Earth and Space Science, High School

Learning Standards for a Full First-Year Course

I. Content Standards

1. Matter and Energy in the Earth System

Central Concepts: The entire Earth system and its various cycles are driven by energy. Earth has both internal and external sources of energy. Two fundamental energy concepts included in the Earth system are gravity and electromagnetism.

1.1 Identify Earth's principal sources of internal and external energy, such as radioactive decay, gravity, and solar energy.
1.2 Describe the characteristics of electromagnetic radiation and give examples of its impact on life and Earth's systems.
1.3 Explain how the transfer of energy through radiation, conduction, and convection contributes to global atmospheric processes, such as storms, winds, and currents.
1.4 Provide examples of how the unequal heating of Earth and the Coriolis effect influence global circulation patterns, and show how they impact Massachusetts weather and climate (e.g., global winds, convection cells, land/sea breezes, mountain/valley breezes).
1.5 Explain how the revolution of Earth around the Sun and the inclination of Earth on its axis cause Earth's seasonal variations (equinoxes and solstices).
1.6 Describe the various conditions associated with frontal boundaries and cyclonic storms (e.g., thunderstorms, winter storms [nor'easters], hurricanes, tornadoes) and their impact on human affairs, including storm preparations.
1.7 Explain the dynamics of oceanic currents, including upwelling, deep-water currents, the Labrador Current and the Gulf Stream, and their relationship to global circulation within the marine environment and climate.
1.8 Read, interpret, and analyze a combination of ground-based observations, satellite data, and computer models to demonstrate Earth systems and their interconnections.

2. Energy Resources in the Earth System

Central Concepts: Energy resources are used to sustain human civilization. The amount and accessibility of these resources influence their use and their impact on the environment.

2.1 Recognize, describe, and compare renewable energy resources (e.g., solar, wind, water, biomass) and nonrenewable energy resources (e.g., fossil fuels, nuclear energy).
2.2 Describe the effects on the environment and on the carbon cycle of using both renewable and nonrenewable sources of energy.

3. Earth Processes and Cycles

Central Concepts: Earth is a dynamic interconnected system. The evolution of Earth has been driven by interactions between the lithosphere, hydrosphere, atmosphere, and biosphere. Over geologic time, the internal motions of Earth have continuously altered the topography and geography of the continents and ocean basins by both constructive and destructive processes.

3.1 Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments, and creates various types of landscapes. Give examples that show the effects of physical and chemical weathering on the environment.
3.2 Describe the carbon cycle.
3.3 Describe the nitrogen cycle.

3. Earth Processes and Cycles (cont.)

3.4 Explain how water flows into and through a watershed. Explain the roles of aquifers, wells, porosity, permeability, water table, and runoff.

3.5 Describe the processes of the hydrologic cycle, including evaporation, condensation, precipitation, surface runoff and groundwater percolation, infiltration, and transpiration.

3.6 Describe the rock cycle, and the processes that are responsible for the formation of igneous, sedimentary, and metamorphic rocks. Compare the physical properties of these rock types and the physical properties of common rock-forming minerals.

3.7 Describe the absolute and relative dating methods used to measure geologic time, such as index fossils, radioactive dating, law of superposition, and crosscutting relationships.

3.8 Trace the development of a lithospheric plate from its growth at a divergent boundary (mid-ocean ridge) to its destruction at a convergent boundary (subduction zone). Recognize that alternating magnetic polarity is recorded in rock at mid-ocean ridges.

3.9 Explain the relationship between convection currents in Earth's mantle and the motion of the lithospheric plates.

3.10 Relate earthquakes, volcanic activity, tsunamis, mountain building, and tectonic uplift to plate movements.

3.11 Explain how seismic data are used to reveal Earth's interior structure and to locate earthquake epicenters.

3.12 Describe the Richter scale of earthquake magnitude and the relative damage that is incurred by earthquakes of a given magnitude.

4. The Origin and Evolution of the Universe

Central Concepts: The origin of the universe, between 14 and 15 billion years ago, still remains one of the greatest questions in science. Gravity influences the formation and life cycles of galaxies, including our own Milky Way Galaxy; stars; planetary systems; and residual material left from the creation of the solar system.

4.1 Explain the Big Bang Theory and discuss the evidence that supports it, such as background radiation and relativistic Doppler effect (i.e., "red shift").

4.2 Describe the influence of gravity and inertia on the rotation and revolution of orbiting bodies. Explain the Sun-Earth-moon relationships (e.g., day, year, solar/lunar eclipses, tides).

4.3 Explain how the Sun, Earth, and solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 billion years ago.

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II. Scientific Inquiry Skills Standards

Scientific literacy can be achieved as students inquire about geologic, meteorological, oceanographic, and astronomical phenomena. The curriculum should include substantial hands-on laboratory and field experiences, as appropriate, for students to develop and use scientific skills in Earth and Space Science, including reading and interpreting maps, keys, and satellite, radar, and telescope imageries; using satellite and radar images and weather maps to illustrate weather forecasts; using seismic data to identify regions of seismic activity; and using data from various instruments that are used to study deep space and the solar system, as well as the inquiry skills listed below.

SIS1. Make observations, raise questions, and formulate hypotheses.

- Observe the world from a scientific perspective.
- Pose questions and form hypotheses based on personal observations, scientific articles, experiments, and knowledge.
- Read, interpret, and examine the credibility and validity of scientific claims in different sources of information, such as scientific articles, advertisements, or media stories.

SIS2. Design and conduct scientific investigations.

- Articulate and explain the major concepts being investigated and the purpose of an investigation.
- Select required materials, equipment, and conditions for conducting an experiment.
- Identify independent and dependent variables.
- Write procedures that are clear and replicable.
- Employ appropriate methods for accurately and consistently
  - making observations
  - making and recording measurements at appropriate levels of precision
  - collecting data or evidence in an organized way
- Properly use instruments, equipment, and materials (e.g., scales, probeware, meter sticks, microscopes, computers) including set-up, calibration (if required), technique, maintenance, and storage.
- Follow safety guidelines.

SIS3. Analyze and interpret results of scientific investigations.

- Present relationships between and among variables in appropriate forms.
- Represent data and relationships between and among variables in charts and graphs.
- Use appropriate technology (e.g., graphing software) and other tools.
- Use mathematical operations to analyze and interpret data results.
- Assess the reliability of data and identify reasons for inconsistent results, such as sources of error or uncontrolled conditions.
- Use results of an experiment to develop a conclusion to an investigation that addresses the initial questions and supports or refutes the stated hypothesis.
- State questions raised by an experiment that may require further investigation.

SIS4. Communicate and apply the results of scientific investigations.

- Develop descriptions of and explanations for scientific concepts that were a focus of one or more investigations.
- Review information, explain statistical analysis, and summarize data collected and analyzed as the result of an investigation.
- Explain diagrams and charts that represent relationships of variables.
- Construct a reasoned argument and respond appropriately to critical comments and questions.
- Use language and vocabulary appropriately, speak clearly and logically, and use appropriate technology (e.g., presentation software) and other tools to present findings.
- Use and refine scientific models that simulate physical processes or phenomena.

III. Mathematical Skills

Students are expected to know the content of the *Massachusetts Mathematics Curriculum Framework,* through grade 8. Below are some specific skills from the *Mathematics Framework* that students in this course should have the opportunity to apply:

- ✓ Construct and use tables and graphs to interpret data sets.
- ✓ Solve simple algebraic expressions.
- ✓ Perform basic statistical procedures to analyze the center and spread of data.
- ✓ Measure with accuracy and precision (e.g., length, volume, mass, temperature, time)
- ✓ Convert within a unit (e.g., centimeters to meters).
- ✓ Use common prefixes such as *milli-, centi-,* and *kilo-*.
- ✓ Use scientific notation, where appropriate.
- ✓ Use ratio and proportion to solve problems.

The following skills are not detailed in the *Mathematics Framework*, but are necessary for a solid understanding in this course:

- ✓ Determine percent error from experimental and accepted values.
- ✓ Use appropriate metric/standard international (SI) units of measurement for mass (kg); length (m); time (s); force (N); speed (m/s); acceleration (m/s^2); and frequency (Hz).
- ✓ Use the Celsius and Kelvin scales.

WHAT IT LOOKS LIKE IN THE CLASSROOM

Surface Processes and Landscape

Adapted from a contribution from Dan Barstow

Earth and Space Science, High School

In Chelmsford, Mr. D's high school earth science students investigated the interconnections between Earth systems by studying river basins and the geologic materials through which they flow. He began this activity by asking the students, "How do rivers affect their surroundings?" Mr. D instructed the class to write down their thoughts, along with what they know about the geology and plant life of the nearby Merrimack River. The class discussed their thoughts.

Next, the class visited two sites on the Merrimack River to gather geologic and ecological data. Mr. D helped the students identify areas along the river where erosion and deposition occurred. At each site, they observed the velocity of the water and noted where it was moving fast or slow. They collected information about the riverbank, including its slope and composition. Mr. D instructed the students on how to classify vegetation near the bank of the river and estimate its density. The students used a Global Positioning System to identify and record the latitude and longitude of both sites so that they could later pinpoint the exact locations they had observed along the river. Students sketched all their observations and recorded their data.

Upon returning to the classroom, Mr. D asked the students to use their observations and data to draw a bird's-eye view of the sections of the river they observed. After completing their drawings, the students found a satellite image of the Merrimack River on the Internet. Using the Merrimack image, Mr. D helped students relate their birds-eye drawings to the satellite image. Students identified patterns of erosion, degrees of meandering, and surrounding vegetation. They used Web sites, topographical maps, and other resources to collect additional information about the river. They researched how the underlying bedrock, topology, and climate shape and alter the Merrimack.

Mr. D then instructed the students to make comparisons between the Merrimack River and other rivers around the world. Students were grouped into pairs and each pair was assigned a specific river to investigate. Among the rivers researched were the Nile, Amazon, Danube, Tigris, Yangtze, and Mississippi. Each pair of students downloaded a satellite image of its assigned river and annotated the image to highlight features of the river. Students collected information on meandering, vegetation, patterns of erosion, and flood plains from the images as they had done for the Merrimack. One pair noted, for example, that the fertile green vegetated Nile flood plain creates a dramatic contrast with the neighboring dry brown desert. Another pair noted that the Mississippi has many meanderings, ox bow lakes, and other erosional features that have evolved over time. As a class, Mr. D and the students discussed the similarities and differences between the rivers they investigated as pairs and the local Merrimack River.

The class then worked cooperatively to summarize how the characteristics of a river are the result of interactions of materials and processes in the river system. They then articulated ideal locations along a river for the following: (1) white water rafting, (2) setting up a farm, and (3) nearby human habitation. They detailed the optimal bank slope, basin shape, and water velocity for each of the locations.

As a result of this experience, students learned how to make ground-based observations, and to accurately collect and analyze data. Students were also able to read, interpret, and analyze satellite images; describe how rivers cause erosion and create landscapes; and explain how surface processes impact human decisions.

WHAT IT LOOKS LIKE IN THE CLASSROOM

Assessment Strategies

- Students can correctly record data using appropriate language and units in an organized way.
- Students can create individual portfolios of their work, including some of the images they collected/downloaded, data charts, a summary of work completed, and a conclusive report. They can also present and communicate their work to other groups using appropriate technology.
- Students can be shown images they have seen or not seen and be asked to annotate the images and summarize their properties according to a scaled rubric. Possible rubric items for working with images could include the following:
    1. Able to make distinction between water bodies (e.g., rivers, lakes, oceans) and land features (e.g., mountains, cities, plains).
    2. Able to identify detailed features of river basins, including ox bows, river erosion patterns, vegetation, and flood plains.
    3. Able to make connections between the change processes and resulting features (e.g., relating river meanders to land topology).

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1.8 Read, interpret, and analyze a combination of ground-based observations, satellite data, and computer models to demonstrate Earth systems and their interconnections.

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Scientific Inquiry Skills Standards

High School

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- Observe the world from a scientific perspective.

SIS2. Design and conduct scientific investigations.
- Employ appropriate methods for accurately and consistently
    - making observations
    - making and recording measurements at appropriate levels of precision
    - collecting data or evidence in an organized way

SIS4. Communicate and apply the results of scientific investigations.
- Use language and vocabulary appropriately, speak clearly and logically, and use appropriate technology (e.g., presentation software) and other tools to present findings.