

An Ohio Academy of Science White Paper

What are Science, Technology and Engineering?

¹What is science?

SCIENCE IS A SYSTEMATIC METHOD OF CONTINUING investigation, based on observation, hypothesis testing, measurement, experimentation, and theory building, which leads to more adequate explanations of natural phenomena, explanations that are open to further testing, revision, and falsification, and while not “believed in” through faith may be accepted or rejected on the basis of evidence.

Science is the study of the natural world that includes observable and measurable phenomena within the universe. The conclusions of scientific inquiry are objective because scientific statements can be verified or disproved by independent observers. Scientific inquiry is restricted to knowledge that can be reduced to simple declarative sentences with observable action or actions that are connected logically to observable results by valid, intermediate logic.

What is an hypothesis?

A scientific hypothesis is a declarative statement within the realm of nature in the broadest sense of this term. The proposition is therefore true or false. Scientific research establishes, confirms, verifies or validates the truth or falsity of hypotheses. Hypotheses address basic questions about the natural world and are tested by using methods that yield valid results or findings: observations and data that either confirm or deny (falsify) the declarative statement or proposition (hypothesis).

In contrast to scientific hypotheses, value statements include categories such as right or wrong, good or bad, beautiful or ugly, wise or unwise, desirable or undesirable—all of which are outside the scope of science. These are categories of ethics and values, and when combined with a belief structure, are the bases of religion. Values are the beliefs, mores and morals that hold society together because they condition and guide behavior, and may give meaning to humanity. These are areas of opinion and belief. Value statements can be used as moral imperatives such as “love thy neighbor” or as a way of expressing delight such as “What a beautiful rainbow!” Such statements are outside the realm of science.

What is a theory as used in science?

A theory as used in science is not a weak, tentative, or abstract explanation of natural phenomena. A theory is the current, highest level of scientific explanation or confidence that explains and predicts the future appearance of natural phenomena. Derived from repeated observations and hypothesis testing, a scientific theory is a robust assembly of related laws, concepts and conceptual models that objectively describe, predict, and explain natural phenomena. This definition contrasts sharply from the common vernacular use of the term theory as speculation or supposition.

Scientific theories result from repeated application of the scientific method and help to organize or explain our knowledge in a particular field. Established theories may

stand for hundreds of years until new facts are discovered, tested and verified or a new hypothesis, which more closely explains the data, is developed and tested. The overthrow of settled theories or established science is popularly called a scientific revolution or a paradigm shift. For example, the popular depiction of an atom structured like a miniature solar system is a recent victim of such a revolution in scientific theory. Now quantum physics explains that electrons are more like probability clouds surrounding an atomic nucleus than like planets orbiting a central point.

Why is science important?

Science is more than a collection of what humankind knows. Science is a tool to understand objectively the ever-changing, natural world in which we live. Science provides a systematic way to determine when to accept or reject a theory or concept. Scientific progress is made by applying the tenets of the scientific method—observation, experimentation, repeated hypothesis testing, and establishment of scientific theory. The application of the scientific method has enabled humanity to develop and improve our understanding of the natural world by using the pragmatism of demonstration, the rigor of mathematical and statistical analyses, and the creative insight of people from all races and cultures.

Science has changed the way we view the world and universe. When coupled with engineering, technology, and the economic system, the methods and results of scientific inquiry have profoundly affected humankind’s material and societal progress. Science provides the tools to understand and master the natural world around us. Science is a knowledge ratchet that builds upon facts, principles, laws, and theories, by advancing one or more clicks, thus enhancing and preserving knowledge for our collective human use and betterment.

²What are Technology and Engineering?

TECHNOLOGY MODIFIES THE NATURAL WORLD through innovative processes, systems, structures and devices to extend human abilities. Engineering is design under constraint that develops and applies technology to satisfy human needs and wants. Technology and engineering, coupled with knowledge and methods derived from science and mathematics, create social and environmental value and economic wealth to improve the quality of life. These short definitions of technology and engineering provide a framework to understand the interdependent relationship between science, technology, engineering and mathematics.

Engineering enhances technology and technology defines civilization. Civilization has passed through the Stone Age, the Copper, Bronze, and Iron Ages, and the Industrial Age; now we are in the Information Age. The unmistakable trend is from materials to processes with information as the new material to be shaped, formed and used in products and services with social, environmental and economic benefits.

However, modern technology is not simply about information and computers. Technology includes agriculture, aviation and aerospace, construction, energy and power, environment and natural resources, information and com-

munications, materials, medicine and health, and transportation. Broadly speaking, technology and engineering include all of the many mechanical, electrical, and chemical disciplines. However, they are much more than that.

Role of creativity

Creativity, innovation and design are at the heart of technology and engineering. Creativity is not the exclusive domain of arts and humanities. Creativity is the imagination that provides new concepts, ideas or ways of looking at the world that engineering can use to meet needs or wants. Creativity is necessary in the fields of technology and engineering within the limits of fundamental technical, scientific and mathematical knowledge and principles.

Creativity benefits engineering by unleashing the bounds of traditional thought. Innovation generates and applies creative ideas to technology through engineering solutions that have practical value in the marketplace and more broadly in social structures such as organizations including business, industry, government and education.

Problem solving

TECHNOLOGY AND ENGINEERING SOLVE PROBLEMS within scientific and mathematical limits or constraints. Scientific inquiry (1) identifies a problem or question and (2) proposes an hypothesis that might offer a solution to the problem or answer the question. Similarly, technological and engineering design projects require (1) a problem or needs statement and (2) a design statement that identifies limiting factors and criteria for success. These limits might include cost or affordability; reliability, material limits (strength, weight, resistance to corrosion, color, surface texture, ease of manufacture or reproducibility), operating environment or conditions (temperature, humidity, barometric pressure, caustic conditions); ergonomics (human factors), health, safety and environmental concerns; and general ease of use or operation.

Design statement

Like the methods used to test a scientific hypothesis, technological and engineering design projects must test the “design statement” to see, for example, how close a prototype meets design criteria. Generally, the results of an engineering and technological design project will describe the extent to which the prototype meets the design criteria. Scientific inquiry states the extent to which the results derived from experimentation validate or invalidate an hypothesis. Thus, an hypothesis is to inquiry as design is to engineering and technology. With science, technology and engineering, the results of repeated trials are important to validate or invalidate the hypothesis, or design.

Roles of science, engineering and mathematics

SCIENCE DEALS WITH HUMANS’ UNDERSTANDING of the real world about them—the inherent properties of space, matter, energy, time and their interactions. Engineering deals with the application of objective knowledge to the creation of plans, designs, and means for achieving desired

objectives. Mathematics defines relationships and contributes logic to problem-solving. Engineering uses tools and techniques to carry out those plans.

Science tests and validates our understanding of nature, while engineering turns this understanding into new machines, processes, and technologies. Engineering consists of thinking and planning about nature and existing materials or products—about how they can be altered and improved to achieve objectives that benefit humankind by “designing under constraint”, where the constraints include the laws of nature, cost, safety, reliability, environmental impact, manufacturability, and other factors. While engineering requires the application of mathematical and scientific knowledge, it is the design process and the practical nature of the solutions that best distinguish this field.

—
Statements adopted ¹April 16, 2004 and ²December 16, 2009 by The Board of Trustees of The Ohio Academy of Science. Permission granted for reproduction for educational purposes if no changes are made in the text and this statement appears: Copyright © 2011 by The Ohio Academy of Science.

References

- Board of Trustees, The Ohio Academy of Science. 2011, What are Science, Technology and Engineering. (Accessed 11 Apr 2011) <http://www.ohiosci.org/WhatareSciTechEng.pdf>
- Shrake DL, Elfner LE, Hummon W, Janson RW, Free M. 2006. What is Science? *Ohio J Sci* 106(4):130-135. (Accessed 11 April 2011) [http://www.ohiosci.org/WhatisScienceOJS106\(4\)130-135.pdf](http://www.ohiosci.org/WhatisScienceOJS106(4)130-135.pdf)

About The Ohio Academy of Science

*Fostering curiosity,
discovery
and innovation
to
benefit society.*

FOUNDED IN 1891, THE OHIO ACADEMY OF SCIENCE is the leading organization in Ohio to foster curiosity, discovery, and innovation and to unite all who value education, science, engineering, technology, or their applications to benefit society. The Academy promotes quality scientific research, improves instruction, disseminates knowledge, encourages interaction and collaboration, and recognizes high achievement in education, science, engineering, technology or their applications. The Academy conducts an annual professional meeting and science days, publishes an international, multidisciplinary, scientific journal, improves STEM education and informs local and state science, technology and education policymakers.

The OHIO ACADEMY of SCIENCE

1500 West Third Avenue STE 228

Columbus OH 43212-2817

Phone 614.488.2228 • Fax 614.488.7629

Email oas@iwaynet.net • Website <http://www.ohiosci.org>