



Standards for Technological Literacy

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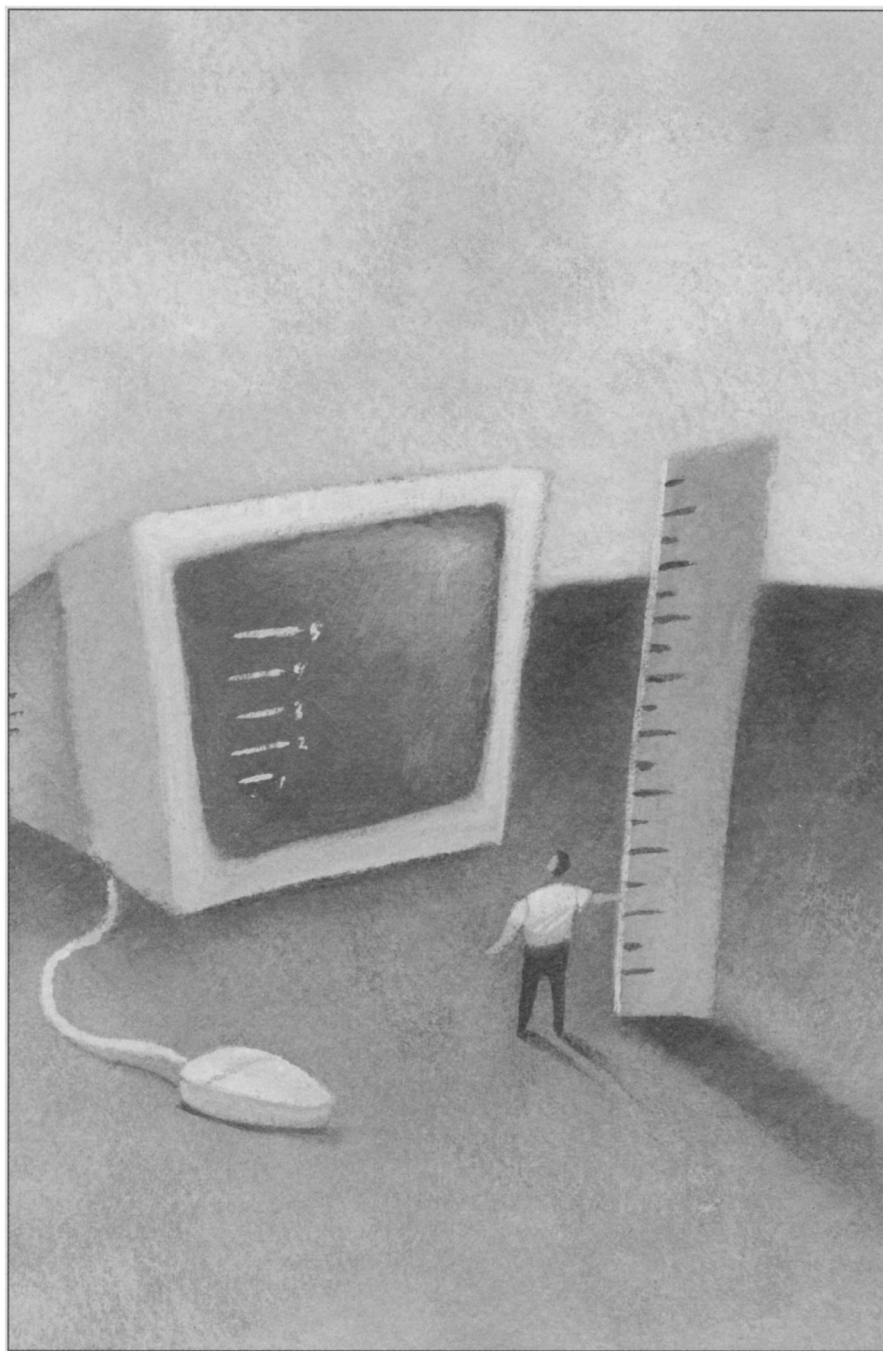
Standards for Technological Literacy

Our world will be very different 10 or 20 years from now, Mr. Dugger points out. We have a choice as to whether we march into that world with our eyes open, deciding for ourselves how we want it to be, or whether we let it push us along, as we remain ignorant and helpless to understand where we're going or why. Technological literacy will enable us to make a conscious choice.

BY WILLIAM E. DUGGER, JR.

WE LIVE in a world that is increasingly dependent on technology. Technology has been a growing human art since the first chipped-edge flint tool was created by our ancestors about 1.5 million years ago in what is now Kenya. Today, technology exists to a degree unprecedented in history.

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Furthermore, our technology is evolving at an extraordinary rate, with new technologies being created and existing technologies being improved and extended.

Surprisingly, there is much confusion in today's society about what technology actually is. Is technology computers? Is it multimedia? Is it calculators? Is it the result of rewiring school buildings to make them Internet accessible? The correct answer to each of these questions is "Yes — and much, much more." Broadly speaking, technology is the way people modify (invent, innovate, change, alter, design) their natural environment to suit their own purposes. From the Greek word *technē*, meaning art or craft, technology literally means the art of making or crafting, but more generally it refers to the diverse collection of knowledge and processes that people use to extend human abilities and to satisfy human wants and needs. From improved communications to new biotechnologies to new wireless networks to new advances in engineering, technology is a key factor in the constant human quest to live longer, more productive lives.

It is particularly important in this technological world that people understand and are comfortable with the concepts and workings of modern technology. From a personal standpoint, people benefit both at work and at home by being able to choose the best products for their purposes, to operate the products properly, and to troubleshoot them when something goes wrong. From a societal standpoint, an informed citizenry improves the chances that decisions about the use of technology will be made rationally and responsibly.

For these reasons and others, a growing number of voices worldwide have called for the study of technology to be included as a core subject in elementary, middle, and secondary schools. Among the experts who have addressed this issue, the value and importance of teaching about technology is widely accepted.

Even with the importance of technology in our lives today, the fact is that the study of technology (technology education) remains a mystery to many teachers and administrators. As a field of study that has evolved over the past 15 to 20 years, technology education is just beginning to establish a new identity that is recognized and understood by people outside the field. There is still widespread misunderstanding about the differences between technol-

ogy education and educational technology, a field that uses technology as a tool to enhance the teaching and learning process.

The ultimate goal of a school program that involves the study of technology is to provide technological literacy to all students. Technological literacy is the ability of a person to use, manage, assess, and understand technology. A person who is technologically literate understands, in in-

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creasingly sophisticated ways that evolve over time, what technology is, how it is created, and how it shapes and is shaped by society. Such a person will be able to hear a story about technology on television or read it in the newspaper and evaluate the information in the story intelligently, put that information in context, and form an opinion. A technologically literate person will be comfortable with and objective about technology, neither scared of it nor infatuated by it.

Because technology is such an important force in our lives and economy, anyone can benefit by being technologically literate. Corporate executives and others in the business world, brokers and investment analysts, journalists, teachers, doctors, nurses, farmers, and homemakers all will be able to enjoy their leisure more fully and perform their jobs better if they are technologically literate.

Standards for Technological Literacy

Recently, the International Technology Education Association (ITEA) and its Technology for All Americans Project have developed and released *Standards for Technological Literacy: Content for the Study of Technology*, which focuses on what every

student in grades K-12 should know and be able to do in order to be technologically literate.¹ Thousands of technology teachers, science and mathematics teachers, and other educators and experts from around the country collaborated to spell out what students in kindergarten through 12th grade should be learning about technology. This group, along with content specialists and representatives from the National Research Council (NRC) and the National Academy of Engineering (NAE), reviewed *Standards for Technological Literacy* and suggested changes and additions. The resulting document, supported by both NRC and NAE, defines the study of technology as a discipline and provides a road map for individual teachers, schools, school districts, and states or provinces to develop technological literacy in all students.

Standards for Technological Literacy does more than provide a checklist for the technological facts, concepts, and capabilities that students should master at each level. Along the way, the document explains how and why technological literacy fits with the broad mission of schools and describes the benefits of the study of technology for students. In short, the document makes the case for why the study of technology should be an integral part of the curriculum of our elementary and secondary schools today and in the future.

Architecture of the Report

The first chapter of *Standards for Technological Literacy* discusses the importance of preparing students to live in a highly technological world. The next chapter provides an overview of the standards and discusses their features and format, as well as the primary users for whom the document was designed. The individual standards presented in *Standards for Technological Literacy* are organized into five major categories, each of which is addressed in its own chapter. These major categories, around which the standards are developed, are the nature of technology, technology and society, design, abilities for a technological world, and the designed world.

The final chapter is a "call to action" for various people within education, the community, and business and industry to work together to promote technological literacy for all students in grades K-12. A comprehensive appendix includes a brief history of the development of the standards,

a listing of the standards along with a compendium of the standards and benchmarks, acknowledgments, references, a glossary, and an index.

Standards. The document *Standards for Technological Literacy* specifies what every student should know and be able to do in order to be technologically literate and offers criteria by which to judge progress toward a vision of technological literacy for all students. There are a total of 20 individual standards in this document, and they fall into two types: 1) what students should know and understand about technology and 2) what they should be able to do. The first type, which could be termed "cognitive" standards, sets out the basic knowledge about technology — how it works and its place in the world — that students should have in order to be technologically literate. The second type, which might be termed "process" standards, describes the abilities that students should have. The two types of standards are complementary. For example, a student can be taught about a design process during the course of a lecture, but the ability to actually use that process and to apply it to find a solution to a technological problem will come only with hands-on experience. Likewise, it is difficult to perform a design process effectively without having some theoretical knowledge of how it is usually done. (For a list of all 20 standards, readers may visit the website of the ITEA at www.iteawww.org.)

Benchmarks. The benchmarks in *Standards for Technological Literacy* provide the fundamental content elements that exist as part of the broadly stated standards. Benchmarks are statements that describe the specific knowledge and abilities that enable students to meet a given standard, and they are provided for each of the 20 standards at the K-2, 3-5, 6-8, and 9-12 grade levels. The benchmarks are followed by supporting statements that provide further detail, clarity, and examples. An example of a standard and its enabling benchmarks for grades 3-5 is shown in Figure 1.

The standards and benchmarks were established to help guide a student's progress toward technological literacy. In developing these standards, the ITEA panel relied on a number of sets of standards in other subject areas, including the *National Science Education Standards*,² *Benchmarks for Science Literacy*,³ *Curriculum and Evaluation Standards for School Mathematics*,⁴ and *Principles and Standards for School Mathematics*.⁵

An Example of Articulation

One of the challenges of implementing *Standards for Technological Literacy* is developing an articulated K-12 curriculum that translates each of the standards into a planned curriculum with instructional activities suited for the content being taught at each grade level. The following example, developed by Mark Sanders and

Sharon Brusica at Virginia Tech, illustrates how this could work in the laboratory/classroom using the theme of transportation technology. Each of the transportation activities presented is age-appropriate and designed to fit with the developmental characteristics and needs of children at the various grade levels. Moreover, activities at each grade level build on the prior one.

Grades K-2

Students in grades K-2 exhibit a range of characteristics that influence the teaching and learning process in technological studies. These students need a wide array of activities because they generally have short attention spans and tire easily. These youngsters are typically energetic and curious learners who enjoy cooperative endeavors that keep them active and allow them to use their rich imaginations. Because the small muscles in young children's hands and fingers are not fully developed, teachers must be cognizant of their students' limited capabilities to do precise, manipulative tasks.

Technology activities in grades K-2 should address students' developmental characteristics, including their natural curiosity and inventive thinking skills. For example, students in grades K-1 should be given ample opportunities to explore and use wheels, axles, levers, gears, pulleys, and cams by playing with a variety of toys and construction kits that include these mechanisms. Older students can take apart, describe, and reassemble a simple toy vehicle, or they can build a model of a conveyor system using plastic building bricks.

By the end of grade 2, students should be able to design, plan, and make original vehicles using commercial construction kits and recyclable or consumable materials such as boxes, straws, and craft sticks. Moreover, they should be able to use safely and appropriately such simple tools as hammers, scissors, and saws to accomplish their tasks.

When students explore mechanisms and design vehicles, they can sketch and describe these components and products to further enhance their understanding of the components' shapes, uses, and names. In addition, younger students can organize mechanisms according to such characteristics as type, size, weight, and color to practice their classification skills and to strengthen their skills in measurement.

At all three grade levels, students

FIGURE 1. A Representative Standard and Its Benchmarks

Standard 8. Students will develop an understanding of the attributes of design.

In order to realize the attributes of design, students in grades 3-5 should learn that

- *the design process is a purposeful method of planning practical solutions to problems.* The design process helps convert ideas into products and systems. The process is intuitive and includes such things as creating ideas, putting the ideas on paper, using words and sketches, building models of the design, testing out the design, and evaluating the solution.
- *requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design.* Technological designs typically have to meet requirements to be successful. These requirements usually relate to the purpose or function of the product or system. Other requirements, such as size and cost, describe the limits of a design.

can begin to use the terminology associated with *Standards for Technological Literacy*. Children can develop the necessary vocabulary by taking part in activities that promote language development, such as orally presenting the projects and designs they have made, making a collage of transportation vehicles with various classifications (e.g., land, water, air, and space), and sketching and labeling drawings of devices they designed.

Teachers should clearly integrate technological studies with other areas of the curriculum throughout grades K-2. For example, connections to history and geography can be made by exploring the use of the inclined plane in the construction of the pyramids of Egypt. Links to mathematics can be made by having students determine the relative speed of the vehicles they build. Reading stories and engaging students in discussions about how their lives might be different without cars and other powered vehicles could clearly support curriculum in language arts and social studies.

Grades 3-5

Students in grades 3-5 are beginning to exhibit a greater sense of themselves as individuals, but peer relationships remain important. These young learners have fully developed hand muscles and greatly improved hand/eye coordination. Thus they are more skillful at manipulative tasks that require smaller and more numerous parts. Because their ability to stay focused on assignments is much improved, these students are prepared to tackle design and problem-solving activities that require greater attention to detail for longer periods of time. As students mature, they become more capable of interpreting abstract concepts and making broad generalizations — essential traits for students being asked to evaluate designs and assess solutions to hypothetical, yet realistic, problems.

Activities in grades 3-5 should provide students with diverse opportunities to develop and enhance skills in designing, making, assessing, and presenting solutions to technological problems. Students can be challenged to use tools and materials for more ambitious tasks, such as creating vehicles that incorporate computer-controlled devices and that use light, sound, or motion sensors. Using raw materials and simple hand tools, students can design, build, and test products that incorporate electricity, magnetism, and motors.

Problems for students at this level

should increase in complexity, and design constraints should become increasingly challenging. For example, at earlier levels students could build and use only one mechanism in their solutions, whereas students in grade 5 might be able to incorporate as many as three mechanisms, each of which might be working in combination with the others. Students should more clearly articulate the positive and negative impacts of their solutions and designs.

For example, fourth-graders could design and construct a model of a wastewater treatment system that moves and filters contaminated water (polluted with oil or containing sediments). Fifth-graders could build and test hydraulic devices that simulate how the human body moves fluids.

All students at this level are capable of documenting their design and problem-solving processes with conventional and computer-based sketching tools. Likewise, students should begin to use the World Wide Web to display their designs, and older students can document their problem-solving processes through the use of a notebook or an electronic portfolio on the Web.

Grades 6-8

Middle-level students are teetering between late childhood and early adulthood. They are experiencing significant physical growth and change. Girls tend to mature somewhat earlier than boys, and they show markedly different interests as well. Students in the middle grades are greatly influenced by their friends, and they may reject adult guidance, which makes them more vulnerable to engaging in risky behaviors and more apt to present attitudinal difficulties. Likewise, these adolescents have an increased sense of self and a blossoming interest in members of the opposite sex. Placing middle-level students in teams allows them to be part of smaller communities for learning within the larger school and enables educators to satisfy students' emotional and guidance needs more effectively as they move toward adulthood.

Students in grades 6-8 are ready to tackle more difficult technological problems. They can feel more mature as they apply concepts and skills from other fields of study, such as mathematics and science, to their technological problems. Small-group activities may be particularly effective in building students' self-esteem by enabling boys and girls to have success with new and perplexing tasks.

Constructing motors and generators from scratch or designing a game contraption that incorporates numerous simple machines and mechanisms to transport marbles or balls through a complicated maze may be well received by students at this level if they are given the opportunity to work in teams.

Students in the middle grades need to be challenged if they are to refine the skills they learned in the lower grades and if they are to apply those skills to new problems and opportunities. Teachers should expect these students to take a more active role in formulating design problems and establishing constraints in order to ensure that activities reflect the interests of both male and female students. Adolescents need to be given a greater part in making decisions, and they should be encouraged to consult with adults (e.g., parents, relatives, and other teachers) as they analyze their design options and assess the value and impact of their solutions. In the process of documenting their progress, whether electronically or in some other form, these students will be able to communicate clearly how they transformed their ideas about transportation into practical solutions and how they appraised the functional, aesthetic, social, and economic value of their solutions. To accomplish their tasks, they will also make use of a variety of educational technology tools, such as multimedia software, database and spreadsheet applications, online search tools, computer-aided design, and computer-control systems over networks.

Grades 9-12

High school students become increasingly independent even as they continue to seek social acceptance. Their ability to think and visualize abstractly provides them with greater flexibility in problem solving. Their physical maturation during these years results in greater size, dexterity, and strength. They develop a clearer definition of their identity and their role in society, and they begin to formulate life ambitions and goals. Wage earning is often an immediate interest, with college and future employment decisions weighing heavily on the minds of these young people as they complete their high school "careers."

Technological studies at the high school level should take advantage of the particular interests students have during these years. Employment and career options, as well as consumer issues, are relevant topics for grades 9-12. Instruc-

tional activities should be challenging enough to hold students' interest and should encourage independent thinking as students pursue solutions to problems.

High school students are quite capable of developing sophisticated designs for research and development projects. Therefore, many activities at this level should have the look and feel of engineering projects. For example, students could develop a "smart" transportation system that employs computers and sensors. Their background research might require them to search technical journals and to use the U.S. Patent Office to conduct online searches. Students at this level might also review the development of the interstate highway system in the U.S. or conduct environmental impact studies associated with such systems.

In another scenario, students could work in "engineering teams" to design and build a simulated space station, giving full consideration to the variety of life-support systems required in space. Perhaps the simulation would involve creating a virtual environment, existing in three dimensions on the Web and accessible and controllable by students anywhere in the world.

A third alternative might be to challenge students to design and build a solar-powered car for a statewide competition. Along the way, students could explore social and environmental impacts, the working of solar cells, and the various subsystems at work within a car.

The study of technology could be addressed, in part, through a series of articulated activities of increasing sophistication that focus on a particular theme. The transportation activities recommended above are developmentally appropriate, so that students will be challenged intellectually every step of the way. On this journey toward technological literacy, students will experience a wide range of technologies in the context of real-world problems, thereby developing a rich understanding of the technological world in which they live.⁶

Conclusion

Rodger Bybee, executive director of the Biological Sciences Curriculum Study (BSCS) and formerly executive director of the Center for Science, Mathematics, and Engineering Education at the National Academy of Sciences, recently wrote an article that summarizes the importance of technological literacy in our schools:

For a society deeply dependent on

technology, we are largely ignorant about technological concepts and processes, and we mostly ignore this discrepancy in our educational system. The need to achieve technological literacy is a national imperative. School programs must include technology education.

In this age of international comparisons such as the Third International Mathematics and Science Study (TIMSS), the U.S. stands in stark contrast to most industrialized countries. Japan, Germany, Israel, Australia, the Netherlands, France, Great Britain, New Zealand, and many others have technology education programs. Why the U.S. does not value technology education may have historical precedents, but they are clearly inappropriate to this age. Through support of the new ITEA *Standards for Technological Literacy*, the National Academy of Engineering, the National Research Council, the National Science Foundation, and the National Aeronautics and Space Administration have worked to position technology prominently in our educational system. The proposed National Science Education Acts of 2000 provide federal advocacy, resources, and partnerships for technology education. All of us are now presented with a great opportunity — to make technology education an essential aspect of American education.⁷

In summary, ITEA's *Standards for Technological Literacy* provides a foundation

for what technological literacy means. And that foundation is based on the vision that the study of technology should be an essential part of every student's basic education.

Our world will be very different 10 or 20 years from now. This is inevitable. However, we have a choice as to whether we march into that world with our eyes open, deciding for ourselves how we want it to be, or whether we let it push us along, as we remain ignorant and helpless to understand where we're going or why. Technological literacy will enable us to make a conscious choice.

1. *Standards for Technological Literacy: Content for the Study of Technology* (Reston, Va.: International Technology Education Association, 2000).
2. *National Science Education Standards* (Washington, D.C.: National Research Council, 1996).
3. *Benchmarks for Science Literacy* (Washington, D.C.: American Association for the Advancement of Science, 1993).
4. *Curriculum and Evaluation Standards for School Mathematics* (Reston, Va.: National Council of Teachers of Mathematics, 1989).
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6. Mark Sanders and Sharon Brusick, "Articulated Curriculum Example," unpublished paper, Technology Education Program, Virginia Tech, Blacksburg, 1998.
7. Rodger W. Bybee, "Achieving Technological Literacy: A National Imperative," *The Technology Teacher*, September 2000, pp. 23-28. **K**

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