

DESCRIPTION OF PROGRAM STRANDS

Nature of Science

The Nature of Science strand allows us to see science as a human endeavor. Women and men of various backgrounds, with diverse interests and motives, are involved in science, engineering, and related fields. While science encompasses many disciplines, such as physics, chemistry, biology, and the geosciences, these disciplines often take different approaches to the study of natural phenomena.

There also are different ways to define science. A lay person might see it as a body of information, a scientist might define it as set of procedures by which hypotheses are tested, and a philosopher might regard it as a way to question the truth of what we know. Each of these views is a valid, but only partial, definition of science. Collectively, however, these concepts begin to define the comprehensive nature of science, which is why a comprehensive science program should include inquiry, as well as the skill-building investigations that demonstrate universal laws of science. (Chiappetta et. al., 1998)

Science is a way of knowing about the world. In science, explanations are limited to those that can be inferred from confirmable data - the results obtained through observations and experiments that can be substantiated by other scientists. (National Academy of Sciences, 1986, p. 27) When observations of a phenomenon have been confirmed or can be repeated, they are regarded as fact. Any scientific confirmation is, however, tentative, because it is always possible that the results occurred by chance.

A scientific theory is an explanation based on a body of continually refined observation, inference, and testable hypotheses. Because science is never irrevocably committed to any theory, no matter how firmly it appears to be established, science is not dogma. Any theory is always subject to change in the light of new and confirmed observations. Students should be taught that uncertainty is not a weakness, but a strength that leads to self-correction.

History provides yet another way to understand how science works. Students should learn that much of the progress in science and technology is the result of a gradual accumulation and application of knowledge over many centuries. (American Association for the Advancement of Science (AAAS), 1993)

Engaging Science

Above all, the pursuit of science should be fun and exciting. Educators can capitalize on children's natural curiosity and the joy they experience "doing" science. Put the "wow" into science education, and students' attention is almost guaranteed.

It was a strange sight: a man, standing before a fountain, watching the falling water and tilting his head from side to side. Drawing closer, I saw he was rapidly moving the fingers of his right hand up and down in front of his face.

I was in the seventh grade, visiting Princeton University with my science class, and the man at the fountain was Albert Einstein.

For several minutes, he continued silently flicking his fingers. Then he turned and asked, "Can you do it? Can you see the individual drops?"

Copying him, I spread my fingers and moved them up and down before my eyes. Suddenly, the fountain's stream seemed to freeze into individual droplets. For some time, the two of us stood there perfecting our strobe technique. Then, as the professor turned to leave; he looked me in the eye and said, "Never forget that science is just that kind of exploring and fun." (Rowe, 1995, p. 177)

Science As Inquiry

Students cannot just read and/or be told about science -- they must do science. All students should experience the excitement of science as they try to understand the natural world. Science experiences should also connect students to everyday life and the science- and technology-related social issues with which local communities, nations, and all humanity struggle (Creed, et. al. 1992; Aikenhead and Solomon, 1994).

The revised North Carolina Standard Course of Study takes students beyond science as merely a body of knowledge to science as inquiry. It requires students to combine science and scientific knowledge with scientific reasoning and critical thinking. Engaging students in scientific inquiry helps them develop:

- An understanding of scientific concepts.
- An appreciation of how we know what we know in science.
- An understanding of the nature of science, along with the skills to become independent discoverers of the natural world.
- The disposition to use the skills and attitudes associated with science.

Science as inquiry is key to organizing and guiding students' activities. Students in all grades and in every scientific discipline should have the opportunity ask questions, plan and conduct investigations, use appropriate tools and techniques to gather data, think critically and logically about relationships between evidence and explanations, and communicate arguments.

With increasing emphasis on experiential learning, we also must teach appropriate safety practices when engaging in any science activity. Teachers

must be aware of safety recommendations, regulations, and laws relating to topics such as eye safety, use of chemicals, and field trip behavior. When students and teachers know how to do science safely, such concerns should not deter meaningful learning activities.

An effective science program provides ample opportunities for students to:

- Apply safe laboratory/manipulative procedures.
- Choose, construct, and/or assemble appropriate equipment.
- Manipulate materials, scientific equipment and technologies.
- Properly handle and care for living organisms, materials, and equipment.

If students are to understand the scientific process, they must make decisions themselves. Time must be allowed for revision and repetition of experiments, presentation of results, and even for response to criticism. Inquiry-based programs lead to integrated studies because students seldom take divisions among disciplines very seriously. Students who learn to question, debate, and explore acquire a deeper understanding of the world. By discovering principles, rather than just memorizing them, students learn not just what we know, but how we know it, and why it is important.

"Science is a way to teach how something gets to be known, to what extent things are known (for nothing is known absolutely), how to handle doubt and uncertainty, what the rules of evidence are, how to think about things so that judgments can be made, how to distinguish truth from fraud and from show." (Fyneman, 1969)

Teaching Inquiry

Different scientific disciplines use various methods and theories to advance knowledge. Investigations may involve discovering, observing and describing objects, organisms or events. They also may involve experiments, a search for more information, or model making. To help focus investigations, students should frame questions, such as "What do we want to find out?" "How can we make the most accurate observations?" and "If we do this, what do we expect will happen?" Scientific inquiry should involve students in establishing and refining the methods, materials, and data to collect. As students investigate and observe, they should consider questions such as "What data will answer the question?" and "What are the best measurements to make?"

New knowledge and methods emerge from these investigations and from interaction. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections among natural phenomena, investigations, and scientific knowledge. In addition, the methods and procedures used to obtain evidence must be clearly reported to encourage further investigation.

Science advances through legitimate skepticism. To evaluate explanations proposed by others, scientists examine and compare evidence, identify faulty reasoning and statements that go beyond the evidence, and suggest alternative explanations. Scientific explanations must be logically consistent, based on historical and current scientific knowledge, and open to question and modification. Students, therefore, should be encouraged to present the results of their inquiries in oral or written reports. Student discussions should center on questions, such as "How should we organize the data to present the clearest answer to our question?" Out of the discussions about the ideas, the background, and the data, learners will gain experience in the practice of science and scientific thought.

Science and Technology

A single problem often has both scientific and technological aspects. For example, investigating the salinity of the water in North Carolina's sounds is science, while creating a way to make this salt water drinkable is technology. In other words, while science tries to understand the natural world, technology tries to solve practical problems. Technology expands our capacity to understand and control the natural and human-made environment.

"Technology" has many definitions. It may, for example, denote a way of doing things, and/or a specific object. Stephen Kiln, Professor of Mechanical Engineering at Stanford University has four definitions of technology (Kiln, 1985):

- Artifact or hardware (e.g., an aspirin, chair, or video tape).
 - Methodology or technique (e.g., painting, using a microscope).
 - System of production (e.g., the automobile assembly line, a process for manufacturing a product or an entire industry).
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- Social-technical system (an airplane, for example, suggests a plethora of interrelated devices, human resources, and artifacts such as airports, passengers and pilots, fuel, regulations and ticketing).
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Science and Technology in Society

“Achieving the goal of scientific and technological literacy requires more than understanding major concepts and processes of science and technology. Indeed, there is a need for citizens to understand science and technology as an integral part of our society. Science and technology are enterprises that shape and are shaped by human thought and social actions.” (Bybee and DeBoer, 1994, p. 384)

Technology has always played a role in the growth of scientific knowledge. The techniques for shaping, producing or manufacturing tools, for example, are the primary evidence of the beginning of human culture.

Science and technology also reflect a culture's values. Consider, for example, how the acceptance of new ideas can be constrained by the environment in which they are conceived. Galileo's efforts to change perceptions of Earth's place in the solar system, Newton's demonstrations of the laws of motion, and Pasteur's identification of infection with microscopic organisms were rejected by the scientific establishment of their times. Only because of contributions from later investigators did they slowly achieve acceptance.

The development of technology also has been crucial to economic growth. For example, in an effort to make the 1890 U.S. Census faster and more efficient, Herman Hollerith drew upon early "counting machines" to develop a prototype of the computer, which in turn has created today's high-tech industries. In the words of C. Purcell (1995, p. xii) "Since individual technologies and their networks enhance or undermine the people we want to be and the society in which we want to live, we as citizens must try to understand this mighty force and see it not only for what it is but also for what it might be."

While properly applied technology will continue to benefit humanity, we must be aware that its misuse can harm the environment and jeopardize human well-being. Responsibility and stewardship are basic to teaching and learning science and technology. Students must understand that scientific and technological discoveries may have complex -- and perhaps unanticipated -- repercussions that must be addressed.

Technology As Design Technology as design is analogous to science as inquiry. All students should engage in problem-solving by designing, building, and testing solutions to real-world problems. By applying critical thinking skills and knowledge of materials, learners can compare and assess technological devices for costs, benefits, applications, practicality, environmental impact, safety, and convenience.

The goals and objectives for technological design call for students to accumulate the skills necessary to:

- Identify and state a problem, need, or product
- Design a solution including cost and risk/benefit analysis
- Implement and evaluate the solution
- Accurately record and communicate observations.

Today's technology provides nearly instant access to a storehouse of information. Students must learn to use technology as a tool to help understand science and increase creativity in scientific investigations.

Science in Personal and Social Perspectives

An essential component of balanced science education is the use of scientific conceptual understandings and processes in personal and public decision-making. Science education gives students a means to understand and act on such issues. In addition, we are so dependent on science and technology that progress is almost universally identified with them. Students must therefore develop a basic understanding of science and technology in order to become responsible citizens capable of making decisions on social, technological, environmental and other problems faced by their communities and throughout the world.

The ability to understand the nature of science and technology, to apply the concepts of and theories about the earth and life, and to use inquiry and technological design in making personal and societal decisions should be the culmination of a K-12 science education. The challenge of science education is to prepare students to be scientifically and technologically literate decision-makers and problem solvers.