The Relationship Among Science, Technology and Engineering in K-12 Education

by

Patrick N. Foster

The “Science and Technology” standard of the National Science Education Standards [National Research Council (NRC), 1996] represents content that goes well beyond what Yager (2004) calls “typical science.” This nontraditional content includes standards in “Science and Technology” and “Science in Personal and Social Perspectives.”

Since 1996, the term “engineering” has also been included in discussions of science and technology in K-12 education (e. g. Center for Science, Mathematics, and Engineering Education, 2000). This article addresses three questions:

1. How are science, technology, and engineering education defined in K-12 education?
2. What content is prescribed for technology, and how does it compare with science content?
3. How can science education and technology education complement each other in K-12 practice?

1. How are science, technology, and engineering education defined in K-12 education?

The American Association for the Advancement of Science (AAAS) in its landmark Project 2061 standards document provided a broad definition of the realm of school science. ‘By ‘science,’ Project 2061 means basic and applied natural and social science, basic and applied mathematics, and engineering and technology, and their interconnections—which is to say the scientific enterprise as a whole.”

The authors of this document add “that the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others” (AAAS, 1989). This leads to several questions: most important, what are technology education and engineering education in grades K through 12?

Technology Education

The term technology has a variety of meanings to K-12 educators. “Technology in the classroom” is usually shorthand for “computers in the classroom,” or more broadly, student use of electronic means to communicate ideas.

For science and social studies educators, technology relates specifically to their content areas. The 1994 standards committee of National Council for the Social Studies (NCSS) says “technology is as old as the first crude tool invented by prehistoric humans, but today’s technology forms the basis for some of our most difficult social choices” (p. 28). According to the NCSS, “social studies programs should include experiences that provide for the study of relationships among science, technology, and society” (p. 132). A related group, the National Council on Economic Education, places emphasis on “technological change” in understanding economics (1995).

Technology, while not directly defined, is characterized in the National Science Education Standards (NRC, 1996) as a partner or complement to science. “The goal of science is to understand the natural world, and the goal of technology is to make modifications in the world to meet human needs” (p. 24).

The use of “technology” in the Standards is not to be confused with “instructional technology,” which provides students and teachers with exciting tools such as computers to conduct inquiry and to understand science (p. 24).

To the International Technology Education Association (ITEA), technology is “human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities” (ITEA, 2000a, p. 242).

Technological Literacy and Scientific Literacy

In the executive summary of the ITEA’s Standards for Technological Literacy, the term “technological literacy” is explained as “a person that understands _with increasing sophistication_ what technology is, how it is created, how it shapes society, and in turn is shaped by society is technologically literate. He or she can hear a story about technology on television or read it in the newspaper and evaluate its information intelligently, put that information in context, and form an opinion based on it” (ITEA, 2000b, p. 4). “Technological literacy,” which is the stated goal of technology education, echoes the term
“scientific literacy,” a term with a longer history. In the National Science Education Standards, “scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (p. 22). This definition is in widespread use (e.g., Carin and Bass, 2001). More important, a consensus is developing that scientific literacy is the ultimate objective of K through 12 science education.

Engineering Education

In differentiating between science and engineering, the Women in Engineering Programs and Advocates Network (undated), notes that while “there are links between science and engineering in that engineers and scientists both use their knowledge of math and science,” engineering goes further, involving “the application of principles, experiences and judgments to solve problems or make things that benefit people.”

Describing engineering to high school students, the American Society of Electrical Engineers (1997) offers these definitions: “Engineering is the art of applying scientific and mathematical principles, experience, judgment, and common sense...” and “Engineering is the process of producing a technical product or system to meet a specific need” (p. 2).

Among the goals of elementary engineering education are to help children explore the relationships between people and technology, use traditional school skills such as math and language arts to solve technological problems, and engage in hands-on projects which build self-confidence and personal interests (Virginia Children’s Engineering Council, undated).

At the middle and high school levels, the most successful engineering curriculum thus far has been Project Lead The Way (PLTW) (2004). PLTW is designed to promote engineering as a desirable profession to schoolchildren. As Table 1 illustrates, this program’s offerings echo secondary science and technology themes.

2. What content is prescribed for technology, and how does it compare with science content? Science Standards

First published in 1996, the National Science Education Standards have a straightforward objective: “standards for all students” (NRC, 1996, p. 20). Only three of the standards represent traditional content areas

<table>
<thead>
<tr>
<th>Middle School Units</th>
<th>High School Courses</th>
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<tr>
<td>Design and Modeling</td>
<td>Principles of Engineering</td>
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<td>The Magic of Electrons</td>
<td>Introduction to Engineering Design</td>
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<tr>
<td>The Science of Technology</td>
<td>Digital Electronics</td>
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<td>Automation and Robotics</td>
<td>Computer Integrated Manufacturing</td>
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<td>Engineering Design and Development</td>
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Table 1. Project Lead the Way courses (2004)

(2. Physical Science; 3. Life Science; 4. Earth and Space Science). Three others reflect a more holistic view of science education – one that views science as much as “a human endeavor” as an abstract content area (Table 2).

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<th>5. Science and Technology</th>
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<td>Abilities of technological design</td>
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<td>Understandings about science and technology</td>
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<th>6. Science in Personal and Social Perspectives</th>
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<td>Environmental quality</td>
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<td>Natural and human-induced hazards</td>
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<td>Science and technology in local, national, global challenges</td>
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<th>7. History and Nature of Science</th>
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<td>History and nature of science</td>
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<td>Science as a human endeavor</td>
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<td>Historical perspectives</td>
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Table 2. Selected Science Standards (NRC, 1996)

Since technology is also a human endeavor, it is not surprising to see technological content among these standards. “Science in Personal and Social Perspectives” is, in effect, “Science, Technology, and Society.” People studied in “History of Science” may include technologists and engineers as well as pure scientists. This is not to say that such standards are not primarily focused on science, but much of the content in the more contemporary standards appears to be technological. Most notably, the components of the “Science and Technology” standard will be very familiar to technology educators—“identify appropriate problems for technological design,” “design a solution or product,” “evaluate completed technological designs or products,” and “communicate the process of technological design” (p. 165-166).

The authors of the National Science Education Standards, cognizant of the similarities between science
education and technology education, sought to clarify the purpose of a “technology” standard in the NRC document: “They are not standards for technology education; rather, these standards emphasize abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology” (p. 106).

The focus on technology in science education documents can be traced back to Science for All Americans, the 1989 publication of Project 2061. Among the twelve AAAS benchmarks were “The Nature of Technology” and “The Designed World,” the latter of which encapsulated nearly all of the content of late 1980’s technology education (Table 3).

Table 3. Selected Standards from Science for All Americans (AAAS, 1989)

<table>
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<tr>
<th>ITEA standard group</th>
<th>Corresponding science standard</th>
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<tr>
<td>The Nature of Technology</td>
<td>The Nature of Technology (AAAS)</td>
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<tr>
<td>Technology and Society</td>
<td>Science in Personal and Social Perspectives (NRC)</td>
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<tr>
<td>Design</td>
<td>Science and Technology (NRC)</td>
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<tr>
<td>Abilities for a Technological World</td>
<td>N/A</td>
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<tr>
<td>The Designed World</td>
<td>The Designed World (AAAS)</td>
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Technology standards

The Standards for Technological Literacy framework was published by the ITEA in 2000. This project was funded primarily by NASA and the National Science Foundation, and while it does not have an overt scientific focus, much of its organization and point of view is similar to or borrowed from related science education standards projects.

The twenty ITEA standards are divided into five topics: (1) The Nature of Technology, focusing on the characteristics and “core concepts” of technology and its relationships with other fields of study; (2) Technology and Society, the interrelationship among technology, society, and the natural environment; (3) Design, consisting of technological research and problem-solving and engineering design; (4) Abilities for a Technological World, namely, designing, using, maintaining, and assessing technologies; and (5) The Designed World, content related to the major economic industries in the United States, including biotechnology, communication, transportation, manufacturing, and construction.

These five themes overlap considerably with science standards. Table 4 suggests the most similar science standard to each of the ITEA themes. Two inferences may be drawn from the overlap:
1. Science and technology education share more content than do most pairs of subjects.
2. As areas of general education, science and technology should be easily correlated, or even fully integrated, in K-12 education.

Although these are not new ideas, the standards movement has recently rekindled interest in (and apprehension about) comprehensive attempts to link science and technology in schools.

Table 4. Comparison of science and technology standards.

3. How can science, technology, and engineering education compliment each other in K-12 practice?

The idea that industry and technology should be treated scientifically in K-12 industrial arts has been prevalent in the literature since the launch of Sputnik in 1957. The notion that technological content has a place in science instruction, at least in the United States, is a more recent phenomenon, becoming popular partly with the introduction of the AAAS benchmarks in the 1980s. An articulation of the relationship between science and technology is particularly critical for technology education. Curriculum changes and student activities have edged the discipline closer to science. Technology teachers are becoming aware of a need for
a better grasp of basic scientific knowledge in order to be prepared to teach technology (Custer, 1991, p. 26).

Vignettes included in both the NRC science standards (1996) and the ITEA/NASA technology standards (2000a) can be regarded as a window into the hopes of professionals in these fields. They tell of serendipitous moments where an enterprising teacher and curious students encounter some unforeseen obstacle or mystery that they use to pose a problem or produce original solutions or findings. At the same time they meet one or more standards! Although they are admittedly a bit different from the reality in most classrooms, comparing vignettes from these and related documents allows us to make the following instruction at different grade levels.

These descriptions are not meant to reflect perfect circumstances. To the contrary, they are meant to suggest ways in which typical elementary, middle, and high school curricula and instruction can be adjusted to take advantage of the opportunities provided by the commonalities between technology and science education at these levels.

Suggestions for K-12 Practice
The Elementary Grades
At the elementary level (NRC K-4 standards and ITEA K-2 / 3-5 standards), science and technology, perhaps under a neutral name such as “children’s engineering,” ¹ would be fully integrated. Each project would be designed to address standards from both fields. According to the standards, these projects should have three emphases: an introduction to scientific and technological thinking and skills (inquiry and design); experience with basic and intermediate content; and an understanding of the interactions among science, technology, and society. Of course total integration would be desirable at all grade levels, but integration here would also be practically necessary, assuming a single classroom teacher is expected to fulfill standards in both areas.

By the first or second grade, children are generally able to distinguish between the natural and the technological. They can also recognize, in a general sense, the degree to which technological processes

¹For example, Linda Gejda and Diane Novak of the Manchester, Connecticut Public Schools are currently implementing a state grant with three other districts that uses this terminology. The term “children’s engineering” has been in use for a few decades in the United Kingdom (e.g., Dunn and Larson, 1990).

(such as mass production) impacts them personally. In later grades students will think more critically about the technology’s positive and negative impacts. Students at all levels can also participate in technological design as a means of understanding and communicating scientific theory and practical application.

The Middle Grades
At the middle level (NRC 5-8 standards and ITEA 6-8 standards), instruction in science and technology are usually the responsibility of separate teachers. Most Connecticut middle school students receive at least some technology instruction from a certified technology teacher, and virtually all receive science instruction from a different teacher. The science teacher is frequently part of a “team” of grade-level teachers who coordinate and ideally integrate instruction among the traditional academic areas. Technology teachers, on the other hand, teach one of the “specials”. In many cases students attend these specials while their academic teachers meet and plan as a team. Thus, integration is more difficult.

Furthermore, the NRC and ITEA standards become more specialized at this point and provide additional rationale for separate technology and science instruction. Under these circumstances, a goal would be to design and implement projects that would bring together elements from both classes in engineering projects. These projects would consist of natural science elements, technological elements, and uniquely engineering elements. In Figure 1, middle-level science and technology are characterized as overlapping substantially in contrast to the elementary level where they could more easily be unified. The middle school overlap could be project-based engineering.

The High School
Identifying the content and curriculum of high school technology education is regarded as more difficult than at other levels (e.g., Foster and Wright, 1996). Although science education professionals have a more agreed-upon secondary content structure (Physics, Biology, Chemistry), this too is increasingly being questioned. A further question raised by the popularity of programs such as Project Lead The Way is whether engineering should be a separate high school subject, or whether it should be a subset of technology. The latter is true in many high schools offering Project Lead The Way, but it appears that in Connecticut more schools are designating a specific teacher to teach engineering in a dedicated laboratory or classroom.
education. An admittedly subjective test of the value of this or any other such arrangement would be whether it address the goals of science, technology, and engineering education while providing meaningful knowledge, abilities, and experiences for children.

It seems clear that science and technology are distinct and important curricular areas in United States public education. At the same time, their commonalities suggest that technology education should not be taught to children—especially elementary school students—in isolation from science.

Figure 1 suggests overlap between pairs of subjects (science, technology, and engineering) as well as among all three subjects at the high school level. Given (1) the departmental orientation of most high schools, (2) that science courses are usually mandatory whereas the others are not, and (3) the nature of the standards for grades 9 through 12, the overlaps could be employed in a deliberate manner which accomplishes these three goals:

- Illustrate the differing perspectives among scientists, technologists, and engineers relative to the overlapped material. How does interest in chemical composition, for example, differ among theoretical physicists, plastics manufacturers, and chemical engineers?
- Identify how decisions made by people affect the social and natural worlds. Using this overlap to address these topics might allow for more in-depth considerations than would the time permitted in individual classes.
- Reinforce and allow students to demonstrate prior knowledge.

Final Thoughts

Figure 1 is one way of integrating and organizing K-12 science, technology, and engineering education.

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