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AUTHOR Pucel, David J.

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ABSTRACT

Technology education should be part of the general education of all students for the following reasons: (1) technological literacy is important in preparing people for life and work; (2) technological literacy must be based on sensory as well as language-based learning; and (3) technology is unique in the school curriculum. The content of technology education is common sense technological knowledge and the teaching and application of the technological method as content separate from other subject matter areas. The technological method is as follows: (1) identify an unmet human need requiring a technical solution; (2) clarify the specific technical problem; (3) identify relevant existing technical methods and knowledge; (4) invent a probable solution, through the invention process; (5) determine the social acceptability and economic feasibility of the solution; (6) modify the solution if needed to maximize efficiency and acceptability; and (7) implement the solution. The following are categories of technological literacy content: (1) technological method; (2) common tool usage; (3) common equipment; (4) basic technological processes; (5) materials; (6) terminology; (7) environmental concerns; (8) social values; (9) scientific principles; and (10) economic factors. There is shared responsibility inside and outside the schools for developing, focusing, and delivering technology education in the classroom. (Contains 21 references.) (CML)

Technology Education: A Critical Literacy Requirement for All Students

(Rationale and Program)

David J. Pucel
Professor
Department of Vocational and Technical Education
University of Minnesota
St. Paul, MN 55108

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An Attitude Goal for Technology Education

IT COULDN'T BE DONE

Somebody said that it couldn't be done,
        But he with a chuckle replied
That "maybe it couldn't," but he would be one
        Who wouldn't say so til he'd tried.
So he buckled right in with the trace of a grin
        On his face. If he worried he hid it.
He started to sing as he tackled the thing
        That couldn't be done, and he did it.

Somebody scoffed: "Oh, you'll never do that;
        At least no one ever has done it";
But he took off his coat and he took off his hat,
        And the first thing we knew he'd begun it.
With a lift of his chin and a bit of a grin,
        Without any doubting or quiddit.
He started to sing as he tackled the thing
        That couldn't be done, and he did it.

There are thousands to tell you it cannot be done,
        There are thousands to prophesy failure;
There are thousands to point out to you, one by one,
        The dangers that wait to assail you.
But just buckle in with a bit of a grin,
        Just take off your coat and go to it;
Just start to sing as you tackle the thing
        That "cannot be done," and you'll do it.

Edgar A. Guest

Guest, E.A. The Path to Home. Chicago, Illinois: Contemporary books, Inc., Circa 1936.

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Abstract

This paper presents a rationale for a technological literacy program to be included in the school curriculum as part of the general education of all youth. It goes beyond a discussion of outcome goals for such a program to the specification of a functional approach for conceptualizing and operationalizing the program. It concentrates on that portion of the content about technology that all students should be taught as part of a technology education program at the middle school level. Technology is defined as "the application of knowledge, tools, and skills to solve practical problems and extend human capabilities" (Johnson, 1989, p. 1). Technological literacy is defined as possession of both language-based and "common sense" technological knowledge needed by all citizens. Language-based knowledge includes understandings developed through books, lectures, discussions and other forms of verbal interactions. Common-sense knowledge includes understandings and the ability to physically and visually interact with real things based on sensory experience. The development of technological literacy in schools is presented as important: a) in professions such as engineering and architecture as a basis for designing products and systems; b) in skilled occupations as a basis for building, servicing and modifying products and services; and c) as essential common knowledge for citizens who will use products and services and who will be influenced by them. The need for a technology literacy program is supported by the growing recognition that: a) technology is an important continuing force in our society, b) technology has unique content which is different from other portions of the curriculum including applied science, c) teaching and learning for technological literacy require different instructional methods and learning skills from those used with typical liberal education and academic basics courses, and d) technological literacy is gained through the sensory experience in laboratories as well as through language.

The paper proposes a generalizable technological method which can be used to logically organize a technological literacy program. The method is a generic set of processes underlying technological evolution and innovation. The method is based on four premises.

1. The goal of technology is to arrive at technical solutions to human needs.
2. All technology evolves through a series of common generic developmental steps.
3. Technology evolves through the interaction of technical and social processes.
4. Individuals can influence how technological problems are defined and what are viewed as acceptable solutions.

The paper also proposes categories of generalizable technological content that apply across technological areas which should be included in a general technology education program required of all students, and ways of delivering that content. It concludes by suggesting societal partners who could unite to advocate mutual benefits of including a technology education program in schools.

Introduction

Most attempts at defining a technology education curriculum for schools have focused on accurately defining the domain of technological content, the forces that impact on technology, and/or the desired overall outcomes of technology education (Johnson, 1988; Savage & Sterry, 1990; Zilbert & Mercer, 1992). Although these efforts have been important, they have not answered the important questions faced by parents, educators, school boards and other policy makers in trying to decide whether such a program should even be included in schools. What theoretical rationale is there to support the belief that a separate technology education program is needed? Can't technology be taught as part of social studies or science and accomplish the same goals? If a program should exist, what should such a program actually look like? Of all possible technological content, what is most important for all students to know, how should it be organized, and how might it be delivered?

This paper provides a rationale for why technology education should be part of the general education of all students. The rationale is based on: a) the importance of technological literacy in preparing people for life and work, b) evidence that technological literacy must be based on sensory as well as language-based learning, and c) evidence that the content of technology is unique from any other portion of the school curriculum. A rationale is also presented for why this unique content is as essential as math, science and social studies in the preparation of people for professions such as engineering and architecture, skilled occupations such as cosmetologist or carpenter, and for citizenship. It suggests that technological literacy is an essential part of the cultural literacy to be communicated through schooling.

The paper finally proposes a technology education program for all students that would be a one year program, delivered one hour a day within the middle school. Given these goals, the purpose of this paper is not to define all of the content which might be included in technology education, nor all of the outcomes which might be achieved throughout the entire K-12 curriculum. The goal is to justify and define a program which should be awarded space in an already crowded curriculum based on its importance to overall cultural literacy and individual development. The proposed program presents a generic technological method as a framework for teaching content generalizable across the many areas of technology, suggests specific content, and suggests methods of teaching that content.

Background

The Concern for Technological Literacy

Technology and its impact are major concerns of society. "It is. . .commonplace that modern science and technology. . .are leading forces of the time. . ." (Rapp, 1989, p. x). Technology, defined as "the application of knowledge, tools, and skills to solve practical problems and extend human capabilities" (Johnson, 1989, p. 1), impacts all of us. However, when asked to define technology most people think of particular objects such as computers, the space shuttle or cellular phones. They are fascinated with what technology produces but few have an understanding of what technology is as a field of study or how technology evolves. Few have skills to apply technology or to participate in its development. Few also have an understanding of how technology affects the broader society in which they live and how the public might influence the direction of technology.

Technology results in things and systems which make our lives easier, more complicated, change faster, and more dependent upon products and services of others. Although it surrounds us and we constantly refer to it, how does it come into existence? How does it fuel and reflect our constantly changing world and society? Why doesn't the evolution of technology stop so we can catch up? How can all citizens become technologically literate? What can be done to provide individuals with a better understanding of it and skills to work with it? Unless questions like these are addressed by schools and can be adequately answered by all citizens, many people will be left feeling they are victims of technology rather than beneficiaries. Brockway (1989) suggests that people who cannot adequately deal with technology are "technopeasants", serfs of technology. This suggests that technological literacy must be viewed as part of cultural literacy.

Definition of Technological Literacy

Technological literacy, as referred to in this paper, is the possession of understandings of technological evolution and innovation, and the ability to apply tools, equipment, ideas, processes and materials to the satisfactory solution of human needs. It is part of cultural literacy. "To be culturally literate is to possess the basic information needed to thrive in the modern world" (Hirsch, 1988, p. xiii).

> In an anthropological perspective, the basic goal of education in a human community is acculturation, the transmission to children of the specific information shared by adults of the group or polis. . .The anthropological view stresses the universal fact that a human group must have effective communications to function effectively, that effective communications require shared culture, and that shared culture requires transmission of specific information to children. . .Like any other aspect of acculturation, literacy requires the early and continued transmission of specific information. (Hirsch, 1988, pp. xvi-xvii)

Cultural literacy has often been mistakenly limited to an association with language. This is reinforced by literature which suggests ". . .literacy is. . .based upon knowledge that all of us unconsciously have about language" (Hirsch, 1988, p. 3). It is also reinforced by suggestions that tests, like the Scholastic Aptitude Test (SAT), are possible measures of literacy (Carroll, 1979). This limited conception of literacy is insufficient for a person to function in the modern technological world. It does not acknowledge the importance of other dimensions of literacy, such as technological literacy, which are not only based on language but upon knowledge and skills gained through experiential activities involving the senses with tools, equipment, ideas, processes and materials.

Given that technological literacy is necessary to function in our modern world, it is an essential part of cultural literacy. It must be transmitted to students as a basis for effectively communicating in our culture and as a basis for applying technology to life and work. Where literacy related to language requires vocabulary and association with common cultural events and activities to provide meaning during communication, literacy related to technology requires familiarization with common technological ideas, tools, equipment, materials and processes, and how they are applied to solving human needs through technological evolution and innovation.

Experiments in language have shown that "we always go beyond a text's literal meanings to supply important implications that were not explicitly stated by the words of the text" (Hirsch, 1988, p. 39). Therefore, depending upon the background information different people have, although they can read the words in a sentence equally well, they will derive different meanings based on past learning and experience. For example, a person who reads the sentence "A boy is riding in a car" will envision one thing if the only car the person experienced was a limousine capable of carrying eight people. The person will envision something else if the only car experienced was a one-seat racing car. Both visions will be more similar if both people have only seen a one-seat racing car. It is difficult to determine what they will envision if neither ever saw a car or heard of one before. It is this concept of attaching meaning based on past learning and experience which has led to the belief that certain common content elements should be taught to all citizens. It is the possession of these common reference points that allow different individuals within a culture to communicate effectively. In his book, Cultural Literacy, Hirsch has a list of common terms, concepts, sayings and events which are often used as a basis for drawing analogies and developing understandings within the American culture. He argues that these common elements are critical for adequately interpreting and gaining full meaning of communication within our culture. For example, "act of God, Achilles' heel, Aladdin's lamp, beware of Greeks bearing gifts, brain trust, dog days, merger and rare bird." Those who do not understand such concepts are often at a disadvantage during everyday and work communications. Assumptions that an individual understands such concepts can greatly affect the extent to which communications are meaningful.

A similar phenomenon is occurring in our society regarding common understandings of technology. Assumptions are being made about a person's familiarization with, and ability to apply basic technology. Those assumptions affect expectations during every day communication and on the job. If a person is asked to adjust a roller with a screw driver, the assumption is that the person not only knows what the word "adjust" means but has common sense knowledge of adjusting. This means that the individual has a sense for such things as what to look for to determine if it is adjusted, a feel for what it means for a screw to be tight but not so tight the screw breaks, and that the person can select a screwdriver and use it correctly.

If citizens do have not have somewhat similar backgrounds in fundamental technology which lead to a level of cultural technological literacy, different individuals will be at widely varied places when discussing or adapting technology related to their lives or work. Those who are technologically literate will be at an advantage over those who are not. Those who are technologically literate will view technology as a tool to accomplish goals, those who are not will be "technopeasants".

> Technology has always presented two faces to society. On the one hand technological innovations have been seen to satisfy objective social needs, and technologists have been regarded as altruistic servants of society in a spirit of professionalism. . .On the other hand, ideologically or politically, technology has played an important role in social processes. . .Those who reproduce technological ideas and structures, i.e., the producers and users of technological knowledge, also formulate patterns of social conditions and consciousness. (Sarkikoski, 1988, p. 341)

The possession of some common fundamental technological understandings and experiences can build a sound foundation for a technologically literate citizenry. Therefore, the content selected for a general education program focused on technological literacy should focus on content which builds this foundation. The challenge is to develop a clear notion of what types of experiences and knowledge are necessary to be technologically literate within our society today. As pointed out earlier, since it is not possible to teach all students about all technology, a further challenge is to determine which sub-set is most important.

Technological Literacy During the Industrial Age

With the coming of the industrial revolution in the late 1800s and early 1900s it became increasingly clear that people needed to become familiar with the technology of the times in order to work with it, and to adapt to the new technology in order to become productive in the workplace. Industrialization required many people to work with machines and objects with which they were not familiar. Factories and mass production required people literate in utilizing the technology of the times. Schools were not prepared to offer the required education. They had historically focused on preparing people for citizenship and continuing education. Therefore, the issue of including education relative to technology in the curriculum was heavily debated. Proponents argued that,

> We live just as truly by the labor of the hand as by the labor of the head, and yet all the machinery of education from the primary school to the higher school is devoted to the cultivation of brain-power exclusively. The hands need training to make them efficient workers in the actual business of life, but our schools think it beneath them to train the hands. (Newell, 1878, p. 8)

With increasing pressure from society, curriculum was eventually introduced into the schools to provide students with options to prepare for employment and to became familiar with the arts of business and industry. These curricular components emerged as vocational education, and practical arts education (including industrial arts). Industrial arts was developed as part of general education and focused on the art of applying industrial practices.

In the process, a wide range of skills associated with industrial occupations were taught and students became literate in the industrial technologies of the times. Agricultural, business and home economics programs were also available. Since most public schools had industrial arts programs, and in some states they were a mandatory part of the general education of all boys in the junior high school (middle school), many boys developed some level of technological literacy. Programs included courses in areas such as metalworking, woodworking, drafting, automechanics, and electricity. Familiarization with practices in these areas were viewed as reflecting the technology of the times. Since most girls were expected to become homemakers, programs for girls concentrated on preparing them for homemaking. Therefore, they received little education focused on technology as applied to the world of work.

As society has evolved from the industrial age to the information age, and fewer and fewer people actually participate in occupations requiring the industrial age skills and practices, both vocational education and practical arts programs have been viewed as less important in the K-12 curriculum. People are increasingly questioning the need for students to be familiar with the industrial practices as part of their general education. Also, there is an increasing trend to postpone specialized skill training until after high school based on educational and occupational trends within the United States.

> In general, a majority of the occupations require education or training beyond high school. In fact, more than 2 out of 3 of the 30 fastest growing occupations and nearly half of the 30 with the largest number of jobs added had a majority of workers with education or training beyond high school in 1990. (p. 82, Silvestri & Lukasiewicz, 1991)

Technological Literacy for the Future

With movements to reduce programs in the schools to prepare students in the industrial age technologies, there are other movements to develop new programs to prepare students in the technologies of the present and future. The fundamental arguments for the inclusion of technology education in the K-12 curriculum that took place at the turn of the century are now being presented again. However, this time the arguments are based on different technologies which are viewed as more relevant to the current lives of the general population. Arguments about the need for all students to become technologically literate and what this means are being presented on the grounds that technologically literacy is essential to society and general cultural literacy. The new technologies are again becoming too pervasive and influential in society to continue to be virtually ignored in the curriculum of our schools.

For example, a panel of Project 2061 of the American Association for the Advancement of Science recently criticized the educational system for not providing students with an adequate education regarding technology. They indicated, "The nation has yet to act decisively enough in preparing young people--especially the minority children on whom the nation's future is coming to depend--for a world that continues to change radically in response to the rapid growth of scientific knowledge and technological power" (Johnson, 1989, p. vii). Again the argument is being made that technological literacy is essential and that a key to improving the technological literacy of all citizens is an educational program which will help them to understand and interact with the technology of the times.

Re-defining the technology that should be taught to all students as part of their general education has been a challenge. During the industrial revolution it was possible to view a set of occupations, to analyze them, and to identify common practices as a basis for providing students with a basic knowledge of relevant technology. Most jobs of the industrial revolution included combinations of those practices as basic building blocks for understanding and working with technology. Today, it is apparent that the identification of technological literacy content cannot be focused on the practices of skilled workers. Those practices are no longer the building blocks for the majority of jobs within the information age. This does not mean that such practices should be excluded from a technology education program. However, the context within which they are selected and presented should change. Therefore, there has been an effort to clarify what new content should be included in a technological literacy program and why that content is important.

Defining the Content of Technology

Differentiating Technology Education Content From Other Subject Matter Areas

When the content of past programs aimed at familiarizing students with technology focused on practices of business and industry, there was a clear distinction between that content and the content of other programs in the schools. However, currently many have difficulty distinguishing between the content of technology education and that of other subject matter areas. Many other subject matter areas claim to address technology from one or more perspectives. What is the unique character of technology education content?

One such area of confusion is the difference between science and technology. Often people have the mistaken notion that technology is just an application of science. If philosophers and educators consider technology as applied science, they minimize the need to consider it as having important content of its own. Recently, scholars have begun to clearly differentiate science from technology, which in turn facilitates more precise definitions of instructional programs designed specifically to enhance technological literacy. They have also begun to more clearly explain why the development of technological literacy requires learning activities and processes different from those typically used to teach the liberal arts or other subjects in the schools.

Rapp (1989, p. x), a philosopher, indicated, "Clearly the structure of thinking in technological sciences, as well as the methodological principles of design and of efficient and purposeful action exhibit patterns of their own which differentiate science from technology." The Project 2061 panel of scientists indicated technology is ". . .different from science, whose role is understanding. Technology's role is doing, making and implementing things. The principles of science, whether discovered or not, underlie technology. The results and actions of technology are subject to the laws of nature, even though technology has often preceded or even spawned the discovery of the science on which it is based" (Johnson, 1989, p. 1). For example, people knew logs would float and if they put them together in a raft they could move things over the water. They did this without understanding the scientific principles underlying buoyancy. The later scientific explanation of why rafts float was useful in making boats and other things float. But such scientific knowledge was not needed to create the original raft technology. Native Americans knew they could brew a tea from the bark of aspen or willow trees and that the tea would help headaches and fevers. Later, scientists interested in this phenomenon found the bark contained the same chemical found in aspirins. The native Americans did not need to know that aspirin would help with headaches and fevers and that the bark of the trees contained the same chemicals so they should brew a tea. In both of these cases a technology (technical means of providing a solution to a human need) occurred before science could explain how and why it worked.

In addition to science courses, schools also contain other programs which are sometimes confused with fulfilling the need for technology education. Each provides complimentary knowledge about technology, but each does not fulfill the primary goals of technology education. Social studies programs often include descriptions of the historical impact of technological innovations upon society; practical arts programs such as traditional industrial arts, general business, general agriculture, general home economics, and vocational education programs often teach students selected practices applied to work and family. However, none of these programs currently present a comprehensive technology education program with the primary purpose of students becoming technologically literate. They all have other primary purposes (e.g., history, scientific principles, occupational skills, industrial practices).

Given that technology has a content of its own, what is that content? Technologically literate people have two primary characteristics: 1) they have developed a common sense knowledge of technology, and 2) they understand the method through which technology evolves to satisfy human needs.

Common Sense Technological Knowledge

In order for a person to become technologically literate he/she must develop a "common sense knowledge" of technology as well as formal language-based knowledge. Language-based knowledge includes understandings developed through books, lectures, discussions and other forms of verbal interactions. Common-sense knowledge includes understandings and the ability to physically and visually interact with real things based on sensory experience. Common sense knowledge is gained through sensory experience with the tools, equipment, ideas, process and materials of technology. Common sense knowledge of technology includes the ability to utilize the techniques and tools of technologists. The term "common sense knowledge" was recently suggested by Hubert Dreyfus from the University of California, Berkeley, and by computer programmers trying to develop artificial intelligence programs designed to simulate human thinking (WGBH Boston, 1992). They found it was virtually impossible to program a computer to simulate sophisticated human thinking. Even simple children's stories could not be understood by a computer. After extensive investigation they determined that this was not due to what they told the computer, but what they did not. They found that humans develop almost endless amounts of common sense knowledge which is assumed during communication. Common sense knowledge is that knowledge which people learn through living and experiences (including education) which provides contextual information within which things around them are interpreted and manipulated. Whereas computers have to be taught all knowledge needed to operate with a given set of problem situations, (including common sense knowledge) people only need to be taught additional information on the fringes of what they already know. The new material is given meaning within the context of material previous learned. The researchers concluded that, "General human intelligence somehow creates a broad model of the world enabling us to cope with all kinds of situations" (WGBH Boston, 1992). They were providing essentially the same arguments that Hirsch did in his discussion of cultural literacy. However, they framed their arguments in terms of experientially-based versus language-based knowledge.

Such a broad model and understanding of technology is what is needed by the American public in order to understand, monitor and work with technology. This knowledge is also needed for individuals to have an adequate model of the world as it exists. Such knowledge should become part of the base for technological literacy upon which all citizens can more completely participate in a technological society.

How does a person develop common sense knowledge of technology? It is becoming increasingly clear that developing a functional understanding of technology requires experiences which go beyond language-based activities typically presented in schools. Engineers, architects, skilled workers and others who apply technology have repeatedly argued that teaching people about technology must include hands-on experiences. However, the reasons why hands-on experiences are critical to such learning have only recently been clearly articulated. The work of the computer scientists helps provide a more concrete rationale.

As the study of artificial intelligence has progressed, it has also become increasingly apparent that real common sense not only requires a set of rules and facts that can be communicated through language, but a human body capable of sensing and developing a set of experiential skills. With experience, some of these skills become semi-automatic responses when a person encounters similar situations. The computer researchers supported this contention by viewing children at play with such common things as blocks, sand and water. They found that children spend hours and years playing with these same things. They suggested that this play had meaning in forming common sense knowledge about each of these objects. The thousands of experiences with pouring, spilling and filling things with water were not all stored in memory as separate cases. They were stored in the brain as a set of neuron charges. When similar situations occurred, individuals adapted almost automatically. With this understanding of common sense knowledge and how it develops, computer scientists are now trying to teach computers through visual inputs which allow the computers to sense, store and generalize from what they see and experience. They are finding that such input allows computers to do things which they were not able to direct computers to do through language and language-based rules.

If people are to develop common sense knowledge of technology, they must also be presented experiences which will allow them to work with the tools, equipment, ideas, processes and materials of technologists. These experiences need not be directed at preparing occupational level competence. The experiences could be examples of technology which have generalizability to many technological applications. Just as children do not think they are developing work skills when they play with water, those skills are applicable to the work of a chemist, photographer, mechanic, and homemaker. Similar experiences with common technology will facilitate the ability of individuals to apply technology during their lives and work.

John Brockway (1989), an experimental psychologist, in a speech to the Sloan Foundation, provided additional support for the need for technology education programs to be more than just programs presented through standard language-based textbooks and typical classrooms. He indicated, ". . .thought patterns of thinkers in liberal arts colleges are distinctly different from the predominant operative thought patterns employed in major institutes of technology" (p. 1). He suggested, ". . .that the core of the domain of liberal arts thinking is textually-based, linguistically-controlled, and delivered orally and verbally in writing" (p. 2) with no major emphasis placed on thinking visually. In contrast he suggested technologists' thought processes deal with images and thinking that are driven predominantly by visual processes. He meant seeing in both the metaphorical and literal manner. "Seeing into the future, into the heart of problems, into the marrow of solutions, is at the core, at the heart of technological knowledge, at least as it is practiced in the United States today" (p. 2). He gives examples of ". . .systems engineers using flow charts, of mechanical, aeronautic, and civil engineers, drafting and revising and being engrossed in blueprints" (p. 2). He suggests that the technologists use visually-derived knowledge. Much of this knowledge is gained through sensory experiences. People who read blueprints, observe radar screens, read tables, inspect real items to determine how they work and how to repair them are all deriving knowledge in non-verbal ways. Brockway's observations support the conclusions of the computer scientists that knowledge is developed through a combination of verbal communications and the senses.

Brockway suggested that by observing engineering and technological thought it is apparent that such thought is different than that used with serially-ordered language which tends to describe things in a linear order. He suggests this is why people say a picture is worth a 1,000 words. The picture presents spatial relationships as well as contextual information which is visually interpreted all at the same time. He suggests that people who are taught to obtain knowledge through visual stimuli can derive meaning even if they do not know the words associated with what they see. They have a more complete set of learning skills than those who are only taught using verbal and written language. This more complete set of learning skills should be a primary goal of a technological literacy program.

Educational researchers have also begun to find that knowledge gained through actual hands-on experiences with objects is different than that gained solely through textbooks. With the current movement toward outcome-based education, educators have become concerned about the extent to which people can actually use material learned after instruction. Therefore, they have been studying the extent to which students can actually demonstrate desired instructional outcomes after instruction. This has required them to focus on performance evaluation. Recently, they found that when comparing the performance of students taught electric mysteries in science classes using hands-on activities versus standard textbook approaches the ". . .mean performance was higher for students in the hands-on than in the textbook curriculum" (Shavelson, Baxter & Pine, 1992, p. 25). They also found that scores on performance assessments were less highly correlated with general aptitude tests than typical standardized science achievement tests, indicating that the performance assessments seem to be measuring something beyond that which is measured with typical written tests. This again suggests that hands-on learning does provide students with types of knowledge which go beyond typical learning through language and textbooks.

The work of the Project 2061 panel and that of philosophers who have explored the relationships between science and technology clearly indicate that technology represents a unique content area important to the general education of all citizens. Work by computer researchers, observations of John Brockway, and experiments of educators also indicate that the long held belief in the need for hands-on experiential instruction leading to common sense technological literacy has a sound theoretical and practical rationale.

Technological Method

A second major content component of any technological literacy program is content leading to an understanding of how technology evolves and how it is developed to meet human needs. The Project 2061 Panel indicated that technology education should reveal the process of technology as it evolves from ideas to fruition, and that such education should show how technology affects individuals and society (Johnson, 1989). The accomplishment of this goal requires a new organizer and vehicle for teaching technology that will ensure an understanding of this process. The importance of common sense knowledge of technology developed through concrete experience is enhanced by understanding that such knowledge is usefully applied to satisfying human needs. The new organizer must provide a general model for viewing the application of technology within modern society.

Just as the scientific method has helped people understand the role of science and how science evolves, a clearly stated technological method can help people understand the role of technology and how it evolves. The following proposed "technological method" is similar in function to the scientific method. It helps explain the fundamental relationships among the many forces which influence technological evolution and innovation that operate within society. It provides a basis for organizing learning experiences and the presentation of activities to develop common sense knowledge of technology.

Whereas the scientific method is generally acknowledged as the principles and procedures for the systematic pursuit of new knowledge, the proposed technological method is a set of principles and procedures for the systematic development of socially acceptable technical solutions to human problems. The scientific method is typically presented as having four basic steps:

1. Recognize and formulate a problem in terms of understanding relationships between events or phenomenon;
2. state hypotheses which express expected relationships;
3. gather data through observation and experimentation to prove or disprove the hypotheses; and,
4. draw conclusions and generalizations focused on providing an explanation of the findings in terms of the relationships.

In contrast, the proposed technological method involves seven basic steps focused on deriving satisfactory technical solutions to human needs. The method was developed based on a one week visit by the author to the American History Museum of the Smithsonian Institution in Washington D.C. to speak with museum personnel and to observe the historical technological developments in computers, communications, transportation, office and agricultural technology. In addition, literature on the processes of invention (Caney, 1985; Doster, Goodwin, & Ross, 1978; Hindle, & Lubar, 1986; Mayr, & Post, 1981; Turvey, 1992), creative engineering (Bailey, 1978), and the interactions between technological change and society were synthesized (Bailey, 1978; Gardner, 1964; Johnson, 1989; Rapp, 1989; Sarkikoski, 1989; Savage & Sterry, 1990). The "technological method" is presented as a set of generic steps which can be applied to any area of technology. The steps are:

1. Identify an unmet human need requiring a technical solution (e.g., product, system, design);
2. clarify the specific technical problem;
3. identify relevant existing technical methods and knowledge;
4. invent a probable solution;
5. determine the social acceptability and economic feasibility of the solution;
6. modify the solution if needed to maximize efficiency and acceptability; and,
7. implement the solution.

Both the scientific and technological methods are not intended to depict the exact processes used by expert scientists or technologists as they practice. However, they are generic representations of the major steps used by scientists as a group, or technologists as a group. In both cases, as individuals develop additional expertise and move from novice to expert status, they will often apply their own special methods of arriving at solutions. This does not detract from the need for novices in an area to start with a way of viewing the development of science or technology as processes. An analogy can be drawn with the preparation of a person to be a chef. It would be very difficult for a chef to teach a person who knew nothing about cooking to apply the types of creativity expected of a chef. Therefore, people who begin to prepare to be a chef are taught recipes, cooking techniques and how various ingredients typically affect food. After mastering these processes and related knowledge, the person can then be taught to apply them creatively as a chef. After the new chef practices a while, that person will also adopt individual variations in food preparation which will differ from the master chef instructor.

Although both the scientific and technological methods are presented in a logical order, it is acknowledged that the application of either method is not linear but iterative. In other words, a person would not always proceed from step one to the end of the process in that order, completing one step before moving on to the next. In fact, in any given circumstance steps might be completed in a different order or in an iterative fashion (i.e., moving back and forth between steps by first doing a little of one, then a little of another, then returning to the first to do more, etc.). Even though the technological method is acknowledged as not being absolutely definitive and totally inclusive, it does present a set of generic developmental steps used by technologists which can be used as a basis for introducing students to technology.

Sample Applications of the Technological Method

Two examples of the application of the technological method are presented. They will be followed by a more in-depth description of how to apply the method. The first is a formal application as it might be applied to the design of a new airplane. The second is an informal application as it might be applied an individual repairing a lawn mower. Both require the same basic technological method steps. The design of a new airplane begins with establishing the need.

1. The unmet need: A quieter airplane is needed that consumes less fuel but carries the same load. People living around airports are complaining that the noise is affecting their quality of life. The public is also concerned about buying foreign oil and the airlines want to reduce fuel costs.

2. Clarify the technical problem: Knowledge about existing airplanes and how each has performed is assembled. This includes detailed information published about previous planes, personal and other existing knowledge about aircraft engineering, and performance data on the noise levels and fuel consumption of previous planes. The new needs which cannot be met by existing aircraft are more precisely identified. In this case, how much quieter and fuel efficient do the planes need to be? Engineers and others familiar with the creation of past aircraft are then asked to design modifications to meet the new needs. They first must identify the specific problem that must be solved in order to make a quieter more fuel efficient plane. Is the problem with the engines, the

design of the plane body, or the weight of the plane? The decision is that the problem is with the engines. The group then decides they can and want to design new engines.

3. Identify relevant existing technical methods and knowledge: Given the decision to design new engines, more detailed information on characteristics of the new engines is gathered. What size do they need to be? What type of fuel will they need to use? How will they be mounted on existing aircraft?

4. Invent a probable solution: Based on the existing knowledge, new creative ideas, desired characteristics and experience, new engines are designed. In some cases new components must be developed through experimentation and simulation before being included. The plan for the new engines is then reviewed by the individuals who will use them on their planes, and other aircraft engine developers to ensure the engines will have a high probability of working and meeting the desired characteristics. Modifications are made in the planned solution as needed. A model is then developed, tested and refined. Prototype engines are then developed and installed on an aircraft.

5. Determine the social acceptability and economic feasibility of the solution: Studies are done to determine if the noise levels are now acceptable to the public and whether fuel consumption is reduced sufficiently to warrant changing the engines on the existing planes. Cost studies are undertaken to determine if the price people are willing to pay, and the volume that can be expected to be sold, will cover costs and return a reasonable return on the investment. It is decided that the engines perform beyond expectations but they cost more than the airlines can pay.

6. Modify the solution if needed: The engines are then redesigned to meet minimum expectations within the cost constraints.

7. Implement the solution: Production occurs only after the engines have been proven reliable, and that they solve the original problems in ways that are economically feasible. Once they are produced they are sold to aircraft owners who install them to reduce noise and decrease fuel consumption.

The example above shows how the technological method would be applied to a technical problem which requires the application of formal design and production principles. The method can also be exemplified with a more informal technical solution. For example, an individual is alone at a remote site cutting grass and the lawn mower stops.

1. The unmet need: The person is faced with a need to start the mower to cut the grass but the mower will not operate.

2. Clarify the technical problem: Since no manual or other people are available, the person draws upon existing personal knowledge and skills. Some possible specific problems are identified as no fuel, a broken fuel line, or a loose spark plug wire. The problem is

finally identified as a broken fuel line. At that point a decision is made that the person has the expertise, tools and materials to fix it, and to try to fix it.

3. Identify relevant existing technical methods and knowledge: The person considers a process for fixing it based on personal expertise and the tools and materials available. The person knows that one could replace the fuel line or repair it. Given that a new line is not available, the decision is made to repair it.

4. Invent a probable solution: A number of ways to repair the fuel line are considered. The person could tape the line, but the gasoline would soon dissolve the tape. The fuel line is quiet long so it might but cut off and reconnected. The decision is made to remove the hose clamps, cut off the hose, and to re-install and clamp the hose.

5. Determine the social acceptability and economic feasibility of the solution: The modified lawn mower is started. indicating a solution has been found. The person judges that the solution is adequate because no fuel is leaking onto the grass which might kill it and the hose is secure.

6. Modify the solution if needed: Since the solution is working adequately no modifications are needed. Also, there is no reason to believe the hose will break again because the original break was caused by normal wear.

7. Implement the solution: The lawn mower is then used to cut the remaining grass.

Solutions in both of these examples, the airplane and lawn mower, require the same basic technological method for their solution. The only difference is in the manner in which each of the steps of the technological method is implemented.

Applying the Technological Method

Understandings of language-based and common sense technological knowledge are developed during the application of the technological method. Teaching students to apply the method requires them to develop and apply technical solutions. During that process students can experience concrete applications of planning and technical skills which will facilitate the development of common sense technological knowledge. Each of the technological method steps is discussed below in more detail as a basis for clarifying the application of the method.

Step 1 - Identify an unmet human need requiring a technical solution

The method begins with the view that technology evolves because of unmet human needs. The old adage "necessity is the mother of invention" applies. At times a technical solution may occur by chance to a need other than the original goal of the invention. However, all invention starts with the definition of a need. For example, one might start off by trying to develop a super oil and chance upon a super glue. However, the process would not have been undertaken without the need for the super oil. Even in the cases when a solution is found to an unintentional need, that need must be recognized in order for the solution to be recognizable as a solution. Therefore, the super glue invented would only be recognized as a solution to the unintentional need if that need for such a glue was recognizable.

The need may be experienced by one person or groups of people. The needs may be societal needs, such as the development of a spaceship capable of going to the moon, or the development of a health care system capable of providing health care to all of our citizens; or less pervasive needs of sub-groups in society such as the development of a better baby diaper which will reduce rash and increase comfort, or a pen that will write more smoothly. The need might also pertain to only one person who wishes to cut grass but the lawn mower will not operate and parts are not available, or to a person who wants to hang an antique on the wall and no suitable hangers are available. Any need experienced by humans which can be solved technically lends itself to technological solution. The identification of such needs takes place when people want to do something which requires a technical solution but a solution is not available.

Step 2 - Clarify the specific technical problem

A need represents a want or desire on the part of the person or group experiencing it. Often human needs are apparent and people can identify them, but the exact problem which underlies the need is not clear. Since a need cannot be met unless an exact problem can be defined, problem clarification is necessary. Problem clarification requires gathering precise information from the people who experience the need and examining desired outcomes in terms of technical possibilities. Once the problem is defined, it may or may not be solvable. All needs cannot be met at a given point in time. For example, for years people dreamt about going to the moon. However, it was not possible until recent history. Also, all problems can not be solved with technical solutions. Some require other solutions such as political or psychological solutions. Even if a problem is solvable with a technical solution, you may or may not want to solve it. The goal is to define a validated technical problem which is obstructing the satisfaction of a perceived need which is viewed as solvable and worth solving.

Step 3 - Identify relevant existing technical methods and knowledge

In most cases solutions to technical problems are based on combinations of existing hardware, software and/or ideas. If a person must develop a technological solution alone, without other available personnel, references or resources, the only resource they have is the limited skills and knowledges they possess. As John W. Gardner (1964) pointed out, many of the major changes in history have come about through successive small innovations, most of them anonymous. It is for this reason that technology in a given area is evolutionary. Because of its evolutionary nature, new solutions are often created based on existing technical methods and knowledge with the injection of some additional genius and new methods and ideas. Therefore, in the development of a new solution, a review of existing technical methods and knowledge in areas which might be relevant should be undertaken. The wider the base of the review the better. It is likely that new knowledge and technical methods may exist in places which are not obvious. For example, when Samuel Morse invented the American telegraph, he used a wind-up clock to provide the mechanical power to move the telegraph tape, he used his brother's print shop to make slugs similar to printers type which were used to raise the sending unit up and down to break the electrical circuit in predictable ways so each letter transmitted a definite signal, and he used the newly developed battery and understanding of electromagnetism to provide the electrical power. The point is that he thought in terms of what existed around him. Similar stories can be told about automobiles that evolved from horse drawn carriages, paddle wheel steamships which used paddle wheels similar to those used to power water driven mills, and early computers which used vacuum tubes from radios and punched cards originally developed to tally United States Census results.

Because new technology is often based on old, people formally educated in a particular technology are often asked to develop new solutions. They possess an understanding of much of the knowledge and many technical methods relevant in a particular technological area. They understand the relevant principles which govern the processes of the technology. Engineers who are trained to design bridges are called upon to design new bridges, architects are called upon to develop plans for new structures, and biomedical engineers are asked to design new medical devices. Because knowledge and technical methods in any area change rapidly, it is important for people to keep up in their fields.

It is also important to realize that many meaningful technological innovations are developed based upon common sense knowledge possessed by those who work in a particular area who may not have formal training. For example, it was only after telegraph operators utilized Morse's equipment for some time that they realized they could send messages without the slugs by pressing a telegraph key in the same pattern that the lead slugs raised and lowered the original sending unit. Later, they also realized that it was not necessary for them to have the incoming message printed, the way Morse originally intended. They could tell by the sound of the receiving unit what letters were being sent. Therefore, the telegraph was greatly simplified and made less expensive and more reliable through common sense knowledge of the technology gained by the operators. These innovations to refine the telegraph were not predictable by Morse when he designed it.

Workers living with the equipment day to day were able to recommend the refinements which made the telegraph more simple to operate, more economical, and therefore, more usable. Similarly, office workers can provide input into the design of office systems based on their experience with what works well and what does not. The realization that workers can provide such insight into the development and refinement of technology based on common sense knowledge is one of the reasons for the implementation of quality circles which involve workers in discussions of how to improve practices.

New technologies in a given area often draw upon ideas and technical methods developed in other technological areas and disciplines. Therefore, the technologist must not only monitor potentially relevant information in a given area of technology, but other areas as well. This fact is recognized by industry in the design and development of new products, service and systems. It is reflected in the recent increased interest in the use of project development teams. These teams include people with a variety of expertise (e.g., engineering, production, marketing, finance). Each has a knowledge base to bring to the project which results in a phenomenon some call "super intelligence"; an intelligence which goes beyond any one discipline or individual.

Relevant existing knowledge becomes the basis for the invention of solutions to technical problems. It often facilitates further clarification of the problem in addition to providing a starting point in thinking about possible problem solutions.

Step 4 - Invent a probable solution

The invention of a probable solution requires four generic sub-steps: the specification of desired characteristics of the problem solution, the development of a plan to solve the problem, optimization of that plan, and the development of a solution. Those steps are presented in Figure 1 as a modification of the engineering "problem solving approach" proposed by Robert Bailey in his book Disciplined Creativity for Engineers (Bailey, 1978, p. 69). The new adapted model is called the "invention process."

Step 4-1. Specify satisfactory solution characteristics - Once the problem has been clarified, characteristics of a satisfactory solution must be specified. Those characteristics are specified in terms of what people who have the need would perceive as a desirable solution, the potential impact of the solution on society, economic constraints on providing the solution and on adoption of the solution, and technical characteristics of the solution. The goal is to determine the desired characteristics of a problem solution.

Step 4-2. Develop a solution plan - The development of a plan for a potential solution for solving the problem requires the application of information assembled during step 3 of the technological method. As the solution is being developed, further and more precise searching into existing knowledge and methods may have to be undertaken. At other times it may become apparent that sufficient knowledge and techniques are not available to arrive at a solution. When this happens new technical needs arise which can be identified and met through additional application of the technological method. In this way, the development of a solution to one problem may give rise to other problems which must be solved first. For example, it became apparent that computers would be needed aboard a space shuttle if it was to be functional. However, the space shuttle had to be small and computers were large. Therefore, the miniaturization of computers became a problem which needed to be solved during the development of the space shuttle.

Figure 1

INVENTION PROCESS

(Step 4 of the Technological Method)

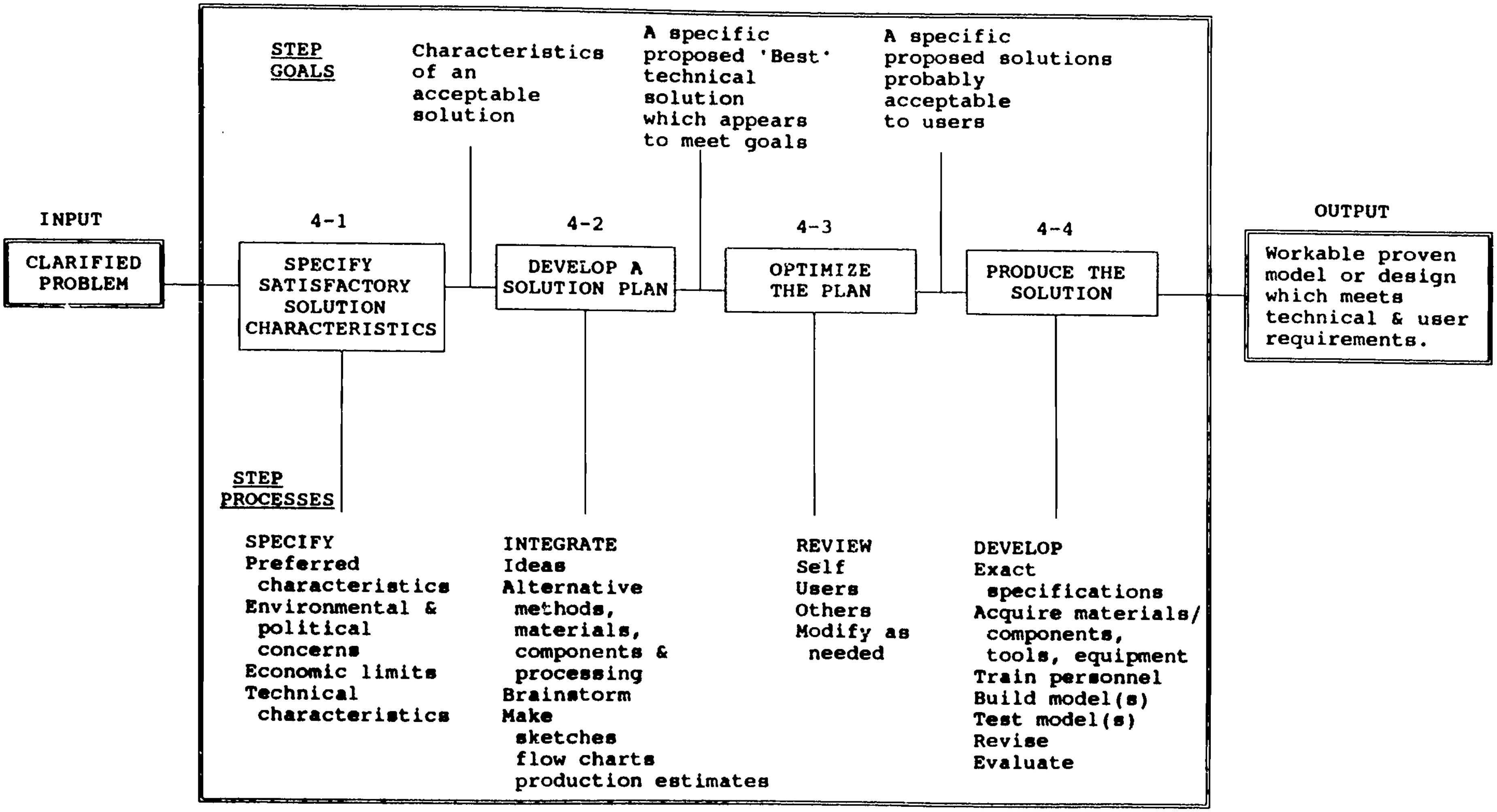

Fig. 1 The four-step "invention process" was adapted from the "problem solving approach" developed by Bailey, R. L. (1978). Disciplined Creativity for Engineers. Ann Arbor, MI: Ann Arbor Science Publishers.

If the means to a solution are not reasonably predictable through known design principles and technical knowledge, experimentation may need to be undertaken. This experimentation may begin as trial-and-error activity but it usually is based on best successive approximations. This activity generates common sense knowledge of the phenomenon which may later be explained through science. Hopefully, each approximation gets closer to the desired end.

Once the alternatives to be considered in developing a solution have been identified through further review or invention, individual or group brainstorming takes place to try to combine the available knowledge and techniques into a best possible solution. It is the ingenuity of assembling knowledge and technical methods in new ways to solve a problem to meet a need which underlies the process of invention. Solutions are then sketched and/or detailed in writing with diagrams if they are complex. Alternative materials, processes and sub-systems for actual production are also proposed. The eventual goal is to propose a plan for a feasible solution to the original problem and a plan to produce it.

Step 4-3. Optimize the solution plan - Once a plan has been developed, it must be re-evaluated to maximize its potential for solving the problem and meeting the original need. This requires a review by those who have the need and by those who can provide insight into whether the proposed solution is feasible. The eventual goal is to refine the plan for a solution to the problem.

Step 4-4. Develop the solution - The actual development of the solution requires the translation of the proposal into a workable model. This requires more precise specification of the form and composition of the solution so those charged with developing the model can produce it. It also requires making available all of the resources needed to produce it (e.g., materials, components, tools and equipment, and trained personnel). The model solution is then developed according to the specifications, tested and revised as necessary. The eventual goal is to produce a workable, proven model or actual solution which solves the problem and meets user needs.

Because invention requires creativity, the conclusions drawn at each step cannot easily be judged as correct or incorrect. What is defined as correct in a particular circumstance is determined by the person's or planning group's basic understanding of the problem, vision, judgement, and experience. Others may define something else as being correct. This is one of the reasons why inventors often arrive at different solutions to similar problems.

Step 5 - Determine the social acceptability and economic feasibility of the solution

Each solution invented must be examined to determine if its production, or the effect caused by its adoption are socially and economically acceptable. This requires the solution to be acceptable to the group with the need, and to other groups that might be affected. Social acceptability must be considered on many grounds. The group that required the solution and any affected groups are identified. Then religious, political, environmental, economic, and other values and expectations that might be affected by the solution are identified. Each value and expectation is weighed to determine if the solution will conflict with it or create a positive reaction. Within formal businesses, the function of assessing the solution's acceptability is often done through market research. However, more recently public agencies dealing with issues such as pollution control, environmental impact and occupational safety must also be considered. For example, the engineers designing an aircraft engine might propose a nuclear engine. It would be quiet and fuel efficient. However, given the current concerns of the public over nuclear power, environmental impact and public safety might be major obstacles.

Social acceptability is relative, meaning that what is socially acceptable at one time and place may not be at another. For example, at one time coal and wood burning stoves to heat homes were viewed as an important new technology. With large concentrations of people in cities and the availability of alternative sources of heat, they are now viewed as causing unnecessary pollution. However, in rural areas with an abundance of wood and low population density, and in countries without alternative fuels, coal and wood burning stoves are still accepted as a source of heat.

It is difficult to determine which characteristics of solutions will be viewed as problematic. For example, when it became possible to finish washing machines in many different colors, washing machine manufacturers did so on their new models. However, most people in the United States buy white washing machines because white is associated with cleanliness. Therefore, even though a new improved washing machine might wash clothes better, if it is painted the wrong color it might not sell. In some cases product acceptability is even more difficult to assess. For example, a South American country with a food shortage asked agriculturalists from the United States to help them satisfy the need for food. After investigating the need, a problem was identified. The citizens in that country ate a substantial amount of corn tortillas. Therefore, an apparent solution was to develop a higher yielding corn so more corn could be grown per acre. This was done, but soon the farmers returned to their old corn even though they had higher yields with the new corn. After extensive investigation, it was found that the homemakers mixing the corn meal while making the tortillas did not like the texture of the new ground corn on their hands, it felt different. Therefore, they only wanted to use the old corn and pressured those producing corn to return to the old practice.

In some cases, the problem might not be with those who use the new technologies, but with the values of the public or secondary customers. For example, electric power companies welcomed nuclear power plants and began to build them throughout the country. However, their customers and the general public were afraid of possible nuclear accidents, and therefore, influenced the passage of laws and regulations to restrict such plants. The result was that much of the technology developed could not be utilized. Not only did the developers of nuclear power equipment experience difficult financial times because they could not sell the products they developed, but many of the power companies that bought the equipment and built plants were not able to operate them and were faced with bankruptcy. Therefore, it is important to remember that each technological solution is subject to both positive and negative reaction and that it must be closely examined for social acceptability.

Economic feasibility must also be assessed. This is accomplished by analyzing the costs of delivering the solution to those that want it, and the possible income that can be generated from the potential market at a price people are willing to pay. Many costs must be considered, the most obvious are the costs of materials, tools, equipment, and/or personnel to produce the solution. In addition, there are such costs as marketing, sales, management, buildings and grounds, utilities, insurance, and energy that are incurred by the time the solution reaches the customer. Such costs are often considered direct costs which can be objectively determined. At times, there are other costs such as the cost of producing one product or service and not being able to produce another.

Step 6 - Modify the solution if needed to maximize efficiency and acceptability

Most invented solutions which have been proven technically possible during step 4 (invent a probable solution) can be modified based on social and economic considerations and still provide an adequate solution to a need. Since the original solution was proven to be technically adequate, the modifications at this point are mainly in terms of social and economic factors. For example, if the color of the washing machine should be made more acceptable, the color could be changed; if a nuclear reactor should be made more acceptable by designing further safeguards, they could be designed; if another material can be manufactured more efficiently, it could be substituted; or if production of parts can be subcontracted to another company and made more efficiently, they should be.

At times addressing social and economic factors might also require returning to step 4 of the technological method to modify the technical aspects of the solution. In such cases the need would be re-defined and a new or modified technological solution sought.

Step 7 - Implement the solution

Implementation refers to utilizing the solution as it was designed. This may mean applying the solution in a limited location or producing systems, services or products in quantity for use by many at different locations.

Differences Between the "Technological Method" And Those Previously Proposed

The "technological method" differs in important ways from other proposed technological methods. The method focuses on the belief that technology evolves to serve functional purposes defined as useful by humans. It focuses on the interaction between the technical aspects of solutions for meeting needs and the social and economic aspects of appropriate solutions. It presents technology as a vehicle for enhancing the quality of human existence. In contrast, the methodology proposed by Savage & Sterry (1990) is based on the belief that technology should be studied because of ". . .the dependence of humans on technical means for survival. . ." (p. 7). That model does not explicitly recognize technology's role in doing something better, or in improving the quality of life, including leisure. The Savage & Sterry model also presents the technological method as being synonymous with the problem solving method. They suggest that "The process of problem solving provides the parallel in technology to the scientific method in science" (Savage & Sterry, 1990, p. 15). Although the technological method is in fact a problem solving method, it has unique characteristics which are not explicitly addressed during the application of a generic problem solving method. Those characteristics must be explicitly addressed in a technological method if one is to argue that there is something unique to technological problem solving. Although the preamble to the Savage & Sterry model accepts many forces which influence the development of technology, their six step method concentrates on the technical solution. Therefore, that method does not adequately integrate important variables which students must envision (e.g., socio-economic variables) when thinking about technological evolution and innovation.

The "technological method" also differs from the 16 steps proposed by the Project 2061 panel (Johnson, 1989, p. 3). The 16 steps concentrate on finite questions which engineers should address in designing a new technology. However, they are not easily generalizable to less highly planned technological invention which occurs without extensive amounts of preplanning. For example, the development of a space shuttle or a new bridge requires the type of preplanning performed by engineers. However, the on-the-spot improvisation needed to make a lawn mower operate does not. Even though highly planned and improvised solutions differ in the precise steps taken to develop solutions, both follow the same generalizable method of evolving solutions to human needs.

The technological method is also explicitly based on the processes of innovation, hence invention. Although this might be implied in the other proposed methods, it is not inherently built into the methodology. To invent implies fabricating something useful as a result of ingenious thinking or experimentation. It is different from creation which implies an evoking of life out of nothing or producing a thing for the sake of its existence rather than its function. It is also different from discovery which supposes the pre-existence of something and implies a finding rather than a making. That which is invented may be a product like a new type of television, or a system such as a production process or system for managing people. The new solution may be as major as the invention of the microchip, which allowed for the miniaturization of computers, or as small as a new fastener which more effectively holds tablecloths on tables. The invention may influence the evolution of many areas of technology or only one. The invention may solve an immediate problem for only one person or a long-range problem for many.

The technological method also acknowledges that there are many types of technology in our world. (For example, the list of 11 technologies developed by the Project 2061 Panel presented on page 26.) Therefore, it was developed as a set of generic steps that could apply to all types of technological innovation. It was not designed just for engineering, skilled occupations or individual invention. Although different areas of technology might have more definitive sets of steps which might be more prescriptive, this generic model provides people with a general understanding of technological innovation.

The technological method explicitly acknowledges that technology evolves within a socio-economic-technical system, not just a technical system. Therefore, the method recognizes that societal values, political influences and economic feasibility are among many societal variables which influence technology. In order for technology to progress in a particular direction it must be supported by society. Lack of support, either political or economic, retards technology. If a solution is not acceptable to societal values, people will exert political pressure which may be so overt as to regulate or outlaw the new technology and/or they will not purchase the technology which soon makes it economically unfeasible. Lack of support does not eliminate the technology but retards its development.

Each solution has many effects, some foreseen and desirable, and others unforeseen or undesirable. The perceived consequences in terms of cost/risk/benefit analysis by various segments of society moderate what is technically allowable. Since technology is defined in terms of meeting human needs, the continual debate over the desirability of various technological possibilities is a healthy and important ingredient to ensuring that technology adds to and does not destroy our society as we wish it to be.

Specific Technology Education Content for All Students

Context for Content Selection

The goal of this paper is to present a rationale for why a technology education program is worthy of being part of the general education of all students and what should be taught in such a program. Therefore, it does not attempt to develop a taxonomy of all potential technological content. It is assumed that the content selected to be included in a foundational technology education program must be limited to a sub-set of all potential information about technology, given that the time all students can devote to technology education is limited (probably one period for one year at the middle school level). It is further assumed that the sub-set selected must focus on the development of technological literacy as part of cultural literacy. Therefore, it should have maximum generalizability across technology areas and to life and work. It should represent that content which provides background for communication about technology in our culture. This foundational program for all students could then be followed by additional elective courses in more specific technologies.

Given these assumptions, it is clear that emphasis on only one technological area, and the unique ways of arriving at solutions within that area, is not appropriate to accomplishing this general education goal. It is also inappropriate to organize the program around examples of currently interesting technology in an episodic fashion without concern for how the specific technological content fits into a total program. For example, a new rocket is sent to Mars so the content of the technology course is focused on space, or a new emphasis is placed on fuel efficient automobiles so the content is focused on automotive technology. These narrow foci do not provide the type of general technological literacy required in society. Capitalizing upon the interest generated by current technological events as a basis for providing contexts to teach technology is appropriate, but using such events as a basis for determining the content of a program is not. The content of the program should be goal oriented to ensure all students taking part in a program anywhere in the country accomplish similar goals. However, it should be flexible enough to allow individual programs to adapt to local circumstances and instructors. This requirement is no different than that imposed on other basic areas of the school curriculum, such as math and science. Therefore, the challenge is to define and identify technological content that is worthy of inclusion in a general course for all students that can lead to the development the types of knowledges and skills that will allow students to become technologically literate, as described earlier in this paper.

Some suggest that technology changes so rapidly that it is not possible to define a lasting body of technological literacy content. With further examination, this assumption appears to be false.

Content which contributes to cultural literacy evolves as society evolves. However, Hirsch found that in creating his list of common elements underlying cultural literacy based on language, "Eighty percent of the listed items have been used for more than a hundred years" (Hirsch, 1988, p. xii). Therefore, one could generalize that a basic cultural literacy curriculum needs only to be periodically updated to be kept relatively current. Again, a similar phenomenon is occurring within technology content. New technology is continually evolving based on past technology. These technological changes are often very visible. For example, the technology related to the circuitry and storage of information within micro-computers has changed dramatically. If the goal was to teach a competent electronics technician, the content would also have to change dramatically. However, the basic technology at the level of understanding needed by the general public to comprehend and experience how a computer works has changed relatively little. Computers still do essentially the same things and the new technical devices just do them faster. Although technological knowledge is growing ever more rapidly, the percentage of the general technological content that remains relatively constant for a period of time is large. The technological method represents content generic to all areas of technology and will remain relatively consistent over time; the basic tools, equipment, ideas, processes, and materials for arriving at technological solutions also remain relatively stable. This is similar to science. The scientific method is relatively stable and basic general scientific content changes relatively slowly.

Technological Literacy Content

A general discussion of technological literacy and its relationships to cultural literacy and society were presented earlier in this paper. This section focuses on defining the specific technological content that such be included in a basic technology education program to develop technological literacy.

A major technological literacy content component is the "technological method" presented earlier. Understanding this method allows individuals to comprehend how technology evolves and develops and its relationship to societal development. The method also provides a framework for teaching for technological literacy. Other technological content can be taught within the contextual framework of the technological method.

However, developing an understanding of the method alone is not sufficient to prepare a technologically literate individual. In addition, a set of experiences is needed which will allow individuals to apply the technological method to real problems requiring technical solutions. In developing and applying technical solutions, students must be allowed to experience the application of technical tools, equipment, ideas, materials and processes in laboratory situations to develop both language-based and common sense technological knowledge. Students should be provided these experiences around content which the public considers to be essential as part of cultural literacy within the United States.

What are the technological areas with which students should become familiar? Project 2061 identified 11 technologies important to modern society (Johnson, 1989, pp. 13-28). They were:

materials
energy
manufacturing
agriculture and food
biotechnology and medical technology
environmental (atmosphere)
communications
electronics
computer technology
transportation
space

Traditionally, technology educators have classified technologies into power, transportation, manufacturing, construction and communications (Warner, 1965). Warner also included management in his original works. More recently they have included other areas such as biological technology (Savage & Sterry, 1990). Regardless of the specific list used, the challenge is to identify content that applies across technological areas as a basis for creating a program which should be part of the general education of all students.

Based on a review by the author of materials from a range of technological areas, two common threads which might serve as bases for developing an instructional program to be taught within the context of the technological method have evolved. They are designing and producing technical solutions. At times designs themselves may be viewed as the technical solution (e.g., organization chart, blueprint, flow chart). At other times designs are viewed as interim processes necessary in the development of physical apparatus. Whether designs are the solutions, or part of the process of arriving at solutions, is determined by the need originally expressed. For example, engineers, architects and systems designers are often called upon to produce solutions in the form of plans or designs. Craftsmen are often called upon to produce solutions in terms of a physical apparatus (e.g., machine, house, duplicator, blood analyzer).

Obviously, in addition to these common threads across technologies, the different technological areas also have unique content that govern the shape, form and substance of designs and physical apparatus. For example, a plan for a computer programmer might be a flow chart while the plan for an engineer might be a set of blueprints. Physical apparatus in medical technology solutions might be a CatScan or a heart catheter, while a physical solution in electronics might be a circuit, and in carpentry a new technique for assembling a house. Even though some of the specifics of designing and developing physical apparatus vary between technological areas, solutions require the same basic planning techniques and the need to manipulate tools, equipment, ideas, processes and materials.

It is these common threads among the technologies that provide the most fruitful vehicles for conveying common sense technological knowledge as part of the general education of all students. These common threads could be taught within the contexts of the various technological areas during the curriculum. This would provide students with an overview of the various technological areas and could make them aware that within all areas of technology, solutions are derived in a similar fashion and that each area also has unique variations. The primary content would be focused on the design and development of physical apparatus solutions focused on satisfying human needs.

This recommendation is made in full recognition that solutions which result in designs or physical apparatus do not cover all of the possible types of solutions in each technological area. Later in the school curriculum, or in post-secondary education, students could be provided with opportunities to elect to study specific technologies in more depth.

Ten Categories of Technological Content

Assuming the most fruitful foci for a general course in technological education are the technological method; and the tools, equipment, ideas, processes and materials for designing or producing physical apparatus solutions, the following 10 categories of content are recommended.

1. technological method (including the invention process)
2. common tool usage (e.g., screwdrivers, wrenches, meters, vises, clamps, t-square, compass, beaker)
3. common equipment (e.g., drill press, sander, table saw, welder, generator, robot, drafting machine, computer, balance scale)
4. basic technological process (e.g., fastening, cutting, shaping, propagating, mixing, measuring)
5. materials (e.g., metals, plastics, wood, composites, paper, fiber, cellulose)

6. terminology (e.g., circuit, flow, kerf, voltage, bonding, adhesion, center-line, hybrid, open-system, contaminants)
7. environmental concerns (e.g., pollution, resource consumption, disposal)
8. social values (e.g., preserve jobs, prejudices, moral implications)
9. scientific principles (e.g., friction, electricity, leverage, nuclear energy, genetics)
10. economic factors (e.g., supply, demand, costs, benefits, return on investment)

Delivering the Technology Education Program

Shared Responsibility for Developing Technological Literacy

The first six categories of content presented above should be the primary focus of the technology education program. The last four areas should be taught primarily by other areas of the curriculum (e.g., science, math, social studies) and should be applied and reinforced during the application of the technological method within technology education programs. This distinction is important in the development of a general technology education program. Given the limited amount of time available, and what can be reasonably expected of a technology education instructor, the content expectations of a technology education program must be realistic. It is not possible to teach all of the content in each of these 10 categories in-depth within one hour a day for one school year. It is also not possible for one instructor to be adequately prepared to teach all of these subjects. Therefore, technology education, in its broadest sense, must be the responsibility of instructors in all areas of the school curriculum. Social studies teachers should relate what they are teaching about society to relationships between technology and society. Science teachers should teach science and how scientific principles manifest themselves in technical solutions to human needs. Math teachers should apply math concepts to real life problems associated with the development and application of technology.

Technology education teachers should also have an equal responsibility for reinforcing and applying math, science and social studies content. However, they cannot be held responsible for systematically teaching that content. In order for schools to accomplish the broad goal of preparing students to enter a technological society, all areas of the curriculum must cooperate while teaching their own unique content. This may require jointly planned curriculum across the subject matter areas.

Given that technology has a content of its own that is worthy of teaching, the technology education instructor should teach about technology and how each of the other subject matter areas impact on technological evolution and the invention of satisfactory technical solutions. The primary role of technology education should not be to serve as an alternative vehicle for teaching science, social studies, or math. The content to be taught in the technology education program should be driven by the technology content, and other content areas should be applied when appropriate to enhancing the teaching of technology.

Focus of Technology Education

The delivery of this newly envisioned technology education program will require a change from how typical industrial arts and other practical arts programs have been delivered if it is to be seriously considered as part of the general education of all students. Typically, most of those programs have focused on teaching sets of skills and practices associated with specific industries and/or projects (Pucel, 1989). Such foci do not concentrate on teaching about technology. They concentrate on student mastery of occupational skills, industrial practices, the arts of industry, or the completion of projects. This does not mean that teaching selected occupational skills, industrial practices, the arts of industry, or teaching around projects are undesirable tools for the delivery of technology education. However, they should not be the end goals of technology education. New technology education programs should focus on teaching the technological method, and the ideas, tools, materials, and processes for arriving at technical solutions. This content could be taught around a variety of projects that serve as vehicles for applied learning within various technological contexts.

A change to this desired focus would require instructors to first identify the ideas. tools, equipment, materials, and processes they wish to teach students. The selection would be based on content requirements to develop technological literacy. Learning activities would then be carefully developed to teach that content. The learning activities should require students to apply the technological method while utilizing the identified ideas, tools, equipment, materials and processes. Projects could be used as vehicles to have students apply the content in order to develop common sense knowledge of technology. The key difference between this approach and the predominant past approaches is that learning about technology becomes the end goal rather than the development of industrial practices or the completion of projects.

The exact content that should be taught to develop technological literacy will continue to be debated. However, it is important to adopt a clear understanding of the end goals of technology education so that content can be taught in such a way that students will develop technological literacy. If the end goals are clear, instructors and curriculum developers can apply alternative approaches to accomplish those goals.

For example, one could decide to teach students the technological method to solve a human need, and how to operate simple woodworking tools and equipment, fasten wood, and finish wood. A learning activity could then be developed which requires students to apply that content. One activity could be to develop a unique way of dispensing paper toweling. The activity would start with the need for a paper toweling dispenser. Students would design and produce a solution to this technical need. The end product would be a paper toweling dispenser, and while producing it students would develop some technical skills which are also used in society, such as designing a product, cutting wood with a jig saw and fastening with screws. In this case, a project would be completed and some skills would be developed, however, they would be used as vehicles to teach students about technology and the development of technological solutions to human needs. After the solutions were developed, students could discuss their ability to satisfy the need and how they might be made more effective.

As indicated earlier, although the technological method can be viewed as a problem solving approach, it has unique characteristics. Therefore, it should be differentiated from generic problem solving approaches which are not specifically designed to arrive at technical solutions, or which do not consider the social and economic ramifications of those solutions. Just defining the basic approach of technology education as problem solving does not convey the unique character of technological innovation. In the example above, a problem was solved. However, it was a technical problem requiring the unique characteristics of a technological solution.

If the unique character of technology education is not clearly defined, technology educators can easily lose sight of their goals when delivering instruction. For example, concentration on only the problem solving method has led some technology educators to ask students to build the longest bridges they can with paper straws and tape. This may teach problem solving, but it does not help students develop the common sense knowledge of technology required to function in life or work. People do not build bridges with straws, tape and scissors. They build bridges with cement, steel and hammers. They do not start off with a problem such as building the longest bridge. They start off with building bridges to serve a human need such as connecting two land masses. Therefore, the key elements which should be contained in technology education learning experiences are not present. What is present is a learning activity that is fun for students with little value for developing technological literacy. Technology education experiences should be authentic in terms of the real world.

Lack of a clear focus on the major goals of technology education has also led other technology educators to focus almost solely on the interactions between technology and society. In the process they have forgotten about the need to develop common sense knowledge of tools, equipment, ideas, materials, and processes and an understanding of technological evolution. Such courses are organized primarily around the environmental impacts of technology and the positive and negative effects technology has had on society. Again, although such content should be part of a technology education program and reinforced, it alone is not sufficient. The unique aspect of technology education is the development of technological literacy through the application of the technological method and tools, equipment, ideas, materials and processes, and not the teaching of technology history or social studies.

Teaching technology education around the proposed technological method and content can help avoid these problems and can help keep instructors, the curriculum and students focused on relevant factors. The approach advocated in this paper allows individual instructors and schools to define the specific content and instructional procedures associated with their technology education program in their own way. However, they would be expected to teach students content derived from the ten categories proposed early in the section on specific technological content, within the framework of the technological method.

Presenting Technology Education in the Classroom

The development of learning experiences for a general education program in technology education for all students has unique challenges which go beyond clearly stating goals. As indicated during the discussion of the third step of the technological method (identify relevant existing technical methods and knowledge), inventions are based on past knowledge and technical methods. A major difficulty faced be technology educators at the middle school level is that students have a limited command of technical methods and technical knowledge. Therefore, educators cannot assume students already possess the knowledge needed to solve a range of technical problems. Students must be taught the technical methods and knowledge while they are being taught about technology. This is different than teaching engineering students, architecture students, or inservice technology education teachers who already have an extensive background in technical knowledge and methods. Two different methods for teaching students with limited technical backgrounds are presented as samples which could be considered by technology education teachers.

Develop Case Studies Around
Past Technical Solutions to Human Needs

This approach, as any approach to teaching technology education, starts with clarifying the types of tool, equipment, ideas, processes and materials to be taught within the framework of the technological method. Then a case study is developed around a past technical solution which requires students to apply the desired content in a laboratory setting. The laboratory should be a well equipped general shop capable of allowing students to work with a wide range of desired materials, equipment, tools and processes. The case study should exemplify the development of a technological solution to a human need. Some portions of the case can be presented by the instructor as an accounting of what happened with the real historical case, and other portions could be completed by having students research information and complete activities within their capability. The balance between how much of a case the instructor presents and how much should be developed by students should be determined by the background of the students and the instructional time available. Each case should require the production of a technical solution. The ability to work with the tools, equipment, ideas, materials and processes should be taught as needed to produce the solution. Key to this approach is making sure the range of cases presented to students during the entire technology education program requires them to encounter all of the content that the program is designed to include.

For example, the instructor could decide the content should include the application of the technological method, cutting and bending metal, cutting and finishing wood, fastening metal to wood, cutting and stripping electrical wire, fastening wires, and using associated tools and equipment. A case could be developed around the invention of the telegraph by Samuel Morse. Each step of the technological method could be explicitly discussed in reference to Morse's invention. The need which existed at the time of Samuel Morse could be defined. It could be defined through an explanation by the instructor or by asking students to participate in researching the history of the need. Samples of technical apparatus and how they can be developed could be demonstrated by the instructor. Students could then be asked to develop the technical apparatus. The technical apparatus should be selected and designed to require students to develop the specific skills identified earlier. The instructor could demonstrate technical skills such as how to use a drill press, screw driver, jig saw, and metal shears to produce devices to connect a battery, to develop a telegraph sender, or to wire a receiver. Students could then be asked to produce their own sending units, as individuals or teams. The developed units could then be attached to an already developed receiver and demonstrated to determine if they satisfy the need. Following student demonstrations of their units, the class could discuss the acceptability of the solutions and provide suggestions for improvement.

Develop Statements of Human Needs and Allow Students to Design Solutions With Guidance

Although this approach allows students to solve technological problems more independently, as soon as the instructor allows students to creatively design and develop solutions, a new set of challenges appear. The major challenge is to lead students to solutions which they can actually achieve based on the expertise they can be expected to have, or develop with the equipment and materials available. This approach requires the instructor to create learning activities around the technological method which students can follow to arrive at technical solutions within their capability, and which require the application of a desired set of technical tools, equipment, ideas, materials and processes. The key to the successful use of this approach is to clearly specify the parameters within which students can create solutions. For example, What need is the solution to address?, What materials can be used?, What equipment can be used?, How long can the student take?, and What process should students follow to be approved to operate equipment? Students are allowed to exercise creativity in developing alternative solutions with the aid of instructor input within parameters provided by the instructor. Using this approach, the technical aspects of working in the laboratory would be taught when the students require them in the process of producing their technical solutions. Some technical skills and knowledge could be taught to all, but since students would be working on unique solutions they would also require unique instruction on skills required to produce their unique solutions. Besides producing the technical solutions, learning activities would be designed to have students address each step of the technological method in reference to the creation of the solutions.

For example, assume the same content defined in the case study above is to be taught. Rather than using the case study format as a means to teach students to develop a telegraph sending unit, students could be presented the development of a telegraph sending unit as a technical problem. They could be told why society needed such a device. They could then be told they need to develop a unit for sending an electrically coded 1.5 volt signal to a receiving unit. The signal should consist of long and short bursts of electricity that will be received by a magnetic sounder. The students could be told to use wire, sheet metal, wood and any of the tools and equipment in the laboratory. Resource materials on how to create such devices would be provided. Students could be told they have ten hours to develop the device. In addition, at the end of the development period they would be expected to participate in a discussion of the value of sending such signals and how technology in the field has changed and improved beyond the device they developed. Students would then develop a design for the device and have it approved by the instructor. Since the instructor knows all of the students will need to cut, strip, and connect wires; a common demonstration could be held. Since all will have to cut metal, another demonstration could be common. When unique approaches to developing the device require unique tools and materials, those could be demonstrated on an individual basis. After the devices were developed they could be demonstrated and a discussion could take place.

Both of these alternative approaches require instructors to deviate from the long held approach which requires students to learn about the tools, equipment, materials and processes through structured learning before they can move on to more creative applications of the content. Both the case study approach and the approach of allowing students to apply the technological method to solutions which are defined in terms of desired content, but which allow students to arrive at creative solutions, require students to be taught relevant content at the time it is needed. They are also not dependent upon students mastering the technical skills associated with the solutions. The solutions developed are working models, not commercially competitive products. This is an important distinction because it relieves both the instructor and the students of the burden of students mastering technical skills to the level needed to practice in an occupation. The goal is technological literacy and not skill mastery.

If these approaches are adopted it will be important to change the expectations of both students and parents. Currently both students and parents judge projects in terms of their quality as judged against products commercially available. For example, if a paper towel dispenser is produced, they expect it to be of competitive quality with paper towel dispensers available on the market so it can be used in the home. If technology education is to accomplish its major goals, projects and products produced should be viewed more as working models rather than products which are technically perfect.

Teaching students technical skills when they need them will require different instructional techniques. Students will be learning independently or in self-directed groups. Demonstrations may need to be available on video tapes. A process for individually checking student ability to use tools and to operate equipment safely will be needed. A reference library should be available so students can research topics such as, What has been done in the past?, What are the implications of certain solutions?, and What materials and processes would work best? Peer teaching may be required. Regardless of the approach used, it is essential that each activity follow the technological method from the presentation of a human need to the eventual adoption of the solution.

Both approaches presented above allow for collaboration with other subject matter areas in the schools. If the case studies or technical needs requiring solutions are planned, or coordinated with math, science and social studies educators, they could be teaching related content at the same time the technology educator is applying it during the teaching of technology. All three subject areas could reinforce one another while teaching their own unique content. Other alternatives would be for teachers to use common examples in their classes or to team teach classes.

Partnerships for Implementing the Technology Education Program

Implementing a quality technology education program as part of the general education of all students can only be accomplished with the cooperation of a number of groups. Some groups are within the schools and some are outside. In order for any content area to be included in the schools it must have advocates that communicate its need and value.

Partners in the Schools

Partners within the schools should include subject matter areas such as social studies, science, math, vocational education and art. It is not possible for all technological literacy content to be taught within one general technology education program. Therefore, other subject areas in the school curriculum should also adopt technological literacy as a goal. Each can present its unique content and reinforce the content relative to technology taught by other subject matter areas. It is important for technology educators to realize that they have a unique role in the schools. They are responsible for teaching the technological method and developing common sense knowledge of technology through concrete experiences with tools, equipment, ideas, processes and materials. In planning with other subject matter areas, they must not be relegated to an alternative method of teaching subject matter from other disciplines. They should reinforce the subject matter of other disciplines, but be responsible for the delivery of their own content. This role should be clearly stated so others in the school can develop realistic expectations and plan accordingly.

The following are some examples of the substantial contributions other subject matter areas can make to technological literacy. Social studies can address how society governs and controls technological development and how technology influences society. Science can address how scientific principles affect technology and how attempts to explain technology lead to scientific principles that influence the design and development of new technology. Math can address how math is used in the process of planning, estimating and developing technology. Vocational education can demonstrate how technology is applied in occupations. Art can address why and how technology should not only meet the technical needs of people but their aesthetic needs.

To ensure that all subject matter areas are complementing one another, it is important for the cooperation to be planned. This might be accomplished through the formation of a technological literacy curriculum task force consisting of representatives from the various subject matter areas. The goal would be to understand the contribution each can make toward enhancing the technological literacy of students and how they can reinforce each other.

Cooperation could take on many forms. Cooperation could stop with acknowledging each other's role and reinforcing each other's content. It could also take the form of planning to teach related content in each of the classes at the same time, as indicated earlier. The most complete cooperation would occur if teachers from the various subject matter areas taught classes as teams. This would require extensive pre-planning of an integrated curriculum and the shared teaching of the same students.

Partners Outside the Schools

Technology educators often discuss possible partnerships with groups in the schools but tend to ignore the need for external partners. Besides having partners within the schools, technology education must also establish partners outside the schools. These partners should obviously include the public, parents, and students who are expressing interest in technological literacy as a basis for preparing for entry into a technological world. In addition, partnerships should be developed with groups concerned with preparing students for particular work roles within society. Traditionally, industrial arts-technology education programs have been narrowly perceived as focused on enhancing the preparation of individuals for skilled occupations. This narrow perception is a result of past experiences most adults have had with industrial arts programs while they were in school. They often saw industrial age practices applied in the context of skilled occupations, and the development of projects that could be taken home and used which required mastery of limited skills. The new technology education programs have attempted to change their focus but perceptions linger on.

The new focus on technological literacy is important to many societal groups. The 2061 Panel of the American Association for the Advancement of Science clearly indicated that the school curriculum must address technology education as a basis for helping students to prepare to enter scientific occupations, in addition to its being an essential ingredient in the education of all students.

The type of general technology education program being proposed not only has relevance to skilled occupations, but many professions. For example, engineering, architecture, physics, biological science, and environmental management can all benefit from the inclusion of a quality technology education program in the schools. All of these professions require sensory learning and "common sense" knowledge of technology, as well as language-based learning. They require an understanding of technological innovation and evolution. Just as math and science backgrounds developed in K-12 schools are important in those fields, so is technological literacy. Expanding the involvement of those professions in the development of a new technology education program will increase their support and ensure that the program is relevant to their needs. Therefore, the new technology education program should be presented to leaders in those professions as a vehicle for developing essential skills and knowledges helpful in preparing students to progress in their fields. If they are convinced the program will facilitate people entering and progressing in their fields, they will provide support to include the technology education in the school curriculum just as they have supported math and science in the past.

With support from the skilled trades which apply technology, the public who is interested in better understanding and working with technology, and the professions which apply and build upon technological literacy, technology education would have a promising future in the schools. Its expanded relevance and value would be apparent.

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