Anne Arundel County Public Schools

TRADITION & VISION

ANNE ARUNDEL COUNTY PUBLIC SCHOOLS

Support provided by NASA Goddard Education Programs

Earth Space Systems Science

Earth/Space Systems Science
Introduction

What is Earth Systems Science?

The objective of Earth System Science is to understand how the Earth is changing and the consequences for life on Earth with a focus on enabling prediction and mitigation of undesirable consequences. This requires an identification and description of how the Earth system is changing, the ability to identify and measure the primary forcings on the Earth system from both natural and human activities, knowledge of how the Earth system responds to changes in these forcings, identification of the consequences of these changes for human civilization, and finally, the ability to accurately predict future changes with sufficient advanced notice to mitigate the predicted effects.

To achieve this level of knowledge and understanding a multidisciplinary approach to studying Earth as a system is needed. Such an approach involves studying the processes and interactions (cycles) among the atmosphere, hydrosphere, cryosphere, biosphere, and geosphere from a global to local point-of-view, and across the time scales (minutes to eons) in which these spheres interact. It requires the use of physical and chemical laws with mathematics to describe the physical, chemical and biological processes within each sphere and the interactions between the spheres. These descriptions are used along with observations from ground, airborne, waterborne, and spaceborne instruments to construct models through which complex interactions of the spheres are studied. It is through the understanding of these complex interactions that accurate, predictive models are developed.

(Dr. Blanche Meeson, Assistant Director of Earth Sciences for Education and Outreach, Goddard Space Flight Center, May, 2000.)

Earth/Space Systems Science
Introduction

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Earth/Space Systems Science
Introduction

About Earth/Space Systems Science

Earth/Space Systems Science emphasizes the dynamic interrelationships between the atmosphere, the geosphere, the hydrosphere, the biosphere and the earth-universe system. There is a strong emphasis on internet-based and technology activities, and laboratory activities. Science skills and processes learned in this course prepare for continued development of scientific inquiry in other science disciplines. A partnership with the Goddard Space Flight Center and collaboration with Montgomery County Public Schools provides enhanced richness to the learning activities. This is a core course and prepares students for the upcoming high school assessment test in earth/space science. This course is recommended for all students.

GOAL:

Earth/Space Systems Science is a course, which develops student knowledge and understanding of the Earth/Space System. This course seeks to empower students to understand their dynamic local and global environments and the Earth as part of a complex system. The student will learn the science content necessary to make wise personal and social decisions related to quality of life, and the management of the Earth's finite resources, environments, and hazards.

This course will provide students with the learning experiences necessary to acquire the skills, processes, and concepts needed to qualify on the proposed High School Assessment in Earth/Space Science.

RATIONALE:

During much of the recent past, scientists have been concerned with examining individual physical, chemical, and biological processes or groups of processes in the atmosphere, hydrosphere, lithosphere, and biosphere. Recently, however, there has been a movement in Earth Science to take a planetary or "systems" approach to investigating our planet. Satellite images show planet Earth as one entity without boundaries. There are concerns with environmental issues on regional, global, and even planetary scales. In Earth/Space Systems Science, Earth is viewed as a complex evolving planet that is characterized by continually interacting change over a wide scale of time and space.

All students have a stake in the future of their environment. We all need to make decisions concerning important scientific issues. In the workplace, jobs demand that people be able to learn, reason, and think creatively, as well as make decisions and solve problems. All high school graduates should be able to design plans of inquiry, gather and interpret evidence, develop and test models, think critically, use/develop the latest technologies, and communicate inferences to make wise decisions about finite resources, changing environments, natural hazards, human risks, and the future.

Earth/Space Systems Science
Introduction

PROGRAM STRATEGIES: As underscored in the National Science Education Standards (1996, National Research Council), there is a changing emphasis in science education.

Greater emphasis should be placed on:

- Activities that investigate and analyze science questions
- Investigations over extended periods of time
- Process skills in context
- Using multiple process skills: manipulation, cognitive, procedural
- Using evidence and strategies for developing or revising an explanation
- Science as argument and explanation
- Communicating science explanations
- Groups of students often analyzing and synthesizing data
  After defending conclusions
- Doing more investigations in order to develop understanding ability, values of inquiry and knowledge of science content
- Applying results of experiments to scientific arguments and explanations
- Management of ideas and information
- Public communication of student ideas and work to classmates.

LABORATORY AND FIELD INVESTIGATION: The goal of this component is to complement the classroom portion of the course by allowing students to learn about the earth system spheres through firsthand observation. Such experiences allow students to explore concepts introduced in the classroom, with depth, and confront science, as it exists, in the "real world."

- Acquire skills in specific techniques and procedures
- Analyze a real data set
- Critically observe earth/space systems
- Develop and conduct well-designed experiments
- Utilize appropriate techniques and instrumentation
- Analyze and interpret data, including appropriate statistical and graphical presentations
- Think analytically and apply concepts to the solutions of environmental problem
  - Make conclusions and evaluate their quality and validity
  - Propose questions for further study
- Communicate accurately and meaningfully about observations and conclusions

Earth/Space Systems Science
Introduction

All students will keep an **Earth/Space Journal.** This journal will include all class and lab notes, experimental designs, and data, etc., related to laboratory and field investigations. All homework and assessments should also be a part of the Earth/Space Journal. The Earth/Space Journal will provide a permanent record for the student and allow the student to record scientific data as it is done in a research laboratory and refer back to it as necessary. A student's Earth/Space Journal will also be a record of all activities and be a tool to enable students to review for the end of course assessment given by the State.

Earth/Space Systems Science
Introduction

Science Core Learning Goals

Goal 1: Skills and Processes

The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.

Expectation 1.1
The student will explain why curiosity, honesty, openness, and skepticism are highly regarded in science.
Indicators of Learning
1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.
1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.
1.1.3 The student will critique arguments that are based on faulty, misleading data or on the incomplete use of numbers.
1.1.4 The student will recognize data that are biased.
1.1.5 The student will explain factors that produce biased data (including incomplete data, using data inappropriately, conflicts of interest, etc.).

Expectation 1.2
The student will pose scientific questions and suggest experimental approaches to provide answers to questions.
Indicators of Learning
1.2.1 The student will identify meaningful, answerable scientific questions.
1.2.2 The student will pose meaningful, answerable scientific questions.
1.2.3 The student will formulate a working hypothesis.
1.2.4 The student will test a working hypothesis.
1.2.5 The student will select appropriate instruments and materials to conduct an investigation.
1.2.6 The student will identify appropriate methods for conducting an investigation (independent and dependent variables, proper controls, repeat trials, appropriate sample size, etc.).
1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.
1.2.8 The student will defend the need for verifiable data.

Expectation 1.3
The student will carry out scientific investigations effectively and employ the instruments, systems of measurement, and materials of science appropriately.

Earth/Space Systems Science
Introduction

Indicators of Learning

1.3.1 The student will develop and demonstrate skills in using lab and field equipment to perform investigative techniques.
1.3.2 The student will recognize safe laboratory procedures.
1.3.3 The student will demonstrate safe handling of the chemicals and materials of science.
1.3.4 The student will learn the use of new instruments and equipment by following instructions in a manual or from oral direction.

Expectation 1.4

The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication.

Indicators of Learning

1.4.1 The student will organize data appropriately using techniques such as tables, graphs, and webs (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title).
1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.
1.4.3 The student will use experimental data from various investigators to validate results.
1.4.4 The student will determine the relationships between quantities and develop the mathematical model that describes these relationships.
1.4.5 The student will check graphs to determine that they do not misrepresent results.
1.4.6 The student will describe trends revealed by data.
1.4.7 The student will determine the sources of error that limits the accuracy or precision of experimental results.
1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.
1.4.9 The student will use analyzed data to confirm, modify, or reject a hypothesis.

Expectation 1.5

The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation.

Indicators of Learning

1.5.1 The student will demonstrate the ability to summarize data (measurements/observations).
1.5.2 The student will explain scientific concepts and processes through drawing, writing, and/or oral communication.
1.5.3 The student will produce the visual materials (tables, graphs, and spreadsheets) that will be used for communicating results.
1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.
1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

1.5.6 The student will read a technical selection and interpret it appropriately.
1.5.7 The student will use, explain, and/or construct various classification systems.
1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.
1.5.9 The student will communicate conclusions derived through a synthesis of ideas.

Expectation 1.6
The student will use mathematical processes.
Indicators of learning
1.6.1 The student will use ratio and proportion in appropriate situations to solve problems.
1.6.2 The student will use computers and/or graphing calculators to perform calculations for tables, graphs, or spreadsheets.
1.6.3 The student will express and/or compare small and large quantities using scientific notation and relative order of magnitude.
1.6.4 The student will manipulate quantities and/or numerical values in algebraic equations.
1.6.5 The student will judge the reasonableness of an answer.

Expectation 1.7
The student will show that connections exist both within the various fields of science and among science and other disciplines including mathematics, social studies, language arts, fine arts, and technology
Indicators of learning
1.7.1 The student will apply the skills, processes, and concepts of biology, chemistry, physics, and earth science to societal issues.
1.7.2 The student will identify and evaluate the impact of scientific ideas and/or advancements in technology on society.
1.7.3 The student will describe the role of science in the development of literature, art, and music.
1.7.4 The student will recognize mathematics as an integral part of the scientific process.
1.7.5 The student will investigate career possibilities in the various areas of science.
1.7.6 The student will explain how development of scientific knowledge leads to the creation of new technology and how technological advances allow for additional scientific accomplishments.

Earth/Space Systems Science
Introduction

Goal 2: Concepts of Earth/Space

The student will demonstrate the ability to use scientific skills and processes (Core Learning Goal 1) to explain the physical behavior of the environment, Earth, and the universe.

Expectation: 2.1
The student will identify and describe techniques used to investigate the universe and Earth.
Indicators of Learning

2.1.1 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the universe.
Assessment Limits (at least) –
- Tools (optical and radio telescopes, spectrometers)
- Delivery systems (satellite-based, ground-based, space probe)
- Techniques (imaging, spectroscopy)

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth.
Assessment limits (at least) –
- Tools (spectrometers, seismograph)
- Delivery systems (satellite-based, ground-based)
- Techniques (imaging, Geographic Information System, Global Positioning System, spectroscopy, Doppler, epicenter location/time-travel graphs)

Expectation: 2.2
The student will describe natural forces and apply them to the study of Earth/Space Science.
Indicators of Learning

2.2.1 The student will explain the role of forces in the formation and operation of the universe.
Assessment limits
- Newton's Universal Law of Gravitation
- Structure and evolution of galaxies and the universe (Big Bang Theory)
- Stellar structure and evolution (life cycle of stars, stellar systems, H-R diagram)
- Formation and evolution of the solar system (Nebular Theory, small bodies)
- Kepler's 3 Laws of Planetary Motion
- Sun-Earth connection (thermonuclear process, sunspot cycle, coronal mass ejection, flares, solar wind, auroras)

2.2.2 The student will explain the role and interaction of revolution, rotation and gravity on the Sun-Earth-Moon system.
Assessment limits (at least) -
- Seasons (change in solar angle, yearly variation in length of day/night, absorption/reflection/scattering of insolation, solstices and equinoxes, rotation/revolution/precession, yearly variation of the sun's altitude and azimuth)

- Eclipses (lunar, solar, total, annular, partial, umbra, penumbra, 2 eclipse "seasons" per Earth year, yearly/monthly variations in lunar position and length of visibility of the moon)
- Earth-moon interactions (relationship between lunar phase and tide, tidal bulge and rate of lunar revolution, tides and Earth-moon distance, sidereal and synodic lunar months)

Expectation: 2.3
The student will explain how the transfer of energy and matter affect Earth systems.
Indicators of Learning
2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits (at least) -
- Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)
- Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter.
Assessment limits (at least) –
- Atmospheric composition and structure (greenhouse gases, stratospheric ozone concentration and distribution, aerosols, temperature)
- Pollutants (particulates, tropospheric ozone concentration and distribution, acid rain)
- Ocean-atmosphere-land interactions (current changes, continental movement, El Niño, La Niña)
- Cloud cover (amount, type, albedo)
- Climate type and distribution (temperature and precipitation)
- Sea level, glaciers and sea ice, biome location and distribution, emergent and submergent coastlines

Expectation: 2.4
The student will analyze the dynamic nature of the Geosphere.
Indicators of Learning
2.4.1 The student will compare the origin and structure of igneous, metamorphic and sedimentary rocks.
Assessment limits (at least) -
- Structure of matter (atoms, molecules, isotopes)
- Physical properties (density) and chemical composition of common rock forming mineral groups
- Origin, texture (crystal size, shape) and mineral composition of common rock groups

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) -

- Destructive processes (weathering, erosion, subsidence, melting)
- Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition)
- Landform change (surface & groundwater, coasts, glacial processes, desert processes)

2.4.3 The student will explain changes in Earth's surface using plate tectonics.
Assessment limits (at least) -

- Continental drift (rock/structure/climate/fossil evidence, jigsaw fit)
- Sea floor spreading (age evidence, mantle circulation, outer core circulation/magnetic reversals, seismic activity, volcanism, mountain building, ocean ridges)
- Theory of Plate Tectonics (crustal plate composition, mantle circulation, divergent/convergent/transform fault boundaries, subduction zones, trenches, island arcs, seismic activity, volcanism, mountain building)

Expectation: 2.5
The student will investigate methods that geologists use to determine the history of Earth.
Indicators of Learning

2.5.1 The student will apply geologic principles used to date Earth's geologic and biologic events.
Assessment limits (at least) –

- Relative dating (superposition in rock columns, core samples, unconformities; uniformitarianism; cross-cutting relationships; correlation of rock layers, fossils)
- Absolute dating (radioactive dating)

2.5.2 The student will compare events in Earth's history that have been grouped according to similarities.
Assessment limits (at least) –

- Geologic time (scale and magnitude)
- Era, period, epoch

Earth/Space Systems Science
Introduction

CONTENT OUTLINE

UNIT I: INTRODUCTION TO EARTH/SPACE SYSTEMS SCIENCE

I. Introduction to Systems
II. Introduction to Earth as a System
III. The Mini Water Cycle
IV. Equilibrium and Conservation of Mass in the Global Water Cycle
V. Equilibrium and Conservation of Energy in the Global Water Cycle

UNIT II: THE ATMOSPHERE

I. Matter in the Atmosphere
  - A. Atmospheric composition
    1. Greenhouse gases
    2. Stratospheric ozone (Concentration and distribution)
    3. Particulates
  - B. Atmosphere structure
    1. Temperature gradients
    2. Pressure gradients
    3. Cloud cover
       - a) Amount
       - b) Type
       - c) Aledo

II. Atmospheric Circulation
  - A. Heat transfer systems
    1. Conduction
    2. Convection
    3. Radiation
    4. Latent heat
    5. Phase change
  - B. Global Circulation
    1. Pressure
    2. Temperature
    3. Volume
    4. Coriolis effect

Earth/Space Systems Science
Introduction

UNIT III: THE HYDROSPHERE

I. Structure of the Hydrosphere
II. Wind-driven Currents
    A. Sea surface temperatures
    B. Coriolis effect
III. Density Driven Currents
    A. Density
    B. Temperature
    C. Fresh water vs. salt water
        1. Composition of salts
IV. The Global Water Cycle and the Cryosphere
    A. Ice
    B. Albedo
    C. Sea level
        1. Sea ice
        2. Coastlines
            a) Emergent
            b) Submergent
V. Transfer of Energy
    A. Vertical currents
        1. Upwelling and downwelling
    B. The Global Conveyer Belt
    C. Weather and Climate
        1. Monsoons
        2. Hurricanes
        3. El Nino and La Nina

Unit IV: The Geosphere

I. Continental Drift
    A. Evidence
        1. Rock layers
        2. Mineral deposits
        3. Climate
        4. Fossils
        5. Jigsaw
II. Sea floor Spreading
    A. Evidence
        1. Age of seafloor
        2. Magnetic reversals
        3. Seismic activity
        4. Volcanism

        5. Mountain building
        6. Ocean ridges
    B. Circulation
        1. Mantle circulation
        2. Outer core circulation

III. Plate Tectonics
- A. Evidence
    1. Crustal plate composition
    2. Seismic activity
    3. Volcanism
- B. Plate Boundaries
    1. Divergent
    2. Convergent
    3. Transform fault
    4. Subduction zone
- C. Plate Features
    1. Trenches
    2. Island arcs
    3. Mountain building
- D. Mantle Circulation

IV. Origin and Structure of Rocks
- A. Structure of Matter
    1. Atoms
    2. Molecules
    3. Isotopes
- B. Common rock forming mineral groups
    1. Chemical composition
    2. Origin/constructive processes
        - a) Cooling/crystallization
        - b) Lithification
        - c) Deformation
        - d) Volcanism
        - e) Metamorphism
        - f) Deposition
    3. Texture
        - a) Crystal size
        - b) Shape
    4. Mineral composition of common rock groups
- C. Physical Properties
    1. Density
- D. Destructive Processes

1. Weathering
2. Erosion
3. Subsidence
4. Melting

E. Landform Change
1. Surface water
2. Groundwater
3. Glacial processes
4. Desert processes
5. Coasts

V. Geological Principles

A. Relative dating
1. Superposition in rock columns
2. Core samples
3. Unconformities
4. Uniformitarianism
5. Cross-cutting relationships
6. Correlation of rock layers
7. Fossil

B. Absolute dating
1. Radioactive dating

VI. Events in Earth's History

A. Geologic time
1. Scale
2. Magnitude

B. Time periods
1. Era
2. Period
3. Epoch

UNIT V: THE SPACE SPHERE

I. Formation and Operation of the Universe

A. Structure and Evolution of Galaxies and the Universe
1. Big Bang theory
2. Stellar structure and evolution
   a) Newton's Universal Law of Gravitation
   b) Life cycle of stars
   c) Stellar systems
   d) H-R diagram

3. Formation and evolution of the Solar System
    a) Nebular Theory
    b) Kepler's three Laws of Planetary Motion
    c) Small bodies

B. Sun-/Earth connection
1. Thermonuclear process
2. Sunspot cycle
3. Coronal mass ejection
4. Flares
5. Solar wind
6. Auroras

C. Sun-Earth-Moon system
1. Interactions
    a) Revolution
    b) Rotation
    c) Gravity
2. Seasons
3. Eclipses
4. Earth-Moon interactions
    a) Lunar months
    b) Tides

UNIT VI: THE BIOSPHERE

II. Natural and Human-Induced Change on Global Conditions

A. Biome
1. Climate
    a) Temperature
    b) Precipitation
2. Location
3. Distribution

B. Pollutants
1. Particulates
2. Tropospheric ozone
3. Acid rain

C. Greenhouse Gases

D. El Nino Southern Oscillation

Earth/Space Systems Science
Introduction

UNIT VI: ANALYZING AN EARTH/SPACE SYSTEM

I. Subsystems (spheres)
II. Event/ Effect/ Problem
    A. Nuclear disaster
    B. Asteroid
    C. Destruction of rainforest
    D. Overpopulation
    E. Flood
    F. Fire
    G. Hurricane
    H. Epidemic
    I. Other
III. Model
IV. Analysis

TIMELINE

Unit	Approximate % of Course	Approximate Number of Days
I. Introduction to Earth/Space Systems Science	7	10
II. The Atmosphere	19	30
III. The Hydrosphere	19	30
IV. The Geosphere	19	30
V. The Space Sphere	19	30
VI. The Biosphere	10	15
VII. Analyzing an Earth/Space Event (after proposed state test)	7	10
Total	**100%**	**155 Days**