The Science/Technology Interaction: Implications for Science Literacy

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Received 15 March 2000; Accepted 9 April 2001

Abstract: Science literacy includes understanding technology. This raises questions about the role of technology in science education as well as in general education. To explore these questions, this article begins with a brief history of technology education as it relates to science education and discusses how new conceptions of science and technological literacy are moving beyond the dichotomies that formerly characterized the relationship between science and technology education. It describes how Benchmarks for Science Literacy, the National Science Education Standards, and the Standards for Technological Literacy have been making a case for introducing technology studies into general education. Examples of specific technological concepts fundamental for science literacy are provided. Using one example from the design of structures, the article examines how understanding about design (i.e., understanding constraints, trade-offs, and failures) is relevant to science literacy. This example also raises teaching and learning issues, including the extent to which technology-based activities can address scientific and technological concepts. The article also examines how research can provide guides for potential interactions between science and technology and concludes with reflections on the changes needed, such as the creation of curriculum models that establish fruitful interactions between science and technology education, for students to attain an understanding of technology. © 2001 John Wiley & Sons, Inc. J Res Sci Teach 38: 1–15, 2001

Introduction

Current educational reform proposals are asking for the introduction of technology studies in the education of all students. Important backers of this proposition are the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993), the National Science Education Standards (National Research Council [NRC], 1996), and the Standards for Technological Literacy (International Technology Education Association [ITEA], 2000). In addition, the United Nations Educational, Scientific and Cultural Organization (UNESCO) has recognized the urgency of technology literacy since 1984 through its Innovations in Science and Technology Education series.

Although each of these documents makes different assumptions about technology and technology education, there is some consensus on what everybody should know and be able to do.
after completing her or his technology studies. These reform movements all urge an education that will enable an understanding of the concepts and principles of technology such as design, control, and systems, as well as of the key ideas about technology in specific areas such as materials, energy, manufacturing, and information (AAAS, 1993; ITEA, 2000; NRC, 1996). One important and relatively recent notion is that of science literacy, which intrinsically includes understanding technology (AAAS, 1989; NRC, 1996). The American Association for the Advancement of Science (1989) has suggested that science literacy should

... include being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. (p. xvii)

This conception of science literacy raises critical questions for the science education community. What exactly is the role of understanding technology in science education? What specific technological ideas and skills are fundamental for science literacy? And, more generally, what changes are needed if we want students to have an understanding of technology? The purpose of this article is to address these questions.

The article is organized into four sections. The first gives a brief historical account of the science and technology education relationship. The second section discusses the meaning of technological literacy as it relates to science literacy. The third section provides an example of the specific technological ideas and skills about “design” that are relevant for science literacy. And the fourth section discusses the teaching and learning issues that emerge with the introduction of technology studies in science education. The article ends with a reflection on the science/technology interaction, particularly on what changes are needed if we want students to understand technology.

Technology and Education

The first problem one faces in studying the role of technology in general education, as well as in science education, is the very meaning of the term technology. Although it is given several connotations, technology is frequently identified with computers. Therefore, technology education is seen as teaching computer skills. In educational circles there is also the interpretation of technology as the artifacts teachers use to teach—that is, educational technology. In this article the meaning of the term technology goes beyond computers and educational technology. Technology is seen from a somewhat wider perspective:

We use technology to try to change the world to suit us better. The changes may relate to survival needs such as food, shelter, or defense, or they may relate to human aspirations such as knowledge, art, or control. (AAAS, 1989, p. 25)

Technology from this perspective can be seen as artifact, knowledge, and social practice (Cajas, 1998). People usually identify technology with artifacts without any connection to the knowledge and social practices that give rise to such artifacts. Histories of technology are usually descriptions of artifacts. The technology of the bow and arrow (artifact), for example, was invented and translated to other generations by apprenticeship processes (knowledge and social
practices). Often we have access to the artifacts but know little about the knowledge needed to design and construct these artifacts or the social practices involved in that process.

The artifact/knowledge/social practice framework can describe the relationship between technology and education. Informal education in technology has a long history. Humans have been learning how to create artifacts through different social practices for thousands of years. But formal technology education is very recent. The study of the social practices that underpin technological artifacts and knowledge is also new in the history of technology studies. Compulsory education began in Western societies about 200 years ago. In the years since there has been a transformation in formal technology education that can be described in terms of three different movements: manual arts, industrial arts, and technological literacy. These movements are not exhaustive but describe three tendencies of technology education that can be related to the different perceptions of technology as artifact (manual arts), as knowledge (industrial arts), and as social practice (technological literacy).

Early in the 20th century, manual arts education included courses such as drawing, woodworking, metalworking, and printing (Bouhdili, 1996; Zuga, 1999). Although the goal was to teach useful skills that could be both relevant in the workplace and valuable for intrinsic reasons, the underlying perception of technology then was as artifact. Later, technology education became dominated by the industrial arts movement. The demands of the industrial revolution required more sophisticated technological knowledge that moved the conception of technology from artifact to knowledge and skills, in particular the knowledge and skills needed to participate in a more technical society, such as being able to repair cars and to wire houses. In the United States industrial arts education dominated technology education during most of the 20th century. The history of the manual and industrial arts movements is much more complex than this simple description. However, it is a useful simplification to say that the manual arts education movement identified technology mostly with artifacts and that industrial arts education identified it mostly with practical knowledge.

An important point is that neither movement was concerned with understanding how technologies affect society. In addition, the manual and industrial arts movements were separated from science education. Until the 1970s technology education and science education took different routes in the school curriculum. The manual and industrial arts movements focused on developing “practical” knowledge, while science education taught more “abstract” knowledge.

According to Bouhdili (1996), C. Dale Lemons introduced the term technological literacy to the industrial arts community at the 1972 Mississippi Valley Industrial Teacher Education Conference. In doing so, Lemons described a new goal for technology education—the preparation of citizens to be able to analyze technology and societal issues. At the same time, science educators were becoming concerned with the limited view of science endorsed by their contemporary curriculum. They called for understanding the interrelation of science, technology, and society (Gallagher, 1971). Other science educators argued that the science curriculum should be organized around societal and technological issues (DeBoer, 1991; Yager, 1996). That movement—science, technology, and society (STS)—would be seen as the first meaningful interaction between science and technology education.

As an academic field the STS movement has enriched our view of science and technology in society (Spiegel-Rössing & Solla, 1977). However, as an educational movement the STS movement has not really clarified what specific aspects of science and technology students are supposed to learn (see Solomon & Aikenhead, 1994; Yager, 1996 for reviews). The same was true for the technological literacy movement that began in the 1970s in the industrial arts community. The concerns for understanding the role of technology in society are part of a wider
process of self-reflection that characterizes Western societies in their late modernity stage. Sociologist Anthony Giddens (1991) has reported how modernity is identified with a new social perception of technological risk. In many ways the fear of nuclear and other technologies on the part of a generation that has witnessed several technological disasters has given rise to other concerns about technology in general. These reactions against technology did not allow the clarification of technological ideas and skills that would help citizens to make sense of technological issues and to have more control over technology, rather than just to fear it.

One of the problems in clarifying what specific knowledge was relevant for technological literacy was a lack of understanding of technological practices. There is no tradition of identifying the specific knowledge technologists use. In addition, there is a widespread notion that technology is the application of science—a simplistic view that avoids any clarification of technological knowledge. Only in the last 30 years have philosophers, sociologists, and anthropologists of technology shed some light on the nature of technology. Scholars have recognized theoretically (e.g., Goldman, 1984) and empirically (e.g., Bucciarelli, 1994; Vicenti, 1990) the uniqueness of technological knowledge and practices. However, this work has not been easily translated into the curriculum of general education.

A first attempt to clarify important technological ideas and skills introduced as part of a comprehensive conception of science literacy was made by Project 2061 of the AAAS (1989, 1993). Its approach broke with old disciplinary conceptions of science and recommended that all students learn key technological ideas such as design, control, and systems, as well as the relationship between science and technology. It called for understanding relevant concepts about specific technologies (e.g., materials, energy, communication, and agricultural technologies). In the United States this was the first formal interaction between science and technology education in the context of a common goal, science literacy.

Clarifying Technological Literacy

Technology studies are being introduced not with the goal of preparing students for the workplace (the training argument) or increasing the relevance of science (by providing applications). Instead, the goal is to have citizens who understand the nature of technology and its interaction with science and society. It is the idea of literacy—core knowledge and skills that are important for all citizens—that connects science and technology education in a new way.

The science and technology education communities have recognized the importance of understanding technology, but the task of clarifying what ideas about technology could be relevant to science education has been difficult for many reasons, some of them discussed above. Potentially, there are many ways to approach this task. Two generic strategies are described here.

The first strategy is to conduct empirical studies to observe how people use technologies or make technology-related decisions. People use technology in their daily lives, and one could extract what ideas about technology are important by observing these uses. During the last 20 years there have been studies that describe how people make decisions on technology-related issues such as the location of nuclear plants and what people’s perceptions are about genetically engineering food (Irwin, 1995; Wynne, 1991).

A problem is the limited number of empirical studies for making sense of the different kinds of technologies people use. Even if there were sufficient numbers of these studies, it would be difficult to use them because they report a diversity of perceptions about various technological issues. In the best of cases these studies would help to clarify people’s perceptions about the technology they are using now. However, technological literacy is not so much about what people are doing today, as it is about what kind of technological knowledge and skills citizens
should have and will need in the future. Empirical work should have a place, but it does not solve
the problem of selecting what everybody should understand about technology.

A second and more effective strategy is working with expert scientists, technologists, and
teachers. The AAAS initiated a process like this through Project 2061. Advised by scientists,
philosophers, engineers, technologists, and teachers, the project identified a set of key
 technological ideas and skills relevant for literacy. These ideas, including a general framework
on the nature of technology, were presented in Science for All Americans and Benchmarks,
particularly in Chapter 3, The Nature of Technology, and in Chapter 8, The Designed World

In addition to the calls for technological literacy endorsed by the AAAS, the National
Research Council and the International Technology Education Association have spelled out—in
two documents, the National Science Education Standards and the Standards for Technological
Literacy—a common set of carefully specified ideas and skills that form the core of literacy in
technology (ITEA, 2000; NRC, 1996). Together, these three efforts have established a consensus
on what is important to understand about technology, including the relationship between science
and technology, the side effects of technologies, and the nature of design and control. They
also call for understanding key ideas from specific technologies such as energy, materials,
agriculture, health, and communication. There is also an array of common themes important for
both science and technology, such as tools, systems, models, and scale (AAAS, 1993; NRC,
1996).

In short, three respected national and international organizations have spelled out a common
set of ideas and skills that form the core of literacy in technology (AAAS, 1993; ITEA, 2000;
NRC, 1996). They provide a common ground for science and technology and make a case for
rethinking the role of technology in general education. To illustrate the nature of the technology
concepts selected for literacy, I will use the topic of design.

Design: An Example of Technological Literacy

Design has been recognized as an essential part of technological practices. For many
individuals the essence of engineering is design (Goldman, 1984). Although we have been
designing artifacts and processes for thousands of years, we have not considered what ideas
about technological design could be relevant for the education of all students. Therefore,
important ideas about technological design are not taught in K–12 education. Perhaps the most
important idea about design is that it always requires the taking into account of constraints. This
idea is central for understanding the nature of such technology practices as engineering in which
accommodating constraints is fundamental. Dealing with constraints, which can be natural,
economic, ethical, or social, requires different kinds of compromises, that is, trade-offs. The
intrinsic relationship between constraints and trade-offs explains the impossibility of perfect
designs. Designs that are good in one respect may be inferior in others (AAAS, 1989). Another
key technological concept is the idea of failure (Petrosky, 1985). All technological designs may
fail, but some steps can be taken to reduce the likelihood of failure (AAAS, 1989). Sometimes
technological systems are created with redundancies to ensure the continued working of other
parts if one part of the system fails (AAAS, 1989; ITEA, 2000). Usually, to prevent failure,
engineers overdesign; for example, they make things stronger than they need to be. The
relationship between failure and its reduction by redundancy and overdesign is part of a picture
about key technological ideas that all citizens should understand at the level of literacy.

In addition to the suggestions presented in Benchmarks for Science Literacy (AAAS, 1993),
the National Science Education Standards (NRC, 1996) and the Standards for Technological
Literacy (ITEA, 2000) also include “design” as a core element of their recommendations for literacy. Table 1 describes ideas about technological design from these three national documents. It illustrates that understanding certain specific ideas about design is key for scientific and technological literacy. The table does not include the development of design abilities that is stressed in the National Science Education Standards and the Standards for Technological Literacy.

Having clarified specific ideas about design that are relevant for literacy, I now turn to a discussion of how one could teach them. Since technology is not a subject in most American schools, the science curriculum could provide opportunities for students to reflect on some key technological ideas relevant for science literacy. In the end, students will benefit from a more positive view of the relationship between science and technology. This closer relationship will also benefit the science and technology education research communities, allowing them to share research interests, methods, and findings.

The Bridge Project

Since the pioneering works of Mario Salvadori, an engineer who popularized the study of structures with his books Building (1979) and Why Buildings Stand Up (1980), designing and constructing bridges has become a common school activity in several middle and high schools. Curriculum materials often include this activity, and commercial software is now available for middle and high school students that simulates the design and construction of bridges.

There are different versions of the “bridge project.” Most include designing, constructing, and testing a bridge made of wood. The task usually is to build a bridge that supports as much weight as possible while keeping the bridge itself as light as possible. Students work with some given constraints that can be more or less open-ended. In some cases, students are allowed to choose the kinds of materials they will use in their designs. In other cases, they have more restrictions. For example, students could be asked to construct a bridge out of wooden blocks, the span of which is greater than the length of a single block. Sadler, Coyle, and Schwartz (2000) have reported the design and testing of a “two-dimensional” bridge made of paper. Students begin their challenge by listening to a scenario. For example, they are told that a town bridge has failed, and they must design a replacement. The overall span is fixed, as are the existing supports for a suspension bridge. Students must model their bridge with a single piece of notebook paper using the least amount of paper needed to support a given weight. It is suspended from two supports, with the load hung from a single hole at the bottom.

The bridge project reflects the relationships among at least three groups: physicists, engineers, and the general public. Individuals from these three groups see the design and construction of bridges from different perspectives. For a physicist, the problem is to isolate the body (bridge) and determine the forces that act on it. For an engineer, the problem is about not only analyzing a given structure but also inventing a new structure to solve a real problem. For the general public, the problem is neither the vectorial analysis of forces nor the design of the structures, nor is it necessarily tied to the particulars of designing a bridge. What is important for literacy purposes is a set of ideas assumed but not made explicit by both the physicist and the engineer in their practices, ideas such as the limits and strengths of technological design and the social implications of technological artifacts, which are also important for the general public. Because a structure such as a bridge lies at the intersection of different disciplines, the bridge project represents a clear interaction between science and technology education.

The section that follows discusses how the new conception of technological literacy calls for a stronger interaction between science and technology studies. Although it uses the bridge
Table 1

The notion of technological design in three national documents: Benchmarks for Science Literacy (AAAS, 1993), National Science Education Standards (NRC, 1996), and Standards for Technological Literacy (ITEA, 2000)

<table>
<thead>
<tr>
<th>Grades</th>
<th>AAAS</th>
<th>NRC</th>
<th>ITEA</th>
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<tbody>
<tr>
<td>K–2</td>
<td>People may not be able to actually make or do everything that they can design. 3B#2, p. 49.</td>
<td>Make proposals to build something or get something to work better; they should be able to describe and communicate their ideas E (K–4), p. 137.</td>
<td>Everyone can design a solution to a problem. A, p. 93.</td>
</tr>
<tr>
<td>3–5</td>
<td>There is no perfect design. Designs that are best in one respect (safety or ease of use, for example) may be inferior in other ways (cost or appearance). Usually some features must be sacrificed to get others. How such trade-offs are received depends upon which features are emphasized and which are downplayed. 3B# 1, p. 49.</td>
<td>Recognized that designing a solution might have constraints, such as cost, materials, time, space, or safety. E (K–4), p. 137.</td>
<td></td>
</tr>
<tr>
<td>6–8</td>
<td>Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of the materials to be used, are unavoidable. Other constraints, including economic, political, social, ethical, and aesthetic ones, limit choices. 3B#1, p. 51.</td>
<td>Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology. E (5–8), p. 166.</td>
<td>There is no perfect design. The best design optimizes the desired qualities—safety, reliability, economy, and efficiency—within the given constraints.</td>
</tr>
<tr>
<td>9–12</td>
<td>Suggest alternative trade-offs in decisions and designs and criticize those in which major trade-offs are not acknowledged. 12E#6, p. 300.</td>
<td>Propose designs and choose between alternative solutions. Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. E (9–12), p. 192.</td>
<td>Requirements for a design, such as constraints and efficiency, sometimes compete with each other.</td>
</tr>
</tbody>
</table>
project to illustrate such an interaction, other examples are possible, activities such as testing paper bags in the elementary grades or designing wind turbines in high school. The section begins with a discussion of how the introduction of such technological ideas as design and failure frame technological tasks not only in the constructing of the artifact but also and mainly in the understanding of how the artifact is designed and how and why it could fail. This way of thinking requires that students use both scientific and technological ideas, including forces (e.g., gravity, tension, and compression), properties of materials (e.g., strength, stiffness, and flexibility), and design (e.g., constraints, trade-offs, and failure). This discussion illustrates some teaching and learning issues that come up when introducing a conception of technology that goes beyond artifact and moves to understanding technological ideas.

Understanding and Explaining Failure

Some science educators have reported that engineering challenges such as the bridge project provide useful contexts for learning science (Roth, 1998; Sadler et al., 2000). They have documented that in designing structures (e.g., bridges or towers) students learn, among other things, concepts about forces. Sorting their findings these researchers have not been specific enough about the particular ideas students learn. Roth (1998), for example, describes how his students use notions of tension and compression to explain properties of the structures they design. Rowell and Gustafson (1998) have conducted longitudinal studies on how teachers and students deal with constructions of different structures and technological projects. However, despite the popularity of the bridge project and similar tasks, there are almost no reports on what specific ideas about forces students learn (e.g., how gravity affects the structure, the relationship between tension and compression and its effect on the structure).

The bridge project represents the status quo of technology-oriented tasks in general education, particularly in science education. Students in real classrooms tend to focus mainly on constructing and testing their structure rather than on designing it. Science educators have explained this situation in terms of students’ tendencies to produce outcomes as opposed to planning how things may turn out based on their understanding of the function of the parts of the structure (Schauble, Klofer, & Raghavan, 1991). For example, when a bridge fails, students do not usually address how and why this occurred. In competitions students usually see failure as an undesirable outcome of their project. How and why the bridge fails and what can be done to improve the design are not usually addressed. Without an analysis of the failure, students will have no need to understand how different kinds of forces (tension, compression, load, gravity, etc.) affect the different parts of their bridge.

Attempting to explain why their designs may fail, students do not have opportunities to use ideas about the forces that affect their bridges. Technological ideas such as design and failure can provide opportunities for taking advantage of the pedagogical richness of the bridge project or similar tasks to teach and learn science.

Researchers have used versions of the bridge project in more open-ended situations in which students have opportunities to design their structures. In a longitudinal study on how children design and construct structures Roth suggests that:

Children have come to this engineering unit with few images of engineering or engineering-related discursive or material practices that would have allowed them to be more successful. One may be tempted to regard this as an ideal situation for teaching a unit. Unlike in some areas—such as Newtonian mechanics where students’ mundane theories interfere with the scientific discourse they are to appropriate in their science
A courses—students here did not bring a set of practices that could have interfered with their classrooms experiences. (p. 74)

These research findings refer to children’s preconceptions, or lack thereof, about structures not forces. Although there has been considerable work on how students use Newtonian conceptions of forces to explain phenomena (e.g., Driver, Guesne, & Tiberghien, 1985; Minstrell, 1982), the connection between this research and how students plan, test, and explain failures in their designs has not been explored. In part this is because tasks like the bridge project come from an old conception of technology identified with constructing artifacts and not with analyzing how they work and why they fail. The redefinition of technology education introduces key ideas such as design and failure that need to be addressed in the bridge project and similar tasks.

Understanding and selecting properties of materials

Some versions of the bridge project allow students to select the materials they will use in the design and construction of their bridges or towers (Roth, 1998). There is some research on how children learn about the different kinds of properties of materials (Russell, Longden, & McGuigan, 1991), and a curriculum has been developed to target specific learning goals about materials (Barlex, 1998). A K–2 benchmark states that young students should know that “some kinds of materials are better than others for making any particular thing. Materials that are better in some ways (such as stronger or cheaper) may be worse in other ways (heavier or harder to cut)” (AAAS, 1993, p. 188).

Before students can learn that some materials are better than others, researchers have reported that it is important to help them make distinctions between the properties of the objects and the properties of the materials of which these objects are made (Russell, Longden, & McGuigan, 1991). Researchers have found that young children have problems in distinguishing the properties of the objects (e.g., this sheet of paper has a rectangular shape) from the properties of the material that made the objects (e.g., the strength of the paper). Science education researchers have explored how children describe materials in terms of their physical properties, which is the basis for understanding later important ideas such as conservation of matter, states of matter, and chemical reactions (Driver, Guesne, & Tiberghien, 1985; Lee, Eichinger, Anderson, Berkheimer, & Blakeslee, 1993; Piaget & Inhelder, 1974; Russell, Longden, & McGuigan, 1991). However, research on how children learn about “functional” properties of materials (i.e., properties of materials based on their use, such as strength, stiffness, hardness, and flexibility) is limited.

Learning about “materials” is introduced in current science education reforms as a goal in itself. The bridge project can be a context in which students learn about the different properties of the materials they select and how these properties affect their bridges. To do so, science educators need to improve their knowledge about how children come to understand functional properties of materials. In selecting materials for their bridges, students will be dealing with an unavoidable connection between science and technology. By selecting different kinds of materials, students will be making choices among different alternatives. The proposition “Materials that are better in some ways may be worse in other ways” is the statement of a basic trade-off. This moves the discussion toward the study of the relationship between materials and design.

Understanding Trade-Offs and Constraints

To illustrate the relationship between materials and design, consider a section of a conceptual strand map that deals with the topic of design constraints (see Fig. 1). This section of
the map lays out three story lines (strands) of ideas and skills that develop over time with increasing sophistication and connections across topics: “failure,” “trade-offs,” and “physical constraints” (AAAS, 2001). The map provides a sense of how ideas about materials and design may progress from kindergarten to 12th grade, what connections to other ideas and skills are important, and how these ideas contribute to literacy.
The ideas presented in the map (Fig. 1) would be addressed in different lessons and units in the context of designing, constructing, and testing structures such as bridges or doing similar tasks, such as the ones reported by Sadler et al. (2000). A careful reading of the map shows a strong interaction between science and technology, with ideas about materials supporting an understanding of the nature of design. Students should understand that design requires taking constraints into account and that some of these constraints have to do with the nature of the materials. Although taking constraints into account could mean making choices about the materials, it could also mean understanding how economic, political, and social factors affect the kind of design. These three story lines are connected to the “social constraints” story line, which for the sake of simplification is not presented in Figure 1. The introduction of ideas about technological design into general education should aim to prepare students to understand not only the physical constraints of the design and the associated trade-offs, but also the economic, political, and social constraints.

The example presented of designing and constructing a bridge shows that students could learn science through engineering tasks. Science education researchers have shown the relevance of technology for learning science. However, despite the progress in studying technology-based environments, researchers still need to attend to scientific and technological ideas and skills, mainly those identified for science literacy (AAAS, 1993; NRC, 1996). For example, there is a lack of research on the role of understanding Newtonian forces in students’ explanations of structural failure. One possible answer is that these kinds of tasks are still dominated by an old conception of technology education that sees the “construction” part of the activity as the most important, rather than the “understanding” of the scientific and technological ideas behind the activity. Addressing concepts such as design, constraints, trade-offs, and failure in tasks like the bridge project will benefit both science and technology education.

The Science/Technology Interaction: Reflections

The example of the bridge project illustrates some of the teaching and learning issues that will come up when the new conception of technological literacy is introduced into general education. The reader could interpret the example as an argument for the integration of science with technology education. However, the issues that emerge when science and technology education interact are very complex, and integration only describes some of them. In fact, there are different alternatives for the interaction between science and technology education. Traditionally, the interaction between science and technology education has been seen in terms of dichotomies (Fensham, 1994; Barak & Pearlman-Avnion, 1999): technology is “doing” while science is “understanding,” and so on. However, when we move to the arena of literacy in science and technology, these dichotomies no longer hold: there is a common body of scientific and technological ideas and skills that is relevant for the education of all students.

Given a coherent set of scientific and technological concepts that students should understand, there is a variety of potential approaches to teaching them. This will depend on how states, districts, and schools will introduce technology into general education. In the United States the situation is very complicated: There are practically no technology education courses in the elementary grades; in high school technology education subjects tend to be vocational studies; and policymakers and educational researchers have yet to invent curriculum models that include technology studies as part of general education.

For the audience of this journal the question is: What will science education do about technology? At its most general level the answer depends on the nation and its goals. England, for example, has created a subject called “technology education,” and Australia seems to be
following this format (Black, 1999; Feshman, 1994). In the American context the science education community took a strong step toward including technology studies as part of science education by selecting and clarifying specific technological concepts and processes relevant for literacy (AAAS, 1990, 1993; NRC, 1996). This unique situation provides policy guides for implementing different potential interactions between science and technology education.

After the clarification of technological ideas and skills suggested by three respected scientific and technological organizations (AAAS, 1993; NRC, 1996; ITEA, 2000), teaching these ideas in schools is the next challenge. In doing so, research on how students learn technological ideas and skills will be an invaluable resource. Technological literacy means asking for the introduction of really new ideas into the school curriculum. Despite the progress in studying technology-based environments by science educators (Roth, 1998; Rowell & Gustafson, 1998; Sadler et al., 2000; Schauble et al., 1991), researchers still need to attend to how technological ideas and skills are learned and how they can be taught. Without this research the efforts to introduce technology studies into science or general education will be well intended but ineffective.

Most research on technology education comes from outside the United States, particularly from Canada, England, and Australia. There is emergent research on how children learn some technological ideas (e.g., McRobbie, Stein, & Ginns, 2000a; Roth, 1996a) and how teachers are dealing with a new subject called technology education (e.g., McRobbie et al., Roth, 1996b; Rowell, Gustafson, & Gilbert, 1999). The unique situation of the United States, where the goal of science and technological literacy is only now being introduced, will require taking a serious look at the role of research in improving science and technological literacy in K–12 education. Research on student learning and teacher knowledge should be at the core of the science/technology interaction.

Research in technology education that targets ideas identified for literacy has the potential to influence science education while also serving its own goals. There is already some collaboration between science and technology educators (AAAS, 2000). Recent studies have reported collaboration at the classroom level between science and technology education (Hepburn & Gaskell, 1998; Barak & Pearlman-Avnion, 1999). This kind of collaboration could stimulate the production of conceptual tools and resources to improve students’ understanding of science and technology.

To help students learn about technology, teachers will need resources and knowledge, high-quality curriculum materials, professional development to improve their content and pedagogical knowledge, and opportunities to interact with other teachers. In addition, teachers will need to find ways to address the ideas and skills that make up technological literacy within the context of the subjects they teach. These interactions and collaborations will not take place until stakeholders recognize the importance of understanding technology. In short, a new and fruitful relationship between science and technology education is emerging, one that can give students the opportunity to learn key ideas that will help them to make sense of a technological world.

Conclusions

This article has used the example of design to illustrate issues concerning teaching, learning, and research that come up in introducing technology ideas and skills identified for science literacy into general education. However, the picture of technology studies for literacy endorsed by as national standards goes beyond the topic of design. It includes understanding the relationship between science and technology, the side effects of technologies, and the nature of technological control. It also calls for understanding key ideas from specific technologies, such as energy, materials, agriculture, health, and communication.
A new role for technology studies in general education is needed, one that moves from manual and industrial arts education toward the goal of technological literacy. In doing so, the intersection of science literacy and technological literacy is relevant for science education. The identification of key technological concepts for literacy was a critical first step. Three respected national and international organizations have spelled out a common set of ideas and skills that form the core of literacy in technology (AAAS, 1993; ITEA, 2000; NRC, 1996). There is enough common ground between science and technology to make a case for rethinking the role of technology in general education.

A growing number of individuals and institutions acknowledge that technology goes beyond computers and that technology education goes beyond teaching computer skills. Computer skills and training in technological fields are essential in this age, and technical and engineering education needs to continue and to be improved for those individuals who want to pursue these careers. However, literacy programs in science and technology should provide all citizens with conceptual tools to make sense of a highly technological world. These programs should help all students to learn about design, the interaction between science and technology, and the limits and strengths of technology.

References


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