9TH GRADE-12TH GRADE

Earth and Space Science

Content Standard D:

As a result of their activities in grades 9-12, all students should develop an understanding of

- **Energy in the earth system**
- **Geochemical cycles**
- **Origin and evolution of the earth system**
- **Origin and evolution of the universe**

Content Summary

National Science Education Content Standards

K-4

Properties of earth materials

Objects in the sky

Changes in earth and sky

5-8

Structure of the earth systems

Earth's history

Earth in the solar system

9-12

Energy in the earth system

Geochemical cycles

Origin and evolution of the earth system

Origin and evolution of the universe

Minnesota Graduation Standards

Primary Level

Direct Science Experience:

Understand basic science concepts through direct experience

Intermediate Level

Living and Non-living Systems:

Understand how individuals and objects interact in life, earth/space systems and physical systems

Middle Level

Earth Systems:

Recognize concepts and evaluate interactions of earth/space systems and the impact upon human life

High School Level

Earth and Space Systems:

Understand concepts, theories and principles of earth and space systems through investigation and analysis

Focus K-12

Grade	Early	Late
K-4	The focus of instruction early in this grade range is on providing opportunities for all students to observe earth materials, their properties, and how they change over time.	The focus of instruction later in this grade range is on providing opportunities for all students to observe and describe objects in the sky and changes in the earth and sky as they identify sequences, look for patterns, and develop possible explanations of phenomena in the earth system.
5-8	The focus of instruction for all students early in this grade range is on developing a basic understanding of the components of the earth system and the movement of objects in the solar system.	The focus of instruction for all students later in this grade range is on developing an understanding of the dynamic nature of the earth system, its evolution, and its relationship to the solar system.
9-12	The focus of instruction in earth and space science at the high school level is on providing all students an opportunity to develop an understanding of the role of cycles in structuring the earth system, the use of evidence to develop an understanding of deep space and deep time, and apply their understandings in a variety of situations.	The focus of instruction for students pursuing further study in earth/space science is on increasing students' knowledge and understanding of the origin and evolution of the earth system and the universe and apply their understandings in a variety of situations.

Close-up 9-12

The focus of instruction in earth and space science at the high school level is on providing all students the opportunity to develop an understanding of the role of cycles in structuring the earth system, the use of evidence to develop an understanding of deep space and deep time, and to apply their understandings to a variety of situations.

All high school students continue their study of the earth system which was introduced in middle school. The emphasis is on a variety of cycles, their origins, processes, circulation patterns, and connections as well as on the methods of historical investigation used to infer how these processes have operated in the past. This includes exploring the water cycle and its role in the transfer of matter and energy, in the regulation of the earth's climate, and in the formation of mineral and fossil resources. Students apply their work from investigations of radiation, convection, and conduction to develop models for how energy is transferred through the earth system. By studying water, rock, and carbon cycles, students gain deeper understanding of the cyclical nature of earth materials and the time required for these cycles to occur. By learning the methods of historical investigation, students understand how we determine how these earth processes have operated in the past. Based on the evidence of these historical investigations, students can construct and use models to explain the earth's history and structure. The study of astronomy from middle school is expanded beyond our solar system to include objects in the universe. Although high school students are better able to comprehend large distances and long time scales, they will still need concrete examples to explore ideas such as the age of the universe and the evolution of galaxies, stars, and planets. Electronic imaging is useful in teaching and learning many earth and space science concepts. Students and teachers observe established science safety procedures.

The focus of instruction for students pursuing further study in earth and space science is on increasing students' knowledge and understanding of the origin and evolution of the earth system and the universe and apply their understandings to a variety of situations.

More advanced students expand their study of earth processes by evaluating what the evidence says about the earth's past and its dynamic crust, fluctuating climate, and evolving life forms. Students use appropriate technology as they investigate geological temperature records and investigate global weather and oceanic current patterns. Their study of long-term stability and change provides opportunities to reason in science. Using their knowledge of physical science, students study the nuclear processes in stars which led to the formation of elements. They research theories about the origin and evolution of the universe. Student abilities and understanding should allow them to work independently as they investigate these concepts. While scale, differences in students' ability to visualize, and the complexity of the earth system and space present significant barriers, the study of earth science can take advantage of everyday experiences and events. Students and teachers observe established science safety procedures.

On Location 9-12

In the land of 10,000 lakes, water is a very important and sometimes not well understood resource. The relationship between ground water and surface water is something about which all Minnesota students should have a good understanding. This vignette illustrates the teaching and learning of abstract earth science concepts in a framework that allows students to use technology and familiar environments as they construct their understanding of geochemical cycles.

Mr. J's high school students are studying ground water sensitivity to potential surface pollution. As they begin their study, students hear a presentation by a ground water expert from the Minnesota Geological Survey on general aspects of ground water research. Collaborative groups of students then conduct on-line computer searches of the scientific literature using the GeoRef database to locate information on the problems of ground water pollution in areas with geologic conditions similar to those in their study area. They gather reference material from local, state, and federal sources to develop ground water sensitivity maps.

In order to establish an adequate number of data points for the maps, students use a variety of information sources. Data for the surface maps comes from county soil surveys, extensive field studies of available outcrops, textural analysis of field samples, geomorphic interpretation from USGS topographic maps, water well logs, seismic data, and logs from test borings. The data points for bedrock maps come from field observations, petrographic analysis of samples, and water well and drill cutting samples from municipal wells. Students determine the water table/potentiometric surface from well logs and well repair records. They use their own and nearby county USGS quadrangles as base maps to locate all of the field sites. Students record data in field notebooks and then transfer it into a computer database.

Each student team is responsible for generating a map which includes surface geology, depth to bedrock, bedrock geology, bedrock topography, and water table/potentiometric surface measurements. Whenever possible student groups visit the sites under study to photograph or otherwise document the physical setting. Students use accepted water testing techniques to further verify and document their results.

Finally, students write formal scientific reports which explain how the maps were generated and ways the maps can be used. The emphasis is on evidence-based interpretation and analysis. This includes the possible effects of the different mapped characteristics on ground water quality, including the effects of streams, lakes, wetlands, and pollution sources. They examine the relationship between surface outcrops and the nature of the aquifer and identify areas which they believe may warrant land use limitation. They submit their reports and maps to the Journal of High School Research for publication. In addition, they share their data and recommendations with local officials to inform decisions about surface activities and their impact on the quality of ground water.

National Science Education Content Standards

9-12 Content Standard D

Energy in the Earth System	• Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation. • The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe. • Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. • Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.
Geochemical Cycles	• The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles. • Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.
The Origin and Evolution of the Earth System	• The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today. • Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed. • Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years. • 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 the earth's atmosphere, which did not originally contain oxygen.
The Origin and Evolution of the Universe	• The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since. • Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe. • Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

Minnesota Graduation Standards

High School Level

Earth and Space Systems:

Understand concepts, theories and principles of earth and space systems through investigation and analysis.

What students should know:

1. Understand earth systems through the interaction of forces and energy (e.g., plate tectonics, terranes)
2. Understand geochemical processes and cycles (e.g., rock cycle, chemical reservoirs)
3. Understand theories of the origin and evolution of the universe (e.g., planetary systems, stellar cycles)
4. Understand energy in the earth system (e.g., global climate, convection)
5. Understand the historical significance of major scientific advances (e.g., geological time scale, plate tectonics)

What students should do:

1. Design and conduct an experiment to investigate a question and test a hypothesis in earth and space systems
2. Analyze data to support or refute hypotheses
3. Design and conduct one investigation through a problem-based study, service learning project or field study:
   a. identify scientific issues based on observations and the corresponding scientific concepts
   b. analyze data to clarify scientific issues or define scientific questions
   c. compare results to current models and/or personal experience
4. Use scientific evidence to defend or refute an idea in a historical or contemporary context:
   a. identify scientific concepts found in evidence
   b. evaluate the validity of the idea in relationship to scientific information
   c. analyze the immediate and long-term impact on the individual and/or society in the areas of technology, economics and the environment

In Addition:

1. Students are encouraged to communicate to an audience outside of the school setting whenever possible.
2. Students must demonstrate basic safety procedures and skills when using tools and equipment.