

“Students should develop an understanding of what science is, and what science is not.”

The purpose of the National Science Educational Standards (NSES) (<http://newton.nap.edu/html/nses/>) is reflected in the above statement. They exist in order to “establish as a goal that all students should achieve scientific literacy,” and they “point toward a destination and provide a roadmap for how to get there.”

The two NSES objectives we wanted to demonstrate are:

- The richness and excitement of knowing and understanding the natural world; and
- Appropriate scientific processes and principles, especially in the analyses and processing of scientific data.

The National Standards emphasize inquiry-based science, and they state that “inquiry is a step beyond ‘science as a process,’ in which students learn skills, such as observation, inference, and experimentation.” Inquiry requires students to combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science.

The NSES categorize the standards as domains which focus on science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use. Of concern to us is the level 9-12 standards for physical science, earth and space science, and technology listed below:

Physical Science	Earth and Space Science	Science and Technology
<ul style="list-style-type: none"> • Structure of atoms • Structure and properties of matter • Interactions of energy and matter 	<ul style="list-style-type: none"> • Energy in the earth system • Origin and evolution of the earth system • Origin and evolution of the universe 	<ul style="list-style-type: none"> • Abilities of technological design • Understanding about science and technology

The major scientific tenet is that the nature of the universe is not capricious but is understandable and predictable. Of special concern for our project is the fact that the NSES recognize that:

Prediction uses knowledge to identify and explain observations, or changes in advance. Applying mathematics, **especially probability**, allows for greater or lesser certainty of predictions.

Objects or events in the universe are ordered and can be described **statistically**. Probability is the relative certainty that can be assigned to selected events happening in a specified space or time. In science, reduction of uncertainty occurs through such processes as the development of knowledge about factors influencing objects, organisms, systems, or events; better and more observations; and better explanatory models.

In grades 5-8 students are taught:

The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation. Energy from the sun transferred by light and other radiation is the primary energy source for processes on earth's surface and in its hydrosphere, atmosphere, and biosphere.

Earth has an outermost rigid shell called the lithosphere that is made up of the crust and part of the upper mantle and is broken into about a dozen rigid plates that move without deforming, except at boundaries where they collide. Those plates range in thickness from a few to more than 100 kilometers. Ocean floors are the tops of thin oceanic plates that spread outward from mid-ocean rift zones; land surfaces are the tops of thicker, less-dense continental plates.

Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions. Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.

However, students do not have direct contact with most of these phenomena and the long-term nature of the processes, and some explanations of moving plates.

In grades 9-12 students learn how to analyze evidence and data from their investigations, other students' investigations, or databases.

Data manipulation and analysis strategies need to be modeled by science teachers and practiced by students. Determining the range of the data, the mean and mode values of the data, plotting the data, developing mathematical functions from the data, and looking for anomalous data are all examples of analyses students can perform. Science teachers can ask questions, such as "What explanation did you expect to develop from the data?" "Were there

any surprises in the data?" "How confident do you feel about the accuracy of the data?" Students should answer questions such as these during full and partial inquiries.

Science teachers should engage students in conversations that focus on questions such as "How do we know?" "How certain are you of those results?" "Is there a better way to do the investigation?" "If you had to explain this to someone who knew nothing about the project, how would you do it?" "Is there an alternative scientific explanation for the one we proposed?" "Should we do the investigation over?" "Do we need more evidence?" "What are our sources of experimental error?" "How do you account for an explanation that is different from ours?"

Questions like these make it possible for students to analyze data, develop a richer knowledge base, reason using science concepts, make connections between evidence and explanations, and recognize alternative explanations. Ideas should be examined and discussed in class so that other students can benefit from the feedback. Science teachers can use the ideas of students in their class, ideas from other classes, and ideas from texts, databases, or other sources—but scientific ideas and methods should be discussed in the fashion just described.

Students need to use technology and mathematics to improve investigations and communications. The use of computers for the collection, analysis, and display of data is part of the standards. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

The National Standards emphasize understanding about scientific inquiry:

Scientists conduct investigations because they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.

Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating.

Results of scientific inquiry--new knowledge and methods--emerge from different types of investigations and the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation.

Concerning interactions of energy and matter,

Waves have energy and can transfer energy when they interact with matter. Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.

Concerning Earth and Space Science all students should develop an understanding of energy in the earth system. Global climate is determined by energy transfer from the sun at and near the earth's surface and results in geochemical cycles. They also need an understanding of the origin and evolution of the earth system and the origin and evolution of the universe.

Because direct experimentation is usually not possible for many concepts, it is important to maintain the spirit of inquiry by focusing the teaching on questions that can be answered by using observational data, the knowledge base of science, and processes of reasoning.

Pertaining to mathematics, the Standards state:

The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics.

Science requires the use of mathematics in the collection and treatment of data and in the reasoning used to develop concepts, laws, and theories. Students gathering data in a science investigation should use tools of data analysis to organize these data and to formulate hypotheses for further testing. Using data from actual investigations from science, students encounter all the anomalies of authentic problems—inconsistencies, outliers, and errors—which they might not encounter with contrived textbook data.

- Develop ability to use realistic applications and modeling in trigonometry
- Understand connections within a problem situation, its model as a function in symbolic form and the graph of that function
- Use functions that are constructed as models of real world problems
- Know how to use statistics and probability.

The National Science Education Standards state, "Science teachers are not fully responsible for implementation. All of the science community must act to make the vision of these standards a reality." Recognizing the challenge these standards present, they encourage:

- Those who work in science centers to use the Standards as an opportunity to collaborate in providing rich science learning experiences for students; and
- Scientists and engineers to use the Standards to work with school personnel to initiate and sustain the improvement of school science programs.

As a consequence, the National Science Foundation has funded and developed the Research Experience for Teachers program to enable teachers to work with the scientific community to develop activities in line with the goals of National Science Education Standards.

