies. This is also true in using the Environment as an Integrating Context for Learning (EIC). Community-based means more than just the town that the students live in. Ideally, workshop participants would be sent into the community to look for evidence of these interactions. However, this won't work for most workshops and there isn't time. This lesson serves as an alternative to allow participants to examine natural and social system interactions.

Exercise 1. I can describe a system and its interacting parts.

Time: 45 minutes

We are going to examine some natural and social systems to see if we can describe their parts and how they interact. Later in the exercise we are going to examine how social and natural systems interact.

- Divide the class into six groups.

- Ask the groups to make a concept map of the parts of their system and discuss how some of the parts interact. Interactions such as those between:
  prairie – family farm
  forest – paper industry
  river – city

- Distribute one of the single systems Environmental Literacy Benchmarks cards to each of the six groups. Ask the group to write the "statement" at the top of the poster paper.
- Ask the groups to select an interaction between two parts they discussed. How does the "statement" relate to this interaction?
- Have each group select a spokesperson (or persons) to read their "statement." Then groups describe their work to the class and tell how the "statement" applies to their work. Give the class a chance to comment or question the presenter.
- Briefly review the six single systems Benchmarks.

Exercise 2: I can describe how a natural and social system interacts.

Time: 45 minutes

- Create three groups by combining the groups in Exercise 1 according to the list of interactions above.
- Instruct the groups to briefly review the systems they mapped in Exercise 1 with each other. Then, in the center of the poster paper, make two overlapping circles. Write the names of the systems in the circles.
- Next, ask groups to map some of the interactions that might occur between the two systems around the circles. Connect the interactions with a line to the overlapped portion of the circles.
- Distribute two multiple systems Benchmark cards to each of the groups.
- Ask the groups to select one interaction they discussed. How do the "statements" relate to this interaction?
- Have each group select a spokesperson (or persons) to read their "statements." Then groups describe their work to the class and tell how the "statements" applies to their work. Give the class a chance to comment or question the presenter.
- Briefly review the six multiple systems Benchmarks.

Discussion

Time: 5 minutes

Could the participants identify alternative interactions that might change the outcomes? How could the Benchmarks be used to help identify alternative interactions?

I can find applications for the Scope and Sequence in EE lessons.

Time required: 45 minutes

Outcome: Learners understand how to use the Environmental Literacy Benchmarks to illustrate their applications to existing environmental education lessons.

Assessment:

1. Learners can draw a concept map of the relationship of an environmental education lesson to the Environmental Literacy Benchmarks.
2. Learners can verbally convey to the rest of the class how a specific Environmental Literacy Benchmark relates to their concept map of an environmental education lesson and give examples.

Materials:

- 1 nontoxic marker/team
- 1 poster tablet sheets/team
- 1 roll of masking tape
- Environmental Literacy Benchmark cards
- WILD Aquatic manual, *Migration Headache,* p. 87
- WILD manual, *Deadly Links,* p. 197
- PLT manual, *Keep on Truckin',* p. 148
- WOW manual, *Get Involved,* p. 310
- WET manual, *Choices and Preferences,* p. 367
- MinnAqua manual, *The Lake Game,* pp. 3-10

In this exercise, we are going to explore how the systems statements we have been working with relate to environmental education materials that you may already have been using.

- Divide the class into three to six groups. Give each group one of the listed manuals with the selected lesson marked with a bookmark or paper clip.
- Ask that a spokesperson from each of the groups reads the lesson to its members.
- Each group writes the name of their lesson in the center of the poster paper. Draw a circle around the lesson name.
- Groups map what the students are "doing." Circle them and connect with a line to the lesson name.
- Groups then select one of the students' "doing" tasks and map what students are learning from doing that task. Circle them and connect to the "doing" item with lines.
- Each group then selects one of the student "learning" items and maps the concepts that are involved in what the students are learning. Circle them and connect to the "learning" item they selected.

- Distribute one new Benchmark to each group. They discuss how it relates to the lesson they examined and report to the other groups.
- Groups examine the Concept sheets that pertain to their "learning" item that they selected from above.
- Groups discuss teaching and assessment strategies they would use to be sure the Concepts and Benchmarksare taught during the lesson.
- Groups use the workshop handout materials to select the Graduation Standard Learning Areas to which their lesson relates.
- Groups' spokespersons report their work to the class. Invite questions and comments.

Summary: The *Environmental Literacy Scope and Sequence* does not require curriculum writing efforts. What it does is provide an opportunity to reexamine what we are teaching and how we could modify our lesson plans/units to include the Environmental Literacy Benchmarks, too. This has the potential of adding an assessment opportunity that was missing before as well as relating what we are teaching to the Graduation Standards.

Extension 1: I can find applications for the Scope and Sequence in lessons I am teaching.

Time: 45 minutes
Use the same process in this lesson, but participants use one of their own lessons or units.

Extension 2: I can change lessons to teach the Environmental Literacy Benchmarks.

Time: 45 minutes
This is an extension of the two lessons above. Use the work they have already completed in either of the two lessons.
Ask participants to do the following:

- Look at the Benchmarks and Concepts that you identified in the last exercise. What teaching strategies would you use to make sure that the students learn and understand the Concepts? How would you help the students learn the Benchmarks and understand how they applied to the lesson? List on poster paper.
- Discuss how you would assess the students to see if they understand the Concepts, Benchmarks, and the objectives of the lesson. Record your assessment plan on poster paper.
- Groups report their findings.
- Discuss the value of using concept mapping as a means of assessment.