Michigan High School Science

EARTH & SPACE

Prerequisite, Essential, and Core Content Statements and Expectations

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Welcome to Michigan's High School Science Content Standards and Expectations

Why Develop Content Standards and Expectations for High School?

In 2004, the Michigan Department of Education embraced the challenge to initiate a "high school redesign" project. Since then, the national call to create more rigorous learning for high school students has become a major priority for state leaders across the country. The Cherry Commission Report highlighted several goals for Michigan including the development of high school content expectations that reflect both a rigorous and a relevant curricular focus. Dovetailing with this call to "curricular action" is Michigan's legislative change in high school assessment. The Michigan Merit Exam, based on rigorous high school learning standards, is to be full implemented by 2007.

The Michigan Department of Education's Office of School Improvement led the development of high school content expectations. A science academic review group of academicians chaired by nationally known scholars was commissioned to conduct a scholarly review and identify content standards and expectations. The Michigan Department of Education will conduct an extensive field review of the expectations by high school, university, and business and industry representatives.

The Michigan High School Science Content Expectations (Science HSCE) establish what every student is expected to know and be able to do by the end of high school and define the expectations for high school science credit in Earth and Space Science, Biology, Physics, and Chemistry.

An Overview

This is a first draft of Science Content Expectations for Michigan High Schools. It was developed by the Science Academic Review Work group. In developing these expectations, the group depended heavily on the *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2006).
In particular, the group adapted the structure of the NAEP framework (including Content Statements, Performance Expectations, and Boundaries). These expectations align closely with the NAEP framework, which is based on *Benchmarks for Science Literacy* (AAAS Project 2061, 1993) and the *National Science Education Standards* (National Research Council, 1996).

The academic review group carefully analyzed other documents, including the Michigan Curriculum Framework Science Benchmarks (2000 revision), the Standards for Success report *Understanding University Success*, ACT's *College Readiness Standards*, College Board's *AP Biology, AP Physics, AP Chemistry,* and *AP Environmental Science Course Descriptions*, ACT's *On Course for Success*, South Regional Education Board's *Getting Ready for College-Preparatory/Honors Science: What Middle Grades Students Need to Know and Be Able to Do,* and standards documents from other states.

Earth & Space Science	Biology	Physics	Chemistry
STANDARDS *(and number of Content Statements in each standard)*			
E1 Systems and Processes in the Environment (4) E2 The Solid Earth (4) E3 The Fluid Earth (4) E4 Earth in Space and Time (9) E5 Chemicals in the Environment (3)	B1 Organization and Development of Living Systems (6) B2 Interdependence of Living Systems and the Environment (4) B3 Genetics (6) B4 Evolution and Biodiversity (3)	P1 Forms of Energy and Energy Transformations (24) P2 Motion of Objects (3) P3 Forces and Motion (10)	C1 Forms of Energy (5) C2 Energy Transfer and Conservation (5) C2 Properties of Matter (10) C3 Changes in Matter (8)

Useful and Connected Knowledge for All Students

This draft defines expectations for Michigan High School graduates, organized by discipline: Earth and Space Science, Biology, Physics, and Chemistry. It defines ***useful*** and ***connected knowledge*** at three levels:

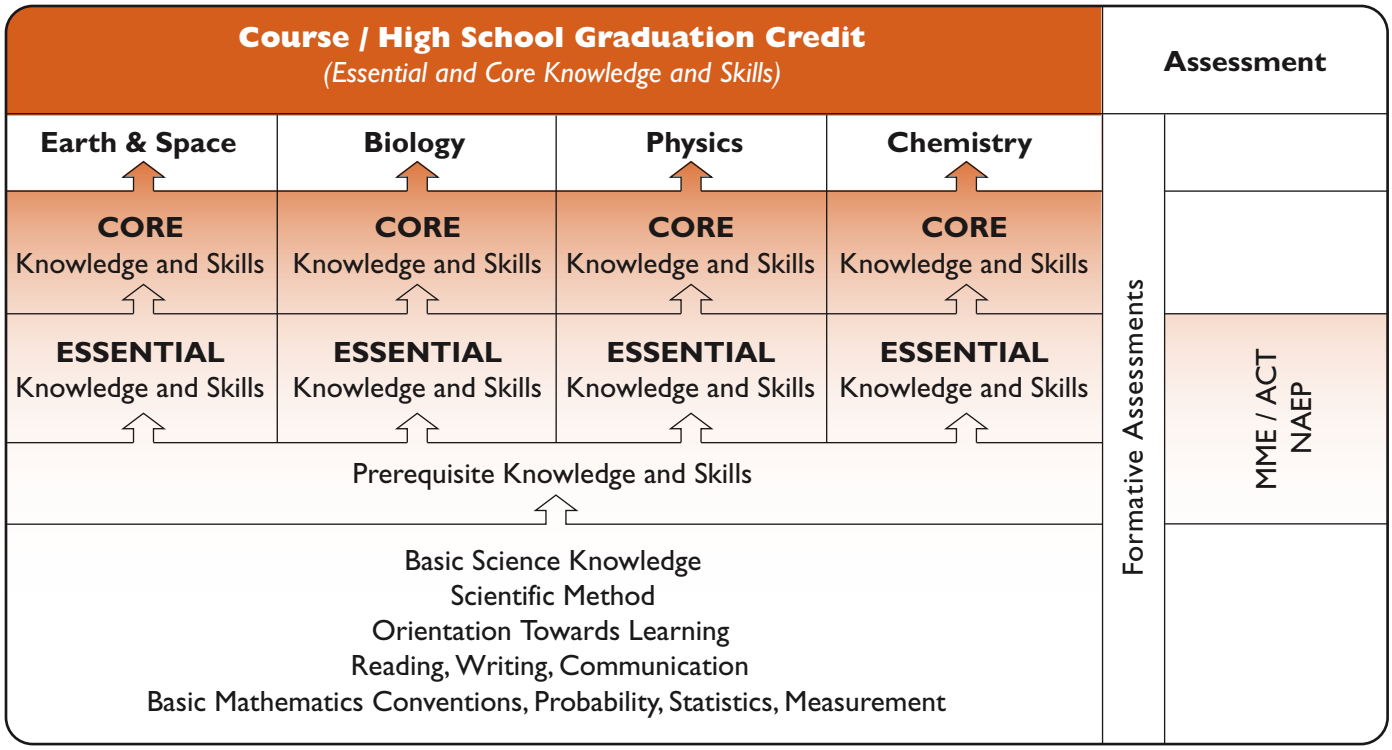
- **Prerequisite knowledge**
  Useful and connected knowledge that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed in the Essential category. Prerequisite content statements and expectations will be included in the middle school science expectations when they are written.

- **Essential knowledge**
  Useful and connected knowledge for all high school graduates, regardless of what courses they take in high school. In general, essential knowledge consists of content and skills that all students need to know and be able to do. Essential content and expectations will be assessable on large-scale assessments (MME/ACT, NAEP).

- **Core knowledge**
  Useful and connected knowledge for students who have completed a discipline-specific course. In general, core knowledge includes content and expectations that students need to be prepared for more advanced study in that discipline.

Useful and connected knowledge is contrasted with ***procedural display***—learning to manipulate words and symbols without fully understanding their meaning. When expectations are excessive, procedural display is the kind of learning that takes place. Teachers and students "cover the content" instead of striving for useful and connected knowledge.

Credit for high school Earth and Space Science, Biology, Physics, and Chemistry will be defined as meeting both essential and core subject area content expectations.



High School Science Overview

Preparing Students for Successful Post-Secondary Engagement

Students who have useful and connected knowledge should be able to apply knowledge in new situations; to solve problems by generating new ideas; to make connections among what they read and hear in class, the world around them, and the future; and through their work, to develop leadership qualities while still in high school. In particular, high school graduates with useful and connected knowledge are able to engage in four key practices of science literacy.

Successful Post-Secondary Engagement

Practices of Science Literacy

Communicate accurately and effectively...

Identifying Science Principles

- Describe, measure, or classify observations
- State or recognize correct science principles
- Demonstrate relationships among closely related science principles
- Demonstrate relationships among different representations of principles

Using Science Principles

- Explain observations of phenomena
- Predict observations of phenomena
- Suggest examples of observations that illustrate a science principle
- Propose, analyze, and evaluate alternative explanations or predictions

Scientific Inquiry

- Generate new questions that can be investigated empirically.
- Design and critique aspects of scientific investigations.
- Conduct scientific investigations using appropriate tools and techniques, recognizing limitations.
- Identify patterns in data and/or relate patterns in data to theoretical models.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions.
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable.
- Gather data and organize the results in graphs, tables, and/or charts.

Reflection and Technology

- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Identify and critique arguments based on scientific evidence.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Propose or critique solutions to problems given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Apply scientific models or patterns in data to technological design decisions.

State/National Landscape

- Expert perspective
- Education reform environment
- Research-based practices
- Work force requirements

State/Federal Expectations

- No Child Left Behind (NCLB)
- National Governors' Association (NGA)
- Legislation/Policy

Michigan High School Science Content Standards and Expectations

Earth and Space Science

Biology

Physics

Chemistry

Models for District Alignment / Mapping

- District curriculum documents
- Documents from other districts/states
- Backmapping to standards and expectations

Other MI Documents/Programs

- State Standards – teaching and learning, content (all areas), assessment
- Grade Level Content Expectations
- State Assessments
- Career/Technical Education Department of Labor and Economic Growth

K-8 Educational Experience

Content Knowledge

- English Language Arts
- Mathematics
- Science
- Social Studies
- Other

Learning Processes

- Strategies & Skills
- Reasoning
- Analytical Thinking
- Constructing New Meaning
- Communication

This chart includes talking points for the professional development model.

Practices of Science Literacy

- **Identifying**
  Indentifying performances generally have to do with stating models, theories, and patterns inside the triangle in Figure 1.
- **Using**
  Using performances generally have to do with the downward arrow in Figure 1—using scientific models and patterns to explain or describe specific observations.
- **Inquiry**
  Inquiry performances generally have to do with the upward arrow in Figure 1—finding and explaining patterns in data.[1]
- **Reflecting and Technology**
  Reflecting and *Technology* performances generally have to do with the figure as a whole (reflecting) or the downward arrow (technology as the application of models and theories to practical problems.

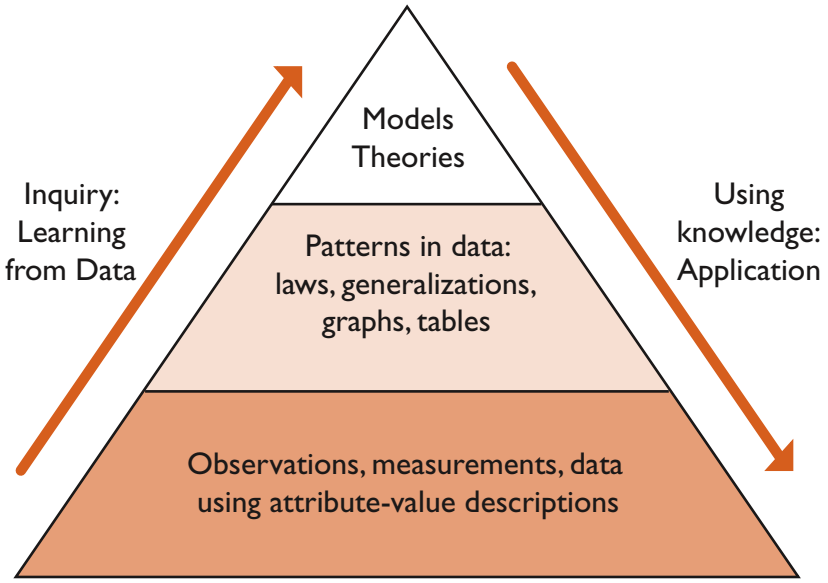


Figure 1: Knowledge and practices of model-based reasoning

Identifying Science Principles

This category focuses on students' ability to recall, define, relate, and represent basic science principles. The content statements themselves are often closely related to one another conceptually. Moreover, the science principles included in the content statements can be represented in a variety of forms, such as words, pictures, graphs, tables, formulas, and diagrams (AAAS, 1993; NRC, 1996). Identifying practices include describing, measuring, or classifying observations; stating or recognizing principles included in the content statements; connecting closely related content statements; and relating different representations of science knowledge.

Identifying Science Principles comprises the following general types of practices:

- Describe, measure, or classify observations (e.g., describe the position and motion of objects, measure temperature, classify relationships between organisms as being predator/prey, parasite/host, producer/consumer)
- State or recognize correct science principles (e.g., "mass is conserved when substances undergo changes of state;" "all organisms are composed of cells;" "the atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor")
- Demonstrate relationships among closely related science principles (e.g., statements of Newton's three laws of motion, energy transfer and the water cycle)
- Demonstrate relationships among different representations of principles (e.g., verbal, symbolic, diagrammatic) and data patterns (e.g., tables, equations, graphs)

Identifying Science Principles is integral to all of the other science practices.

Using Science Principles

Scientific knowledge is useful for making sense of the natural world. Both scientists and informed citizens can use patterns in observations and theoretical models to predict and explain observations that they make now or that they will make in the future.

Using Science Principles comprises the following general types of performance expectations:

- Explain observations of phenomena (using science principles from the content statements)
- Predict observations of phenomena (using science principles from the content statements, including quantitative predictions based on science principles that specify quantitative relationships among variables)
- Suggest examples of observations that illustrate a science principle (e.g., identify examples where the net force on an object is zero; provide examples of observations explained by the movement of tectonic plates; given partial DNA sequences of organisms, identify likely sequences of close relatives)
- Propose, analyze, and evaluate alternative explanations or predictions

The first two categories—***Identifying Science Principles*** and ***Using Science Principles***—both require students to correctly state or recognize the science principles contained in the content statements. A difference between the categories is that Using Science Principles focuses on what makes science knowledge valuable—that is, its usefulness in making accurate predictions about phenomena and in explaining observations of the natural world in coherent ways (i.e., "knowing why"). Distinguishing between these two categories draws attention to differences in depth and richness of individuals' knowledge of the content statements. Assuming a continuum from "just knowing the facts" to "using science principles," there is considerable overlap at the boundaries. The line between the Identifying and Using categories is not distinct.

Scientific Inquiry

Scientifically literate graduates make observations about the natural world, identify patterns in data, and propose explanations to account for the patterns. Scientific inquiry involves the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses to explain patterns in data. Scientific inquiry is a complex and time-intensive process that is iterative rather than linear. Habits of mind—curiosity, openness to new ideas, informed skepticism—are part of scientific inquiry. This includes the ability to read or listen critically to assertions in the media, deciding what evidence to pay attention to and what to dismiss, and distinguishing careful arguments from shoddy ones. Thus, Scientific Inquiry depends on the practices described above—Identifying Science Principles and Using Science Principles.

Scientific Inquiry comprises the following general types of performance expectations:

- Generate new questions that can be investigated in the laboratory or field.
- Design and critique aspects of scientific investigations (e.g., involvement of control groups, adequacy of sample)
- Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision)
- Identify patterns in data and/or relate patterns in data to theoretical models
- Describe a reason for a given conclusion using evidence from an investigation.
- Explain how scientific evidence supports or refutes claims or explanations of phenomena.
- Predict what would happen if the variables, methods, or timing of an investigation were changed.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions (e.g., check to see that the premises of the argument are explicit, notice when the conclusions do not follow logically from the evidence given)
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts.

Scientific inquiry is more complex than simply making, summarizing, and explaining observations, and it is more flexible than the rigid set of steps often referred to as the "scientific method." The *National Standards* makes it clear that inquiry goes beyond "science as a process" to include an understanding of the nature of science (p. 105). Further:

It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations (p. 171).

When students engage in Scientific Inquiry, they are drawing on their understanding about the nature of science, including the following ideas (see Benchmarks for Science Literacy):

- Arguments are flawed when fact and opinion are intermingled or the conclusions do not follow logically from the evidence given
- A single example can never support the inference that something is always true, but sometimes a single example can support the inference that something is not always true
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables
- The way in which a sample is drawn affects how well it represents the population of interest. The larger the sample, the smaller the error in inference to the population. But, large samples do not necessarily guarantee representation, especially in the absence of random sampling

Students can demonstrate their abilities to engage in Scientific Inquiry in two ways: students can *do* the practices specified above, and students can *critique examples* of scientific inquiry. In *doing*, practices can include analyzing data tables and deciding which conclusions are consistent with the data. Other practices involve hands-on performance and/or interactive computer tasks—for example, where students collect data and present their results or where students specify experimental conditions on computer simulations and observe the outcomes. As to *critiquing*, students can identify flaws in a poorly designed investigation or suggest changes in the design in order to produce more reliable data. Students should also be able to critique print or electronic media—for example, items may ask students to suggest alternative interpretations of data described in a newspaper article. For more on item formats, please see Chapter Four.

Reflection and Technological Design

Scientifically literate people recognize the strengths and limitations of scientific knowledge, which will provide the perspective they need to use the information to solve real-world problems. Students must learn to decide who and what sources of information they can trust. They need to learn to critique and justify their own ideas and the ideas of others. Since knowledge comes from many sources, students need to appreciate the historical origins of modern science and the multitude of connections between science and other disciplines. Students need to understand how science and technology support one another and the political, economic, and environmental consequences of scientific and technological progress. Finally, it is important that the ideas and contributions of men and women from all cultures be recognized as having played a significant role in scientific communities.

In both the *National Standards* and *Benchmarks*, the term "technological design" refers to the process that underlies the development of all technologies, from paperclips to space stations. Technological Design describes the systematic process of applying science knowledge and skills to solve problems in a real-world context. The reason for including technological design in the science curriculum is clearly stated in the *National Standards*: "Although these are science education standards, the relationship between science and technology is so close that any presentation of science without developing an understanding of technology would portray an inaccurate picture of science" (p. 190).

Reflection and Technological Design include the following general types of practices, all of which entail students using science knowledge to:

- Critique whether questions can be answered through scientific investigations.
- Identify and critique arguments based on scientific evidence.
- Compare the effectiveness of different graphics and tables to describe patterns, explanations, conclusions, and implications found in investigations.
- Explain why results from a single investigation or demonstration are not conclusive.
- Explain why a claim or a conclusion is flawed (e.g. limited data, lack of controls, weak logic).
- Propose or critique solutions to problems, given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Apply science principles or data to anticipate effects of technological design decisions.
- Explain the social, economic, and environmental advantages and risks of new technology.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Discuss topics in groups by making clear presentations, restating or summarizing what others have said, asking for clarification or elaboration, taking alternative perspectives, and defending a position.

Organization of the Expectations

The Science Expectations are organized into Disciplines, Standards, Content Statements, and specific Performance Expectations.

Disciplines

Earth and Space Science, Biology, Physics and Chemistry.

Organization of Each Standard

Each standard includes four parts, described below.

- A standard statement that describes what students who have mastered that standard will be able to do.
- Content statements that describe Prerequisite, Essential, and Core science content understanding for that standard.
- Performance expectations that describe Prerequisite, Essential, and Core performances for that standard.
- Boundary statements that clarify the standards to set limits to expected performances.

Standard Statement

The Standard Statement describes how students who meet that standard will engage in Identifying, Using, Inquiry, or Reflection for that topic.

Content Statements

Content statements describe the Prerequisite, Essential, and Core *knowledge* associated with the standard. This draft identifies five levels of expectations:

1. ***Prerequisite science content*** that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed with Essential content and printed in the left-hand column of the expectations documents.
2. ***Essential science content*** that all high school graduates should master. Essential content and expectations are organized by topic (e.g., E4.2 Earth in Space) and printed in the left-hand column of the expectations documents.
3. ***Core science content*** that high school graduates need for more advanced study in the discipline and for some kinds of work. Core content and expectations are organized by topic (e.g., E4.3x Stars; note that "x" designates a core topic) and printed in the right-hand column of the expectations document.
4. ***Basic mathematics skills.*** These will be included in an Appendix at the end of the document.
5. ***Basic English language arts skills.*** These will be included in an Appendix at the end of the document.

Performance Expectations

Performance expectations are derived from the intersection of content statements and practices—if the content statements from the Earth and Space Sciences, Biology, Physics, and Chemistry are the columns of a table and the practices (Identifying Science Principles, Using Science Principles, Using Scientific Inquiry, Reflection and Technological Design) are the rows, the cells of the table are inhabited by performance expectations.

Performance expectations are written with particular verbs indicating the desired performance expected of the student. The action verbs associated with each practice are not firmly fixed. The use of any action verb must be contextualized. For example, when the "conduct scientific investigations" is crossed with a states-of-matter content statement, this can generate a performance expectation that employs a different action verb, "heats as a way to evaporate liquids."

Boundaries

Boundaries elaborate the Performance Expectations. The boundaries are intended as "notes to curriculum and assessment developers," not as comprehensive descriptions of the full range of science content to be included in the high school science curriculum. In the boundary statements, the terms "such as," "including," "e.g.," and "etc." are used to denote suggestions. The boundaries do not stand alone and should be considered in conjunction with the relevant content statements and narrative introductions for each of the disciplines—Earth and Space Science, Biology, Physics, and Chemistry. Some content statements are very detailed and require less specification of boundaries. Although the boundaries relevant to a given subtopic may focus more heavily on some content statements than others, this is not intended to denote a sense of content priority.

EARTH AND SPACE SCIENCE (E)

In recent years, the study of Earth has undergone profound changes. It has shifted from surface geology and the recovery of economic resources toward global change and Earth systems. Concurrently, research methods have changed from human observations and mapping to remote sensing and computer modeling. The advent of technology has made it possible to conduct more integrated and interdisciplinary research and view the Earth as a single dynamic entity composed of four interacting systems. The Earth System is usually subdivided into the geosphere (solid Earth), the hydrosphere (the liquid part of the planet), the atmosphere (the gaseous part of the planet), and the biosphere (the living part of the planet). These four parts do not exist in isolation, but are interconnected by complex cycles. Alterations to one part of the Earth system result in effects on another part of the system. The study of the individual components and their interactions are necessary to completely understand the complex dynamics of our planet.

There has also been a shift in goals, as advances in theory have made it possible to more accurately predict changes (especially in weather and climate), to provide life-saving warnings of floods, hurricanes, and volcanic eruptions, and to understand how human activities influence air and water quality, ecosystems, and climate across the globe. We are also better prepared to understand the processes that occur within and between each of the Earth systems.

Recent research in the Earth Sciences has focused on:

1. climate variability and change
2. impact of chemicals on ecosystems
3. water and energy cycles
4. atmospheric processes
5. earth surface and internal processes.

As national education standards have moved to mirror these foci, students must explore the methods and tools for studying Earth systems. In addition, public awareness and education is critical in mitigating the effects of natural hazards as economic and population growth expand in areas susceptible to the effects of nature (e.g., Florida, Texas, California). The impact of such events as hurricane Katrina and the Sumatra tsunami demonstrate the significant impacts of the Earth on society. Some of the decisions students will need to consider include, where to live, where to store waste, and where to develop.

The Earth System, however, is generally too complex for students to view as whole, thus it is best to look at each of the components separately. It is imperative, however, that students inquire about and understand the interconnections between Earth systems and distinguish between systems at "micro" and "macro" levels. In light of this, many content statements in this document cross standard boundaries and are interconnected.

Unlike many other disciplines, direct experimentation is difficult in many aspects of the Earth Sciences. Even direct observations can be difficult and scientists must depend on the formulation of models both to describe and determine the implications of various factors. Many aspects of the Earth Sciences also occur over very long time frames ("deep time") that are studied more like a murder mystery with inferences from indirect data; such concepts are often difficult for students to comprehend.

On the other hand, the tools available to both scientists and students for learning about Earth and space have changed as well. Communication and visualization tools, such as the internet and data bases, have made it possible for Earth Science students to have direct access to the raw data and models used by scientists. Other web-based programs allow students to view and process satellite images of Earth, to direct a camera on board the Space Shuttle, and to access professional telescopes around the world to carry out science projects.

The five Earth and Space Science standards focus on:

1. the physical and material properties and processes of the environment in which we live
2. the solid earth and its hazards
3. the fluid earth and its hazards
4. the history of the Earth and the universe, and
5. the movement of chemicals through Earth Systems.

The standards begin with an overview of Earth systems and cycles that interconnect the individual subsystems within it. This is followed by an examination of the major components of the Earth system that are covered in Earth Science courses, focusing on the solid Earth (global tectonics) and fluid Earth (climate and weather). The next standard covers the position of the Earth in the universe and its evolution over time, including the near future. Finally, there is a return to the interconnections of the Earth system by examining chemicals as they move through the Earth and human impacts on these chemical cycles.

The interdisciplinary nature of the Earth Sciences makes it difficult to rigidly separate and sequence subject matter. Many topics can fit equally well in many different places. This document represents one organizational structure.

Outline of Earth and Space Science Expectations

Standard E1: Systems and Processes in the Environment

E1.1 Rocks
E1.2 Water
E1.3 Landforms and Soils (Middle School)
E1.4 Earth Systems Overview

Standard E2: The Solid Earth

E2.1 Structure of the Earth
E2.2 Plate Tectonics
E2.3x Plate Evolution
E2.4 Earthquakes and Volcanoes

Standard E3: The Fluid Earth

E3.1 Oceans
E3.2 Weather and the Atmosphere (Middle School)
E3.2x Global Circulation and Climate
E3.3 Severe Weather
E3.3x Mesometeorology
E3.4 Glaciers

Standard E4: Earth in Space and Time

E4.1 Sky Observations (Middle School)
E4.2 The Earth in Space
E4.3x Stars
E4.4x Magnetosphere
E4.5x Evidence for the Nature of the Universe
E4.6x Planetary Geology
E4.7 Earth History and Geologic Time
E4.8x The Early Earth
E4.9 Climate Change

Standard E5: Chemicals in the Environment

E5.1 Geochemical Cycles
E5.2 Energy Resources
E5.3 Human Effects on Earth Systems

Standard E1: Systems and Processes in the Environment

Standard Statement

Students will describe the interactions within and between Earth systems. Students will explain how both fluids (water cycle) and solids (rock cycle) move within Earth systems and how these movements form and change their environment. They will describe the relationship between physical process and human activities and use this understanding to make wise decisions about land use.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E1.1: Rocks –** Igneous, metamorphic, and sedimentary rocks are composed of minerals and are constantly forming and changing through various processes. As they do so, chemicals move through the Earth system. They are indicators of geologic and environmental conditions that existed in the past. ***Identifying and Using Performance Expectations*** **E1.p1** Identify common minerals by their properties. (***middle school prerequisite***) **E1.1A** Identify common igneous, metamorphic and sedimentary rocks and describe the processes that change one kind of rock to another. **E1.1B** Explain the relationship between the rock cycle and the plate tectonics theory. **Instruments, Measurement, and Representations** **Technical Vocabulary** Names, composition, and identification of common sedimentary, igneous, and metamorphic rocks. Common terms for processes in the rock cycle. **Clarifications** Focus on the rock cycle and rock forming processes and how the rock cycle is a part of plate tectonic and geochemical cycles.	***Content Statement*** **E1.1x Advanced Rock Cycle –** Rocks show evidence of changes over time. These include changes in, or exposure to, pressure and temperature, exposure to the surface, and transport. Many of these processes are controlled by plate tectonics and climate. ***Identifying and Using Performance Expectations*** **E1.1c** Explain how and why the size of rock fragments in a sedimentary rock might differ depending on whether it formed in the Arctic or the tropics. **E1.1d** Explain how the chemistry of rocks is affected at various stages of the rock cycle. **Instruments, Measurements, and Representations** **Technical Vocabulary** Chemical composition of important rock forming minerals such as quartz, feldspar, mica, hornblende, and pyroxene Models or animations to show how rocks weather in different environments such as the desert or tropics Common terms for the rock cycle **Clarifications** Focus on the chemistry of common rock forming minerals and how they change depending on the climate of a given area.
Content Statement **E1.2 Water –** Water circulates through the crust and atmosphere, and in oceans, rivers, glaciers and ice caps and connects all of the Earth systems. Groundwater is a significant reservoir and source of freshwater on Earth. The recharge and movement of groundwater depends on porosity, permeability, and the shape of the water table. The movement of ground water occurs over a long period time. Groundwater and surface water are often interconnected. ***Identifying and Using Performance Expectations***	***Content Statement*** **E1.2x Water and the Earth –** Water has unique properties that make it essential for both chemical reactions and the development of life. ***Identifying and Using Performance Expectations***

E1.2A Compare and contrast surface water systems and ground water systems. **E1.2B** Identify and describe your local watershed within the Great Lakes Basin using maps, including drainage basins, divides, reservoirs, tributaries, and surface run-off **E1.2C** Explain how heat is transferred through Earth Systems when water changes states. **Instruments, Measurement, and Representations** Know about instruments used to measure the flow of water Diagrams showing water cycle and role of heat stored in ocean as well as role of other Earth systems Charts of data to calculate the precipitation and vapor pressures (relative humidity) Data of thermal properties of water including heat capacity and latent heat as related to phase changes. **Technical Vocabulary** permeability, porosity, aquifer, water table, reservoirs, sedimentary transport Common terms such as evaporation, condensation, absorption, percolation, infiltration, surface runoff, and groundwater **Clarifications** Focus on cyclic nature of water and how it moves across boundaries and through Earth systems	**E1.2d** Describe how the density of pure water changes with temperature, and explain why ice forms at the surface of oceans and lakes. **Instruments, Measurements, and Representations** **Technical Vocabulary** Surface tension and capillary action **Clarifications**
Content Statement **E1.3p: Landforms and Soils (*Middle School*) –** Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruptions and deposition of sediments transported in rivers, streams and lakes through watersheds. Destructive forces include weathering and erosion. The weathering of rocks and decomposed organic matter result in the formation of soils. *(prerequisite)* ***Identifying and Using Performance Expectations*** **E1.3p1** Explain the origin of local landforms. Describe and identify surface features using maps and satellite images. **E1.3p2** Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments. **E1.3p3** Describe how coastal features are formed by wave erosion and deposition. **Instruments, Measurements, and Representations** **Technical Vocabulary** <u>Exclusions</u>	

Names of soil types. **Clarifications** Focus on mechanisms that build up and tear down Earth structures	
E *Content Statement* **1.4 Earth Systems Overview –** The Earth is a system consisting of four major interacting components-- geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth's crust, oceans, atmosphere, and living organisms. Plans for land use and long-term development must include an understanding of the interactions of Earth systems with human activities. ***Identifying and Using Performance Expectations*** **E1.4A** Compare an open and closed system and explain why Earth is essentially a closed system. **E1.4B** Describe the major systems (geosphere, hydrosphere, biosphere, atmosphere) that make up the Earth. **E1.4C** Explain, using specific examples, how a change in one system affects other Earth systems. **E1.4D** Describe how the interaction of physical processes and human activities impact water, land and air. **Instruments, Measurement, and Representations** Diagrams showing the connection of the different cycles of the Earth systems **Technical Vocabulary** **Clarifications**	***Content Statement*** **E1.4x Earth Systems –** Interactions between the systems have resulted in ongoing evolution of the earth system over geologic time. ***Identifying and Using Performance Expectations*** **E1.4e** Explain how feedback loops affect systems. **Instruments, Measurement, and Representations** Models of the evolution of earth systems over the geological time scale **Technical Vocabulary** **Clarifications** Focus: on the length of time it takes for certain elements to cycle through the Earth system and show how it has changed through geological time
Inquiry, Reflecting, and Technology Performances	
E1.R1 Write the geologic history for your area based on rock types using Michigan geologic (bedrock) maps and local data. **E1.R2** Make a model, illustrating the processes that transport water between reservoirs in the water cycle. This model should be based on local water sources and include the drinking water supply for your community. **E1.R3** Justify a community land use plan considering risks and benefits.	**E1.r4** Map a feedback loop in an Earth system

Standard E2: The Solid Earth

Standard Statement

Students will explain how scientists study and model the interior of the Earth and its dynamic nature. They will use the theory of plate tectonics, the unifying theory of the Earth Sciences, to explain a wide variety of Earth features and processes and how hazards resulting from these processes impact society.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E2.1 Structure of the Earth** –The Earth is composed of a series of concentric layers classified by their chemical composition (crust, mantle and core) or based on their physical characteristics: (lithosphere, asthenosphere, lower mantle, outer core, and inner core). The crust and upper mantle compose the rigid lithosphere that moves over a "softer" asthenosphere (part of the upper mantle). The dynamic interior of the Earth cannot be directly sampled and must be modeled using data from seismology. ***Identifying and Using Performance Expectations*** **E2.1A** Explain how scientists infer that the Earth has interior layers. **E2.1B** Explain the uncertainties associated with models of the interior of the Earth and how these models are validated. **Instruments, Measurements, and Representations** Cross sections and scales. Models of the Earth's interior. **Technical Vocabulary** crust, mantle, outer core, inner core, lithosphere, asthenosphere. **<u>Exclusions</u>** All other minor subdivisions in the crust and mantle (e.g., transition zone, Moho, D"). **Clarifications** The crust-mantle-core subdivision of the Earth is based on chemical composition (seismic velocity) while the lithosphere and asthenosphere are distinguished on the basis of rock behavior.	***Content Statement*** **E2.1x The Interior of the Earth** – Plate motions are driven by forces acting primarily along their boundaries using energy derived from convective heat transfer. The pattern of convection in the mantle can be inferred from the speeds at which earthquake waves travel through the Earth. ***Identifying and Using Performance Expectations*** **E2.1c** Explain how patterns of convection in the mantle are determined. **E2.1d** Predict general regions of rising and sinking upper mantle material using the distribution of plate boundaries. **Instruments, Measurements, and Representations** Seismographs and seismograms **Technical Vocabulary** Elastic, viscous, and plastic behavior Terms for mechanisms of heat transfer such as convection, conduction and radiation relative and absolute plate motions **Clarifications** Plates are part of the convection system.

Content Statement **E2.2 Plate Motions** – Plates are composed of the lithosphere and move at velocities of cm/yr as measured using the global positioning system. Oceanic plates are created at mid-ocean ridges and cool until they sink back into the Earth at subduction zones. At some localities, plates slide by each other. Mountain belts are formed both by continental collision and as a result of subduction. The outward flow of heat from the Earth provides the driving energy for plate tectonics. ***Identifying and Using Performance Expectations*** **E2.2A** Describe how the direction and the rate of movement for the plate on which you live has affected the local climate over the last 600 million years. **E2.2B** Explain how plate tectonics accounts for the features and processes (sea floor spreading, mid ocean ridges subduction zones, earthquakes and volcanoes, mountain ranges) that occur on or near the Earth's surface. **E2.2C** Describe how the transfer of heat from inside the Earth could result in plate movements. **Instruments, Measurements, and Representations** Relative and absolute motion (frames of reference) Topographic (including the ocean floor showing ridges and trenches) and geologic maps, cross sections (topographic and geologic), satellite imagery of plate boundary structures. Cross sections of plate boundaries Maps of plate motions GPS systems **Technical Vocabulary** Types of plate boundaries (convergent, divergent, transform), processes (subduction, sea-floor spreading, rifting), and physiographic features (mid-ocean ridge, trench, island arc, etc.) associated with them. Relative plate motions. **<u>Exclusions</u>** Names of specific plates except North America, Pacific, and Eurasia. **Clarifications** Focus: On the evidence for plate movements and their relationship to mountain building, earthquakes, island arcs, and volcanoes. Plate movements are driven by convective heat transfer in the mantle (specific mechanism is covered in XE2.1)	***Content Statement*** **E2.2x Plate Motions** – The magnetic field of the earth, which is believed to originate in the outer core, is a dipole which reverses direction approximately every million years. This helps us demonstrate that continents have moved and that new ocean floor is created at mid-ocean ridges. Plate motions have also been determined using volcanic islands. ***Identifying and Using Performance Expectations*** **E2.2d** Determine the rate of sea-floor spreading, using the correlation of magnetic anomalies and the magnetic reversal time scale. **E2.2e** Describe the paleomagnetic evidence for continental drift. **E2.2f** Explain how linear island chains can be explained by the hot spot model **Instruments, Measurements, and Representations** compass, GPS systems Maps of magnetic orientation of rocks on both sides of a mid-ocean ridge Calculations of spreading rate using magnetic lineations and distance from the ridge Maps showing radiometric dates of rocks on different Hawaiian islands. Know about magnetometers, radiometric dating methods, and GIS systems. **Technical Vocabulary** Geographic and magnetic north; dipole, magnetometer, magnetic anomaly (or lineation) **<u>Exclusions</u>** details of radiometric dating methods **Clarifications** Focus on evidence for sea-floor spreading and continental movements
	Content Statement **E2.3x Plate Evolution** – Oceanic plates cool as they move away from the ridge. Accretion of material to the continents can occur at subduction zones.

	Identifying and Using Performance Expectations **E2.3a** Predict the temperature distribution in the lithosphere as a function of distance from the mid-ocean ridge. **Instruments, Measurements, and Representations** Graphs of the temperature distribution in the lithosphere Geologic maps **Technical Vocabulary** Mechanisms for heat transfer (convection, conduction, radiation), relative plate motions. Link to physics. **Clarifications** Focus on how oceanic lithosphere evolves and how do continents grow.
Content Statement **E2.4 Earthquake and Volcanic Hazards** – Plate motions result in potentially catastrophic events (earthquakes, volcanoes, tsunamis) that affect humanity. Prediction of these events largely depends on periodicity (historically, how often they have occurred) and the identification of precursory phenomena (warning signs). ***Identifying and Using Performance Expectations*** **E2.4A** Use the distribution of earthquakes and volcanoes to locate plate boundaries **E2.4B** Explain how volcanic eruptions can affect climate **E2.4C** Describe how the sizes of earthquakes and volcanoes are measured or described. **E2.4D** Describe the effects of earthquakes and volcanic eruptions on humans **E2.4E** Describe safety procedures for earthquakes and volcanoes **Instruments, Measurements, and Representations** Know about instruments such as seismographs, laser ranging systems, tiltmeters used in recording earthquakes and forecasting volcanic eruptions Quantitative measures of earthquake size (intensity and magnitude) Map projections and maps of earthquake and volcano distribution and their relationship to plate boundaries, topography, and hazards Seismograms **Technical Vocabulary** Terminology for common hazards of earthquakes and volcanoes (e.g., mud flows, landslides, tsunami, subsidence, debris flow, liquefaction), terms for simple precursory phenomena for both earthquakes (foreshocks, radon release, etc.), and volcanoes (earthquakes, gases, etc.).	***Content Statement*** **E2.4x Earthquakes and Volcanoes** – The intensity of volcanic eruptions are controlled by the chemistry and properties of the magma. Igneous rocks are created from magmas both below and on the surface of the Earth. Earthquakes are the result of abrupt movements of the Earth and generate energy in the form of body and surface waves. Plate movements also affect climate and ocean circulation on long time scales ***Identifying and Using Performance Expectations*** **E2.4f** Explain how the chemical composition of magmas affects explosivity. **E2.4g** Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems. **E2.4h** Explain why fences are offset after an earthquake, using the elastic rebound theory. **E2.4i** Determine the epicenter of earthquakes using P- and S-wave arrival times. **Instruments, Measurements, and Representations** Know about tiltmeters, seismographs, tsunami detection bouys, satellites, etc. **Technical Vocabulary** silica content of magmas, VEI scale. General characteristics of end-member volcano types. Terminology related to earthquake prediction (Dilatancy, strain accumulation, creep) and description of volcanic eruptions (pyroclastic flow) Elastic, viscous, and plastic behavior Moment magnitude, **Clarifications** Focus on what controls how severe a hazard will be and why

Magnitude and intensity, volcano explosivity index. Associated content from physics – waves and wave descriptors **Exclusions** Different magnitude and intensity scales (except for moment magnitude). Specific names for types of volcanic eruptions or names of igneous rocks. **Clarifications** Focus on understanding the natural processes that cause hazards, specific effects of hazards, and the warning signs of an impending disaster	

Inquiry, Reflecting, and Technology Performances	
E2.R1 Make observations (sound, mass, etc.) of a hidden physical model and infer the internal characteristics of the model. **E2.R2** Develop a scale model based on data that describes the nature of the Earth's interior. **E2.R3** Design model structures that would be resistant to horizontal shaking. **E2.R4** Evaluate the consequences of erroneous or spurious forecasts of natural hazards. **E2.R5** Investigate how plate motions impact oceanic circulation, weather, climate, and the distribution of natural resources.	**E2.r6** Predict how the passage of seismic waves through the Earth would differ if the lower mantle was also a fluid. **E2.r7** Develop a hypothesis for why the continental geology near subduction zones is complex, using geologic map data. **E2.r8** Develop a model for the generation of tsunamis.

Standard E3: The Fluid Earth

Standard Statement

Students will explain how the ocean and atmosphere move and transfer energy around the planet. They will also explain how these movements affect climate and weather and how severe weather impacts society. Students will also explain how long term climatic changes (glaciers) have shaped the Michigan landscape.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E3.1 Oceans** – Oceans redistribute matter and energy around the Earth, through surface and deepwater currents, waves, and interaction with other Earth systems. Motion of the ocean is controlled by temperature, density, gravity, Coriolis effect, and coupling with the atmosphere. Oceans and large lakes (e.g., Great Lakes) have a major effect on climate and weather because they are a source of moisture and a large reservoir of heat. Interactions between oceanic circulation and the atmosphere can affect regional climates throughout the world (e.g., El Nino).	***Content Statement*** **3.1x Oceans and Coastlines** – The ocean covers a large portion of the Earth's surface and contains almost all of its water. Ocean water is salty as a result of chemical weathering and volcanic eruptions. Different zones in the ocean can be described by differences in density, temperature, light penetration, oxygen content, etc. Tides and waves erode the shoreline and beaches.

Identifying and Using Performance Expectations **E3.1A** Explain the relationship between El Nino and changes in ocean circulation. **E3.1B** Explain how the Coriolis effect controls oceanic circulation. **E3.1C** Explain the dynamics of oceanic currents, including upwelling, density, and currents, and their relationship to global circulation **E3.1D** Identify factors affecting seawater density and salinity and describe how density affects oceanic layering. **Instruments, Measurements, and Representations** Maps of ocean circulation and ocean-atmosphere interactions Climate maps showing data such as snowfall, prevailing wind direction, temperatures Common terms such as El Nino, La Nina, and Gulf Stream **Clarifications**	***Identifying and Using Performance Expectations*** **E3.1e** Identify types of shoreline structures (dikes, breakwaters, etc.) and describe the effects they have on shorelines. **E3.1f** Summarize how waves originate and know wave terminology. Understand orbital motion and the difference between deep- and shallow-water waves. **E3.1g** Explain the differences between maritime and continental climates **E3.1h** Describe thermohaline (deep ocean) circulation and explain how and where water masses are produced. **E3.1i** Explain how El Nino affects economies (in South America for example). **Instruments, Measurements, and Representations** Know about echo sounding, Seasat, underwater probes and submersibles, GIS Computer simulations of mechanisms that produce El Niño-Southern Oscillation (ENSO) and La Nina events. **Technical Vocabulary** salinity **<u>Exclusions</u>** specific % for water in various reservoirs, specific concentrations **Clarifications**
Content Statement **E3.2p Weather and the Atmosphere (*Middle School*) –** The atmosphere is divided into layers defined by temperature. Clouds are indicators of weather. *(prerequisite)* ***Identifying and Using Performance Expectations*** **E3.2p1** Describe the layers of the atmosphere. **E3.2p2** Explain the differences between fog and dew formation and cloud formation. **E3.2p3** Describe relative humidity in terms of the moisture content of the air and the moisture capacity of the air and how these depend on the temperature. **Instruments, Measurements, and Representations** Weather map reading and interpretation	***Content Statement*** **3.2x Global Circulation and Climate** – Energy from the sun, differential heating, and the rotation of the Earth control global atmospheric circulation. Climate is controlled by the general circulation of the atmosphere as well as static conditions such as the positions of mountain ranges and bodies of water. Global climate models are being developed that can predict climate over decades into the future. Regional models are used for more localized studies. ***Identifying and Using Performance Expectations*** **3.2a** Identify the main sources of energy to the climate system **3.2b** Identify the effects of various physical parameters (such as air pressure, temperature, CO2) using a computer simulation. **3.2c** Explain how climate results from the interaction among the different components of the Earth system. **3.2d** Explain feedback mechanisms and their role in the climate system. **3.2e** Provide examples of how the unequal heating of the earth and the Coriolis effect influence circulation patterns, and show their impact on Michigan weather and climate. **Instruments, Measurements, and Representations** Global and regional climate models

Diagrams and illustrations to determine the differences between cloud types Simple instruments such as wind gauges, barometers Models of planetary motion to demonstrate seasons Maps of global wind patterns **Technical Vocabulary** Common terms including major atmospheric layers (troposphere and stratosphere, ozone layer, jet stream) and names of weather instruments Common cloud names such as stratus, cumulus, alto, nimbus, cirrus, fog, dew Technical terms for weather and climate may be introduced but emphasis should be on understanding the processes rather than knowing the names of the processes **Clarifications**	Maps and models of atmospheric circulation **Technical Vocabulary** Convection cells, trade winds, westerlies, polar easterlies, land/sea breezes, mountain/valley breezes, jet stream, weather map reading and interpretation, Coriolis effect. **Clarifications**
Content Statement **E3.3 Severe Weather –** Tornadoes, hurricanes, and thunderstorms are severe weather phenomena that impact society and ecosystems. Hazards include downbursts (wind shear), strong winds, hail, lightning, heavy rain and flooding. The movement of air in the atmosphere is due to differences in air density resulting from variations in temperature. Many weather conditions can be explained by fronts that occur when air masses meet. ***Identifying and Using Performance Expectations*** **E3.3A** Describe the various conditions of formation associated with tornadoes, hurricanes, thunderstorms, drought and heat, and floods, their impacts. **E3.3B** Describe the damage resulting from, and the societal impact of, hurricanes, floods, and tornadoes. **E3.3C** Describe conditions associated with frontal boundaries that result in severe weather. **E3.3D** Describe how mountains, frontal wedging (including dry fronts), convection, and convergence to form clouds and precipitation. **E3.3E** Describe severe weather and flood safety and mitigation. **Instruments, Measurements, and Representations** Know about radar (distinguish doppler and reflectivity), Weather map reading and interpretation Topographic maps of flood plains **Technical Vocabulary** high and low pressure areas, fronts, rotation, heat transport **<u>Exclusions</u>** details of windspeeds, storm surges, etc., associated with Saffir-Simpson and Fujita scales.	***Content Statement*** **E3.3x Mesometeorology –** Many weather conditions can be explained by fronts that occur when air masses meet. Tornadoes and hurricanes are both heat transfer mechanisms. Additional longer term hazards include severe cold, severe heat and drought. Prediction of severe weather is dependent on the identification of instability in the atmosphere. Regional weather and climate can be impacted by topography and land use. ***Identifying and Using Performance Expectations*** **E3.3f** Explain the process of adiabatic cooling and adiabatic temperature changes to the formation of clouds. **Instruments, Measurements, and Representations** satellite imagery (visible, IR, water vapor), computer simulations (Global climate models) Weather map, vertical profiles (soundings), and satellite image (remote sensing) reading and interpretation. Tools such as pyschrometer to determine the relative humidity Computer simulations of the effects of topographic features and land use on regional weather **Technical Vocabulary** Common terms such as adiabatic cooling and orographic lifting, frontal wedging (including dry fronts), convection currents, and convergence lifting descriptive terminology such as relative humidity, dew point **Clarifications** Focus: on weather conditions that explain fronts and the movement of air masses that lead to the development of severe weather.

Clarifications Severe weather has extensive impacts on society as a whole.	
Content Statement **E3.4 Glaciers –** Glaciers are large bodies of ice that move under the influence of gravity; they form part of both the rock and water cycles. Glaciers and ice sheets have shaped the landscape of the Great Lakes region. (see also climate change) ***Identifying and Using Performance Expectations*** **E3.4A** Describe how glaciers have affected the Michigan landscape and how the resulting landforms impact our state economy. **E3.4B** Explain the formation of the Great Lakes. .**Instruments, Measurements, and Representations** Maps, diagrams or charts showing the advance and retreat of the Great Lakes and ice sheets Topographic and geologic maps showing landforms due to glaciation (e.g., kettle lakes, drumlins and moraines). **Technical Vocabulary** Common glacial landforms (e.g., moraine, kettle lakes, drumlin, etc.) Common glacial descriptors such as continental, alpine, ice sheet **Clarifications** Focus on ice sheets and Great Lakes geomorphology as evidence for the last ice age.	***Content Statement*** **E3.4x Glacial Rebound –** Areas that have been occupied by ice sheets are depressed; when the ice sheet is removed, the region uplifts according to the principle of isostasy. ***Identifying and Using Performance Expectations*** **E3.4c** Explain what happens to the lithosphere when an ice sheet is removed. **Instruments, Measurement, and Representations** Mathematical formulation of isostasy Lake level gauges, tiltmeters Charts of data for the thickness of glacial ice sheets to calculate the isostatic rebound of the Great Lakes region. Soil and sediment maps and their relationship to glaciation. **Technical Vocabulary** glacial rebound, isostasy, deglaciation, glaciers. **Clarifications**
Inquiry, Reflecting, and Technology Performances	
E3.R1 Identify areas subject to lake effect precipitation, using snowfall data (e.g., from western Michigan) and prevailing wind direction. **E3.R2** Develop land use criteria for a flood plain. **E3.R3** Investigate possible mitigation strategies for hurricanes, floods, and tornadoes. **E3.R4** Determine the direction of ice or water flow in the Great Lakes region, using topographic maps. **E3.R5** Develop a model showing how a glacier moves	**E3.r6** Apply tornado damage reports and map its path and history. **E3.r7** Illustrate and explain both current weather conditions and forecasting, using satellite and radar images and weather maps. **E3.r8** Investigate the effects of topographic features and land use on regional weather, using a computer simulation. **E3.r9** Design structures that are more resistant to hurricane and straight line winds. **E3.r10** Using the thickness of the glacial ice sheets, calculate the isostatic rebound in the Great Lakes region.

Standard E4: The Earth in Space and Time

Standard Statement

Students will explain how the Earth and universe formed and evolved over a long period of time. Students will predict how human activities may influence the climate of the future.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Performances, and Boundaries	
Content Statement **E4.1 Sky Observations (*Middle School*) –** Common sky observations (such as lunar phases) can be explained by the motion of solar system objects in regular and predictable patterns. Our galaxy, observable as the Milky Way, is composed of billions of stars, some of which have planetary systems. Seasons are a result of the tilt of the rotation axis of the Earth. ***Identifying and Using Performance Expectations*** **E4.1A** Describe the motions of various celestial bodies and some the effects of those motions (MS) **E4.1B** Explain the primary cause of seasons. **Instruments, Measurement, and Representations** Telescopes and binoculars to see stars, nebulae, and galaxies Space probes and satellites to obtain images of stars, nebulae, and galaxies. **Technical vocabulary** Common terms such as constellation, revolution, nebula, star cluster, galaxies **Clarifications** Focus: use what we see from Earth to explain phenomena such as the movement of constellations and moon phases	***Content Statement*** **E4.1x Planetary Motion** Kepler's Laws of Motion can be used to mathematically represent the motions of bodies in the universe under the influence of gravity. ***Identifying and Using Performance Expectations*** **E4.1c** Predict the orbit of bodies in the solar system, using Kepler's Laws. **E4.1d** Describe how a change in the Earth's orbit or its axis of rotation affect climate **Instruments, Measurement, and Representations** Mathematical representations such as Kepler's Laws, force and gravitational equations **Technical Vocabulary** Retrograde motion, axial retrograde and moon retrograde **Clarifications** Focus: on mathematically representing the motions of planets
Content Statement **E4.2 The Earth in Space –** Scientific evidence indicates the universe is orderly in structure, finite, and contains all matter and energy. The sun provides energy to the Earth. The motions of the moon and sun affect the phases of the moon and ocean tides. Information from the entire light spectrum light tells us about the composition and motion of objects in the universe. Early in the history of the universe, matter clumped together by gravitational attraction to form stars and galaxies. The universe has been continually expanding at an increasing rate since its formation about 13.7 billion years ago. ***Identifying and Using Performance Expectations*** **E4.2A** Describe how nuclear fusion and other processes in stars have led to the formation of all the other chemical elements	***Content Statement*** **E4.2x Studying the Universe.** Information from the entire light spectrum light tells us about the composition and motion of objects in the universe. ***Identifying and Using Performance Expectations*** **E4.2d** Explain the characteristics of EM waves (photon energy, refractive characteristics of waves, attenuation) **E4.2e** Explain the nature (energy – longer wavelengths has a lower energy etc., refraction) of EM waves and their

E4.2B Describe the position and motion of our solar system in our galaxy and the overall scale, structure, and age of the universe. **E4.2C** Describe a theory for the formation of the Universe. **Technical Vocabulary** Tropics, sunrise/sunset points, solar path and noon altitudes. Phase and moonrise time. **Instruments, Measurement, and Representations** Telescopes and binoculars to see the lunar surface and phases Charts such as phase and moonrise times Types of telescopes (optical, radio, space), spectroscopes to determine electromagnetic spectra Spectroscopes to measure the speed of stars and galaxies moving away or toward us Interpretation of graphs in terms of relationships (e.g., distance to galaxies vs. red shift) **Technical Vocabulary** Common terms such as electromagnetic spectrum, spectroscopes, and magnitude radio waves, light, spectra Names of light elements (e.g., hydrogen, helium), fusion, radiation, red shift, big bang. **Clarifications** Focus: use the entire light spectrum to determine stellar composition and characteristics and observational evidence and physics concepts that support the Big Bang theory	behaviors **E4.2f** Describe the advantages and disadvantages of various instruments to study space (e.g., telescopes, spectrographs) and what they tell us about the structure and composition of objects in space. **E4.2g** Compare and contrast two EM waves based on energy, travel paths, wavelength, and velocity **E4.2h** Explain how spectra are used determine the temperature and composition of stars. **E4.2i** Explain how a light year can be used as a distance unit. **Instruments, Measurement, and Representations** Charts such as phase and moonrise times Types of telescopes (optical, radio, space) Mathematical representations such as inverse square relationship Spectroscopes to determine the chemical composition and to measure the speed of stars and galaxies moving away or toward us Interpretation of graphs in terms of relationships (e.g., distance to galaxies vs. red shift, comparing magnitudes of starts to determine distance) Computer simulations of the formation of galaxies and the Big Bang **Technical Vocabulary** **Clarifications**
	Content Statement **E4.3x Stars** – Stars, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. These and other processes in stars have led to the formation of all the other chemical elements. There are a wide range of stellar objects of different sizes and temperatures. Stars have varying life histories based on these parameters. ***Identifying and Using Performance Expectations*** **E4.3a** Explain how the H-R diagram can be used to deduce other parameters (distance, etc.). **E4.3b** Explain how you can infer the temperature, life span and mass of a star, and its mass from its color. Use the H-R diagram to explain the life cycles of stars.

	E4.3c Explain how the balance between fusion and gravity controls the evolution of a star (equilibrium) **E4.3d** Compare the evolution paths of low, moderate and high mass stars using the H-R diagram. **E4.3e** Compare and contrast the final three outcomes of stellar evolution based on mass (black hole, neutron star, white dwarf). **E4.3f** Identify patterns in solar activities (sun spots, solar flares and relate patterns to effects on Earth. **Instruments, Measurement, and Representations** Radio, optical and other types of telescopes, spectroscopes to determine the composition of stars Images taken by large or space-based telescopes and spectra of stars and galaxies Interpretation of graphs in terms of relationships (e.g., brightness vs. temperature) Computer simulations of processes in stars **Technical Vocabulary** red giant, pulsar, planetary nebula, nebula, supernovas, nuclear fusion Magnitude, **Clarifications** Focus: use observational evidence and physics concepts to support theories about how stars shine
	Content Statement **E4.4x Magnetosphere** – The magnetic field of the Earth partially shields the Earth from harmful radiation. Solar flares are associated with sunspots and intensify the solar wind. Interactions between charged particles from the sun and the Earth's atmosphere produce auroras. ***Identifying and Using Performance Expectations*** **E4.4a** Explain solar wind and its effect on "space weather" **Instruments, Measurement, and Representations** Compass to measure the direction of the magnetic field Magnetometer on the surface of Earth and flown on spacecraft to measure strength and direction of magnetic field Computer simulations of magnetic field generation Solar magnetograms or simple solar telescopes or internet images to analyze sunspot activity to predict times of increased solar activity **Technical Vocabulary** Terms such as aurora, geomagnetic storm, magnetosphere, magnetopause, and magnetometer, sunspot cycle, magnetogram, solar flare, space weather **Clarifications** Focus: on generation, strength, and direction of the magnetic field

	Content Statement **E4.5x Evidence for the Nature of the Universe –** Evidence for the nature of the universe comes from a variety of observations of mass and light. ***Identifying and Using Performance Expectations*** **E4.5a** Differentiate between the cosmological and Doppler red shift. **E4.5b** Explain how observations of the cosmic microwave background have helped up determine the age of the universe. **E4.5c** Explain how dark energy and dark matter support the big bang theory. .**Technical Vocabulary** Red shift, Hubble's law, nucleosynthesis (fusion), dark energy, dark matter, big bang, red shift. **Clarifications**
	Content Statement **E4.6x Planetary Geology** – There are a wide variety of non-stellar objects in the solar system and the universe, including comets, asteroid, meteors, planets and their satellites. They fall into two general categories: rocky objects like the inner planets, moons, asteroids and meteors, and large gaseous objects like the outer planets. They can be studied through probes and other remote observations. ***Identifying and Using Performance Expectations*** **E4.6a** Describe and explain the structure of planetary bodies and terrestrial satellites. **E4.6b** Describe the early evolution of the solar system and the segregation into terrestrial and jovian types of planets. **E4.6c** Differentiate between meteoroids, comets, asteroids, minor moons of planets and Kuiper Belt objects. How are they different? How are they similar? How might one evolve into another? **Instruments, Measurement, and Representations** Telescopic and spacecraft-based photos of planets, moons, and comets. Fly-by based spectral and geodetic data. **Technical Vocabulary** **Clarifications** Focus: Variability of the geology, tectonism, and atmospheres of planets and satellites. Evidence for the existence of extra-solar planets
Content Statement **E4.7 Earth History and Geologic Time –** The Solar System formed from a nebular cloud of dust and gas 4.6 Ga (billion years ago). The Earth has changed through time and has been affected by both catastrophic (earthquakes, meteorite impacts, volcanoes, etc.) and gradual geologic events (plate movements, mountain	***Content Statement*** **E4.7x Geologic Dating** – Early methods of determining geologic time, such as the use of index fossils and stratigraphic principles, allowed for the relative dating of geological events. However, absolute dating was impossible until the discovery that certain radioactive isotopes in rocks have known decay rates, making it

building, etc.) as well as the effects of biological evolution (formation of an oxygen atmosphere, etc.). Geologic time can be determined through both relative and absolute dating. ***Identifying and Using Performance Expectations*** **E4.7A** Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago). **E4.7B** Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them **E4.7C** Relate major events in the history of the Earth to the geologic time scale (e.g., formation of the Earth, formation of an oxygen atmosphere, rise of life, major extinctions). **Instruments, Measurement, and Representations** Graphical representations of the structure, scale and composition of the solar system Topographic maps, geologic maps, geologic cross-sections, geologic columns Cross sections to reconstruct the sequence of events using stratigraphic principles Stratigraphic sections and index fossils to correlate the geologic history of a region Charts of long time spans to demonstrate "deep time" **Technical Vocabulary** Accretion Include vocabulary associated with geology and principles of relative dating, as well as relevant terms from life and physics. Can use names of Eras (Pre-Cambrian, Paleozoic, Mesozoic and Cenozoic) **<u>Exclusions</u>** Names of geologic Periods (Cambrian, Mississippian, etc) should be avoided unless relevant (e.g., K-T extinction event) , names of specific life forms (stromatolites, etc.), and specific processes of radioactive decay **Clarifications** Focus on how the Earth was formed from a nebular cloud of dust, the evidence for measuring geologic time and determining a sequence of events, and on understanding how geological processes work over a long time span; relate to the rock and water cycles.	possible to determine how many years ago a given mineral or rock formed. Different kinds of radiometric dating techniques exist; which is used depends on the material to be dated, the age of the material, and what geologic event that affected the material is being dated. ***Identifying and Using Performance Expectations*** **E4.7d** Determine the approximate age of a sample, when given the half-life of a radioactive substance (in graph or tabular form) along with the ratio of daughter to parent substances present in the sample. **E4.7e** Explain why can C-14 be used to date a 40,000 year old tree but the U-Pb can not. **Instruments, Measurement, and Representations** Graphical representation of radioactive decay, in particular different isotopes such as carbon-14 versus U-Pb, and use thereof as a tool to determine the age of a rock sample given ratios of different isotopes in a mineral. **Technical Vocabulary** Common terms such as radioactive decay, isotope, carbon-14, uranium-lead dating **Clarifications** Focus on understanding the principle behind dating techniques
	Content Statement **E4.8x The Early Earth –** Early Earth was very different from today's planet. Evidence for one-celled forms of life—the bacteria— extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of Earth's atmosphere, which did not originally contain oxygen.

	Identifying and Using Performance Expectations **E4.8a** Describe the evolution of the atmosphere. **Instruments, Measurement, and Representations** **Technical Vocabulary** Common terms such as oxygen, one-celled bacteria, atmosphere, and evolution **Clarifications** Focus: on the development of Earth's atmosphere and the evolution of life
Content Statement **E4.9 Climate Change** – Changes in climate have profound effects on society. Carbon dioxide and other "greenhouse" gases trap reradiated energy from the Earth's surface and increase atmospheric temperature. Human activities can greatly increase the concentration of greenhouse gases. Climates of the past cannot be directly measured, but must be inferred. ***Identifying and Using Performance Expectations*** **E4.9A** Distinguish between natural (Milankovich cycles) and human-induced (greenhouse effect) climate changes **E4.9B** Explain the causes of short-term climate changes such as catastrophic volcanic eruptions and impact of solar system objects. **E4.9C** Describe the evidence for ice ages from geology (e.g., geomorphology, striations, and fossils). **E4.9D** Describe the difference between weather and climate. **E4.9E** Determine the empirical relationship between the emission of the three important greenhouse gases (carbon dioxide, methane, nitrous oxide) and global temperature **E4.9F** Predict the global temperature increase by 2100, given data on the annual trends of CO_2 concentration increase. **Instruments, Measurement, and Representations** Graphs of temperature changes over time Models showing global climate change Maps of major atmospheric and oceanic currents from the past through to the present Charts of data to calculate the impact on sea-level of the melting of ice caps and glaciers in various parts of the world. Computer models to investigate feedback mechanisms associated with global warming/climate change. **Technical Vocabulary** Common terms such as methane, carbon dioxide, greenhouse effect, feedback mechanisms, and global warming **Clarifications** Focus: on what global warming is and causes for	***Content Statement*** **E4.9x Determination of Paleoclimate –** Climates of the past can be determined by indirect indicators such as isotopic ratios in foraminifera, gas bubbles, etc. These have been correlated with variations in the insolation of the Earth. Major ice sheets can also affect the surface of the Earth after they are removed. ***Identifying and Using Performance Expectations*** **E4.9g** Use Oxygen isotope data to estimate paleo-temperature **E4.9h** Explain how the climates of the past (e.g., ice ages) can be determined using proxy indicators (e.g., oxygen isotopes, CO_2 content of the atmosphere) **Instruments, Measurement, and Representations** Charts and tables Oxygen isotope data to estimate the paleo-temperature **Technical Vocabulary** Common terms such as paleoclimate, proxy indicators, and foraminifera, oxygen isotopes **Clarifications** Focus on the reliability of proxy indicators to determine paleoclimate.

global warming in the present and past. See also glaciers.	
Inquiry, Reflecting, and Technology Performances	
E4.R1 Create a model of the Earth-Moon-Sun system that can be used to predict moon phases tides, and local time. **E4.R2** Reconstruct the sequence of events using stratigraphic principles and data from a geologic cross section.. **E4.R3** Construct and analyze a time line for the Earth that indicates both the relative and absolute times of the events. .**E4.R4** Investigate the possible consequences of global warming both on society and on natural ecosystems.	**E4.r5** Construct a regional geologic history, using index fossils and correlation, given data from disconnected stratigraphic sections. **E4.r6** Use a drawing of rock layers with the location of fossils from an extinct prehistoric animals, along with dates of volcanic rock layers determined by radioisotope methods above and below the fossils, to determine the upper and lower bounds of time during which the extinct animal lived **E4.r7** Apply Hubble's Law to verify that the universe is expanding **E4.r8** Describe the likelihood and consequences of an impact event. **E4.r9** Design an experiment to detect extra-solar planets using light and gravitational effects.

Standard E5: Chemicals in the Environment

Standard Statement

Students will explain how chemicals move through Earth systems as parts of many processes and cycles and the energy that drives them. Students will also describe human uses of energy and other resources and evaluate the consequences of their use.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **E5.1 Chemicals in the Earth System (Geochemical Cycles) –** The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and forms; they move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of the earth system. The movements within the cycles can be slow or rapid and are often accompanied by changes in the physical and chemical properties.	***Content Statement*** **E5.1x Biogeochemical cycles –** Many chemicals have significant impacts on the biosphere and have important impacts on human health.
Identifying and Using Performance Expectations **E5.1A** Explain how chemicals are found in different forms in different parts of the earth system. **E5.1B** Explain how nitrogen and carbon move through the Earth System (including the geosphere) and how they may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society. ***Note: Additional performances associated with this content statement are embedded under other standards and expectation (see also below).***	***Identifying and Using Performance Expectations*** **E5.1c** Explain why small amounts of some chemicals may be necessary for health but are poisonous in large quantities. **E5.1d** Explain how certain chemicals in the Earth system (e.g., DDT, Pb) can affect human health.

Instruments, Measurements, and Representations Chemical tests and instruments to monitor quality of soil, water, and air and the health of ecosystems (e. g. wetlands, deserts, plains, rainforests, etc.) **Technical Vocabulary** decomposition, weathering, erosion, precipitation, evaporation, photosynthesis, transpiration, absorption, infiltration, respiration; other relevant terms from the rock and water cycles relevant terms from chemistry **Clarifications** Focus on interaction of Earth systems on a global scale with emphasis on tracing processes between systems and the energy sources that drive them.	**Instruments, Measurements, and Representations** Graphs and models of the movement of chemicals, oxygen, carbon dioxide, and carbon **Technical Vocabulary** Common chemicals such as potassium, sulfur, phosphorus, oxygen, and calcium **Clarifications** Focus on the health impacts of chemicals in the Earth system.
Content Statement **E5.2 Energy –** Movement of matter and its component chemicals, through and between Earth's systems is driven by Earth's internal (radioactive decay and gravity) and external sources (sun) of energy. Energy moves by radiation, convection and conduction. Fossil fuels are derived from plants and animals of the past and are non-renewable and limited in availability. Alternative fuels include solar and wind power, nuclear, ethanol, geothermal, and hydroelectric, etc. and have advantages and disadvantages. ***Identifying and Using Performance Expectations*** **E5.2A** Describe the Earth's principal sources of internal and external energy, e.g., radioactive decay, gravity, solar energy. **E5.2B** Describe how your electricity is generated. **E5.2C** Describe the processes by which fossil fuels are formed and why they are non-renewable. **E5.2D** Recognize, describe, and differentiate between renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy. **Instruments, Measurement, and Representations** Diagrams showing the flow of energy and matter through Earth systems and resulting phenomena Mathematical formula such as kinetic energy and potential energy Laws such as the first Law of Thermodynamics **Technical Vocabulary** Common physics terms such as kinetic energy, potential energy, heat, gravity. Renewable and non-renewable resources, nuclear power, ethanol **Clarifications** Focus on how energy moves through Earth systems and how some resources are non-renewable	***Content Statement*** **E5.2x Energy –** Energy can exist in numerous forms (heat, fossil fuels, tidal energy, etc.) and can be transformed from one state to another and move from one reservoir to another. ***Identifying and Using Performance Expectations*** **E5.2e** Explain how the first and second laws of thermodynamics affect the amount of energy available on Earth to do work. **E5.2f** Predict the change in state of a chemical as it moves from one reservoir to another. **E5.2g** State where in Earth systems energy transfer occurs by conduction, convection, radiation, radioactive decay and gravity. **Instruments, Measurement, and Representations** Laws such as the first and second Law of Thermodynamics should be understood **Technical Vocabulary** Common physics terms such as kinetic energy, potential energy, heat, gravity. **Clarifications** Focus on reservoirs that store energy.
Content Statement	***Content Statement***

E5.3 Human Effects on Earth Systems The Earth provides resources (including minerals) that are used to sustain human affairs. The supply of these resources is limited and their extraction and use can release chemicals into Earth systems. They affect air and water quality, ecosystems, landscapes, and may have effects on long-term climate. ***Identifying and Using Performance Expectations*** **E5.3A** Describe the effects on the environment of using both renewable and nonrenewable sources of energy. **E5.3B** Explain how human activities impact air, soil and water quality. **E5.3C** Explain how one human activity, for example, cutting down a large tract of forest for mining, can affect the entire Earth system. **E5.3D** Describe the life cycle of a product, including the resources, production, packaging, transportation, disposal, and pollution. **Instruments, Measurements, and Representations** Rain gauges, thermometers, etc. to measure and record attributes of an environment (e.g., patterns and changes in mean min/max monthly temperatures, rainfall, cloud coverage) and determine the quality of an environment Diagrams showing the life cycle of a product Appropriate chemical tests and instruments to monitor environmental quality – see geochemical cycles. **Technical Vocabulary** Common terms such as resource, production, fossil fuels, waste disposal, transportation, disposal, mining, reclamation, and ecosystems **Clarifications** Focus on how resource use affects humans by interfering with the quality of the Earth system .	**E5.3x Society and the Environment –** Humans impact the environment in a number of different ways. Alternative fuels and other energy sources may be necessary to carry us forward into the 22nd century. ***Identifying and Using Performance Expectations*** **E5.3e** Explain what makes a society sustainable. **E5.3f** Explain how soil erosion can result in desertification. **E5.3g** Explain how carbon dioxide sequestration may slow global warming. **E5.3h** Explain ozone depletion in the stratosphere and methods to slow human activities to reduce ozone depletion. **Instruments, Measurements, and Representations** Charts and data of resource use **Technical Vocabulary** resource, production, packaging, transportation, disposal, pollution, renewable and nonrenewable resources and terms associated with them **Clarifications** Focus on alternative fuels and new ideas for controlling pollution during production of resources.
Inquiry, Reflecting, and Technology Performances	
E5.R1 Develop strategies for reducing the dependence on fossil fuels **E5.R2** Evaluate long range plans for resource use and by-product disposal in terms of environmental and economic impact. **E5.R3** Propose methods for reducing air and water pollution.	**E5.r4** State the movement of simple ecosystem with the chemicals, oxygen, carbon dioxide, and carbon in a simple ecosystem, using a computer model. **E5.r5** Identify relationships and connections between the nitrogen, carbon, water, and rock cycles. **E5.r6** Determine why there may be a conflict between individual versus societal needs of resources. **E5.r7** Develop procedures to reduce waste. **E5.r8** Investigate feedback mechanisms associated with global warming/climate change, using computer simulations.

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