Minnesota Science

Earth and Space Science

Exploring phenomena or engineering problems 9E.1

1 **Asking questions and defining problems** 9E.1.1

1 Students will be able to ask questions about aspects of the phenomena they observe, the conclusions they draw from their models or scientific investigations, each other's ideas, and the information they read. 9E.1.1.1

1 Ask questions to clarify how seismic energy traveling through Earth's interior can provide evidence for Earth's internal structure. (P: 1, CC: 6,CI: ESS2) Emphasis is on how wave propagation depends on the density of the medium through which the wave travels and how seismic data is used to support the idea of a layered earth. 9E.1.1.1.1

1 **Planning and carrying out investigations** 9E.1.2

1 Students will be able to design and conduct investigations in the classroom, laboratory, and/or field to test students' ideas and questions, and will organize and collect data to provide evidence to support claims the students made about phenomena. 9E.1.2.1

1 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. (P: 3, CC: 6, CI: ESS2) Emphasis is on physical and chemical investigations with water and a variety of solid materials to provide the evidence for how processes in the water cycle and rock cycle interact. Examples of physical investigations may include transportation and deposition of various sediment types and sizes, erosion of surfaces with varying amounts of soil moisture content and/or ground cover, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations may include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids). Examples specific to Minnesota may include chemical weathering of limestone to create karst topography. 9E.1.2.1.1

2 Plan and conduct an investigation of the properties of soils to model the effects of human activity on soil resources. (P: 3, CC: 2, CI: ESS3, ETS2) Emphasis is on identifying variables to test, developing a workable experimental design, and identifying limitations of the data. Examples of variables may include soil type and composition (particularly those found in Minnesota), erosion rate, water infiltration rates, nutrient profiles, soil conservation practices, or specific crop requirements. 9E.1.2.1.2

Looking at data and emirical evidence to understand phenomena or solve problems 9E.2

2 **Analysing and interpreting data** 9E.2.1

2 Students will be able to represent observations and data in order to recognize patterns in the data, the meaning of those patterns, and possible relationships between variables. 9E.2.1.1

2 Analyze geoscience data to make a claim that one change to the Earth's surface can create feedbacks that cause changes to other Earth systems. (P: 4, CC: 7, CI: ESS2, ETS2) Emphasis is on using data analysis tools and techniques in order to make valid scientific claims. Examples may include climate feedback mechanisms, such as how an increase in greenhouse gases causes a rise in global temperatures that melt glaciers and sea ice, which reduces the amount of sunlight reflected from the Earth's surface (albedo), increasing surface temperatures and further reducing the amount of ice. Examples may also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent and longevity. 9E.2.1.1.2

2 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems and human infrastructure.* (P: 4, CC: 7, ESS3, ETS1) Examples of evidence (for both data and climate model outputs) may include precipitation and temperature and their associated impacts on sea level, glacial ice volumes, and atmosphere and ocean composition. Engineering examples may include using climate change data (rising sea levels) to evaluate the impact on the ability of sewer system to handle runoff or of existing wells to produce potable water. 9E.2.1.1.3

2 Using mathematics and computational thinking 9E.2.2

2 Students will be able to use mathematics to represent physical variables and their relationships; compare mathematical expressions to the real world; and engage in computational thinking as they use or develop algorithms to describe the natural or designed worlds. 9E.2.2.1

- 2 Use mathematical and computational representations to predict the motion of natural and human-made objects that are in orbit in the solar system.** (P: 5, CC: 3, CI: ESS1, ETS2) Emphasis is on Kepler's laws of planetary motion and Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons. 9E.2.2.1.1

- 2 Develop a computational model, based on observational data, experimental evidence, and chemical theory, to describe the cycling of carbon among Earth's systems.** (P: 2, CC: 5, CI: ESS2) Emphasis is on quantitative modeling of carbon as it cycles through the ocean, air, rock (particularly limestone), soil, and organisms. Emphasis is also on using empirical evidence and scientific reasoning to inform the algorithmic thinking about the conservation and cycling of matter. 9E.2.2.1.2

- 2 Develop or use an algorithmic representation, based on investigations of causes and effects in complex Earth systems, to illustrate the relationships within some part of the Earth system and how human activity might affect those relationships. (P: 5, CC: 4, CI: ESS3, ETS2) Emphasis is on students identifying the interacting components of a system, mathematically modeling how those factors interact and accounting for the effects of human activity on the system. Examples may include local systems in which natural and human-influenced variables impact the amount of runoff. 9E.2.2.1.3

Developing possible explanations of phenomena or designing solutions to engineering problems. 9E.3

- 3 **Developing and using models** 9E.3.1
  - 3 Students will be able to develop, revise, and use models to represent their understanding of phenomena or systems as they develop questions, predictions and/or explanations and communicate ideas to others. 9E.3.1.1
    - 3 Develop and use a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. (P: 2, CC: 3, CI: ESS1) Emphasis is on showing the relationships among the fuel, products and the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach the Earth. Examples of evidence that students might use include the masses and life times of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares, sunspot cycles, and non-cyclic variations over the centuries. 9E.3.1.1.1
    - 3 Develop and use a model based on evidence to explain how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. (P: 2, CC: 7, CI: ESS2) Emphasis is on how the appearance of land features (such as mountains, and valleys), and seafloor features (such as trenches and ridges) are a result of both constructive mechanisms (such as volcanism, and tectonic motion) and destructive mechanisms (such as weathering, and coastal erosion). Examples specific to Minnesota may include features formed relatively recently during continental glaciation and volcanic features that have long since been eroded away. 9E.3.1.1.2
    - 3 Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. (P: 2, CC: 4, CI: ESS2) Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean currents, which is constrained by the Coriolis effect and the outlines of continents. Examples of models may be diagrams, maps and globes, or digital representations. 9E.3.1.1.3
    - 3 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. (P: 2, CC: 2, CI: ESS2). Emphasis is on using a model to describe the mechanism for how energy flow affects changes in climate. Examples of the causes of climate change differ by timescale and may include: 1 - 10 years: large volcanic eruptions, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10 - 100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10 - 100s of millions of years: long term changes in atmospheric composition. 9E.3.1.1.4

3 **Constructing explanations and designing solutions** 9E.3.2

- 3 Students will be able to apply scientific principles and empirical evidence (primary or secondary) to explain the causes of phenomena or identify weaknesses in explanations developed by the students or others. 9E.3.2.1

  - 3 Construct an explanation that links astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe to the Big Bang. (P: 6, CC: 5, CI: ESS1, ETS2) Emphasis is on how the redshift of light from galaxies is an indication of cosmic expansion, on how the cosmic microwave background radiation is a remnant of the Big Bang, and on how the observed composition of ordinary matter, primarily found in stars and interstellar gases, matches that predicted by the Big Bang. 9E.3.2.1.1

  - 3 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. (P:6, CC: 7, CI: ESS1) Emphasis of the practice is on linking the evidence to the claims about Earth's formation. Emphasis of the core idea is on using available evidence within the solar system to reconstruct the early history of Earth. Examples of evidence include the absolute ages of ancient materials, the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces. 9E.3.2.1.2

- 3 Students will be able to use their understanding of scientific principles and the engineering design process to design solutions that meet established criteria and constraints. 9E.3.2.2

  - 3 Evaluate or refine a technological solution to reduce the human impacts on a natural system and base the evaluations or refinements on evidence and analysis of pertinent data.* (P: 6, CC: 7, CI: ESS3, ETS1, ETS2) Emphasis is on prioritizing identified criteria and constraints related to social and environmental considerations. Examples of data for the impacts of human activities may include the quantities and types of pollutants released into air or groundwater, changes to biomass and species diversity, or areal changes in land surface use (for surface mining, urban development, or agriculture). Examples for limiting impacts may range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean). 9E.3.2.2.1

Communicating reasons, arguments, and ideas to others. 9E.4

4 **Arguing from evidence** 9E.4.1

- 4 Students will be able to engage in argument from evidence for the explanations the students construct, defend and revise their interpretations when presented with new evidence, critically evaluate the scientific arguments of others, and present counter arguments. 9E.4.1.1
  - 4 Evaluate the evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. (P: 7, CC: 1, CI: ESS1) Emphasis is on evaluating the strengths, weaknesses and reliability of the given evidence along with its ability to support logical and reasonable arguments about the motion and age of crustal plates. Examples of evidence may include the ages of oceanic crust which increase with distance from mid-ocean ridges (a result of seafloor spreading), the ages of North American continental crust decreasing with distance away from a central ancient core (a result of past plate interactions). 9E.4.1.1.1
  - 4 Evaluate the evidence and reasoning for the explanatory model that Earth's interior is layered and that thermal convection drives the cycling of matter. (P: 7, CC: 5, CI: ESS2) Emphasis is on how plate tectonics is controlled by mantle convection (due to the outward flow of energy from the decay of radioactive isotopes and the gravitational movement of denser materials toward the interior). 9E.4.1.1.2
  - 4 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* (P: 7, CC: 5, CI: ESS3, ETS1) Emphasis is on the conservation, recycling, and reuse of resources (such as minerals, metals or soils) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for fracking sand, iron ore, and rare metals), and pumping (for oil and natural gas). 9E.4.1.1.3

4 **Obtaining, evaluating, and communicating information.** 9E.4.2

- 4 Students will be able to read and interpret multiple sources to obtain information, evaluate the merit and validity of claims and design solutions, and communicate information, ideas, and evidence in a variety of formats. 9E.4.2.1

  - 4 Compare, integrate and evaluate sources of information in order to determine how specific factors, including human activity, impact the groundwater system of a region. (P: 8, CC: 2, CI: ESS2, ETS2) Emphasis is on the making sense of technical information presented in a variety of formats (graphs, diagrams and words). Example of sources of information may include student experimental data. Examples of factors may include porosity, permeability, sediment or rock type, recharge or discharge factors, and potential energy. Examples of human factors may include usage rates, run-off, agricultural practices, and loss of wetlands. 9E.4.2.1.1

  - 4 Apply place-based evidence, including those from Minnesota American Indian Tribes and communities and other cultures, to construct an explanation of how a warming climate impacts the hydrosphere, geosphere, biosphere, or atmosphere. (P: 8, CC: 4, CI: ESS3) Examples of cultures may include those within the local context of the learning community and within the context of Minnesota . Emphasis is on understanding and using American Indian knowledge systems to describe regional impacts of climate change to Minnesota. Examples may include the water cycle and how precipitation change over time impacts cultural practices related to nibi ("water" in the Ojibwe language); or the decline/species loss of wiigwaas ("paper birch" in the Ojibwe language and an important tree in Anishinaabe culture) due to climate stressors like drought or changes in snow cover. 9E.4.2.2.1