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ABSTRACT

This paper examines the relationship among technology, science, engineering, and mathematics in the context of education. It strives to shape a perspective on how future citizens should best be educated to live in an increasingly more complex technological world? The eight sections of the paper cover the following: (1) the history of technology, science, mathematics, and their relationships; (2) basic definitions of technology, science, engineering, and mathematics; (3) technology and science compared; (4) technology and engineering compared; (5) technology and mathematics compared; (6) the symbiotic relationships between and among technology, science, engineering, and mathematics; (7) the emergence of technology as an equal partner with science and mathematics as a school subject; and (8) individual discipline subjects versus an integrated curriculum. The paper recommends that technology become a fundamental core school subject that is equal in importance with science and mathematics in the schools worldwide in order to produce students who are scientifically, mathematically, and technologically literate to be prepared for the future. (Contains 36 references.) (KC)

The Relationship Between Technology, Science, Engineering, and Mathematics

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By

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Technology is the most subtle and the most effective engineer of enduring social change. Its apparent neutrality is deceptive and often disarming.
Robert MacIver

Technology has become a major force that transforms and adds new dimensions to our lives. It has become the predominant change agent in our lives today to such a degree that we wonder if it is getting out of hand. Technology can both create problems as well as solve them. A major question about the technological world is posed by the American Association for the Advancement of Science in its Project 2061 publication Technology when it states: "Who will develop and control the technologies so that they can best serve all citizens?" The answer to this fundamental question has to be, in a democratic society, a better educated citizenry who are technologically literate and capable. The school subject which can provide this fundamental education to all citizens in the future about the discipline of technology is technology education.

Technology education is a new subject area in the schools today. In most countries in the world, technology education is less than a decade old thus it is still in the developmental process. With the evolution of the discipline called technology, there naturally are some different opinions on what it is and where it should be taught. Some view technology as a part of science curriculum, while others think that it is more closely allied with engineering. Some countries place technology as a component of vocational education. Others believe that technology should be taught in an integrative manner with mathematics, science, social studies and other subjects (the science, technology, society -STS movement is a good example of this).

What should be the relationship between technology, science, engineering, and mathematics in education in the future? How should future citizens be best educated to live in an increasingly more complex technological world?

In the publication "America's Academic Future" which was a report of the National Science Foundation Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics and Science Education for the Year 2000 and Beyond, it was presented that our society in the next decade should be as follows:

> *We envision a society in which the public regards science, mathematics and technology as relevant to their personal lives. Engineers, mathematicians, and scientists are perceived by the public as vital to society, and scientific and technological literacy are well defined. Engineering, mathematics, and science concepts and contributions are communicated effectively to all segments of society, principally through formal instruction in our schools and universities but also through informal out-of-class educational opportunities and programs. The public can apply the principles of science to the solution of their everyday problems.*

What Does History Tell Us?

Technology is not about tools, it deals with how humans work.
Peter Drucker

Technology, science, and mathematics are all human enterprises; however, according to historians, technology far precedes science, engineering, or mathematics in their development. About 2.4 million years ago, the first recorded technology documented that humans created primitive tools using the process of chipping the edges away from stones. This research, which was done by Dr. Richard Leakey and others at the Koobi Fora site in northern Kenya, showed that our ancestors were creating these tools to cut with and to scrape the meat which was used for food. This process was also used to produce primitive clothing from animal pelts. This provided an early record of how we as humans adapted our natural world to modify and alter it in order to improve it. Over the millennium, we have refined this human capability to create, control, and solve problems.

We have become more than just being tool makers. Likewise, technology is much greater than the producer of artifacts which provide both comfort and clutter. In the book titled The Scientist (Margenau, 1964), it is stated that humans have pursued scientific knowledge since the Stone Age (5000-100,000 years BC). The first phase of this pursuit was **pragmatic experimentation** which was best characterized as discovery by trial and error. The second level of sophistication was **logical analysis and proof** which the Greeks developed. The third level was the evolution of the **scientific method** (1590-1690) which grew out of the brilliant works of men like Galileo, Kepler, Newton, Bacon, Gilbert, Boyle, van Leeuwenhoek, Huygens, Descartes, Harvey, Halley, Hooke, and others. In a response to an interested admirer, Albert Einstein once wrote a brief, but very insightful, response regarding the historical development of science as follows: "Dear Sir, Development of Western Science is based on two great achievements, the invention of the formal logical system (in Euclidian geometry) by the Greek philosophers, and the discovery of the possibility to find out causal relationship by systematic experiment" (which was the scientific method developed in the Renaissance period).

In a very real sense, civilization itself depends on the evolution of technology so aptly delivered through engineering. The record of ancient engineer's achievements is preserved in the surviving remnants of their work scattered throughout the world. Engineering had its formal beginning about 3000 years BC with the building of many temples, tombs, and pyramids along the valley of the Nile by the Egyptians. The largest of these is the Great Pyramid at Gizeh which stands today and is enjoyed as one of the greatest technological feats ever accomplished. The title: "engineer", however, was not created until the Middle Ages when the builders of battering rams, catapults, and other "engines" of war were called *ingeniators* by Latin writers. Engineering, along with the priesthood and soldiering, is one of the earliest professions to emerge after humans achieved civilization. (Furnas, 1966)

Mathematics had its beginnings when humans began to count with the invention of numbers. Prehistoric humans had very limited need to count. Later, about 10,000 years ago, nomadic Stone Age hunters became farmers because of the retreating glaciers. This caused a need for a system to keep up with such matters as when to plant; identifying the days and seasons; knowing how much grain to store and later to replant; and developing a monetary system (Bergamini, 1963). Much of what we do today mathematically is still based on the 10-based or "decimal" numbering system. This is named after the Latin word *decima*, which means tenth or tithe. Also, a numbering system using a 20-base (10 fingers and 10 toes) was developed and used over the centuries. Today, the binary (base-2) numbering system has allowed us to develop sophisticated digital computer systems which rely in microelectronic integrated circuits to perform mathematical computations with giga-second (.000000001 sec.) speed.

Some Basic Definitions of Technology, Science, Engineering, and Mathematics

In their simplest form, how can technology, science, engineering, and mathematics be defined? What are the school subjects that teach about these three disciplines?

There are many definitions of technology which can be found in the literature today. Many of these definitions are obtuse or complex. One of definitions which can be used when comparing technology to science or mathematics is:

> **"Technology is a study of our human created and controlled world and universe." (Dugger, 1993)**

Again, technology education is the school subject which teaches about how we, as humans, create the technological (non-natural) world around us. In the AAAS Project 2061 report titled, Technology, a recommendation is given that:

> *Technology education should reveal the process of technology as it evolves ideas to fruition. This can best be learned using laboratory experiences to augment classroom instruction. Likewise, such education should show how technology affects individuals and society.*
>
> *Technology education should be appropriate to the students' age and experience. It should begin with descriptive material and then involve principles and concepts, incorporating direct experience at all levels.*
>
> *Technology education that includes social impacts as well as the technics provides the opportunity to integrate the two in newly formulated curricula, possibly making increased use of teaching.*
>
> *The sciences and mathematics are important to the understanding of the processes and meaning of technology. Their integration with the technology education curricula is vital. (AAAS, p. 3)*

Currently, technology education is found in the educational systems in the world as both an elective course as well as a required course in grades K-12. Technology education should not be confused with "educational technology." The first teaches "about technology" while the latter teaches "with technology" and it is the media part of education. Science has been defined by the National Research Council in their work on developing the Science Education Standards and Assessment for the United States as follows:

> **"Science is a study of our natural world and universe" (National Research Council, 1992)**

According to the National Committee for Science Education Standards and Assessment of the National Research Council, science education or school science:

> *".... introduces young people to the scientific way of understanding our natural world. That aspect of school science content centered on science subject matter focuses on the body of information (facts, concepts, laws, theories) that the scientific community has developed in creating its interpretations of the natural world. (National Research Council, 1992, p6)*

This committee which is currently developing the science education standards, also states that the subject matter of school science should be limited to the traditional natural science disciplines of biology, chemistry, physics, earth and space sciences.

Engineering is defined by the Accreditation Board for Engineering Technology (ABET) as follows:

> **"Engineering is the profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind."**

In 1952, the American Society for the Engineering Education commissioned a study of engineering and published a report which had a profound influence on modernizing the education of engineers. This report which was titled the "Grinter Report" deemphasized the "art and practice" approach to engineering and provided more focus on the science of engineering. It called for: "an integrated study of engineering analysis, design, and engineering systems for professional background, planned and carried out to stimulate creative and imaginative thinking, and making full use of the basic and engineering sciences" (ASEE). Engineering has a symbiotic relationship between science and technology. The movement towards fundamentals created by the Grinter Report has emphasized both natural sciences and engineering sciences in engineering education. The teaching of the fundamentals and principles in engineering provide a stable core content in an ever changing technological world.

In the new draft copy of the American Association for the Advancement of Science, Project 2061 "Benchmarks for Scientific Literacy," a definition for mathematics is presented as:

> **"Mathematics is a study of all conceivable abstract patterns and relationships" (American Association for the Advancement of Science, 1993, Project 2061 Draft of Benchmarks for Scientific Literacy)**

The AAAS Project 2061 is in the process of producing a coordinated set of reform tools for educators to use in their efforts to achieve literacy in science, mathematics, and technology, as outlined in Science for All Americans. A component of these tools are the Benchmarks which are statements of what all students should know or be able to do in science, mathematics, and technology by the end of grades 2, 5, 8, and 12.

In 1989, The National Council of Teachers of Mathematics (NCTM) developed a set of national standards for the mathematics profession. The NCTM Standards state that schools must insure that all students must have an opportunity to become mathematically literate, are capable of extending their learning, have an equal opportunity to learn, and become informed citizens capable of understanding issues in a technological society. The Standards articulate five general goals for all students: (1) that they learn to value mathematics, (2) that they become confident in their ability to do mathematics, (3) that they become mathematics problem solvers, (4) that they learn to communicate mathematically, and (5) that they learn to reason mathematically. There are four major components which make up the standards which are: (1) standards for teaching mathematics, (2) standards for the evaluation of the teaching of mathematics, (3) standards for the professional development of teachers of mathematics, and (4) standards for the support and development of mathematics teachers and teaching.

Technology and Science Compared

Science and technology are different, yet there are symbiotic areas where both overlap and contribute to each discipline. Technology is much more than applied science and science is quite different from theoretical technology. When one alters the natural world using technology, it impacts both science and technology. Science is dependent upon technology to test, experiment, verify, and apply many of its laws, theories, and principles. Likewise, technology is dependent upon science for its research, laws, principles, and knowledge base.

What are the similarities and differences between technology and science? A comparison is provided in Table 1.

TABLE 1
COMPARISON OF TECHNOLOGY & SCIENCE

TECHNOLOGY	SCIENCE
Involved with our human created world.	Involved with our natural world/universe.
Concerned with "how to."	Concerned with "what is."
Knowledge created and being created.	Knowledge discovered or being discovered.
More directly involved.	Detached...Generates knowledge for its own sake.
Guided by trial and error or skilled approaches derived from the concrete.	Guided by hypotheses deduced from theory.
Concerned about the solution of problems and application of knowledge to that solution.	Concerned with reality and its basic meaning.

Used in combination with such words as: Application, Instrumental principles, Tools, Response to perceived needs, Artifacts, Practice, Effectiveness, Empirical laws, Invention, Innovation,	Used in combination with such words as: Theory, Theoretical principles, Research, Generalization from theory
Its success or failure is usually determined by social acceptance and success in the marketplace.	Its success is <u>not</u> judged by social utility.
Action oriented & requires intervention.	Research/theory oriented.
Involved constantly in studying means-ends relationships.	Remains separate from what is being investigated.
Systems oriented.	Laws/principles oriented.
Making/doing things.	Understanding things.
Philosophical relation: pragmatism.	Philosophical relation: realism.
Dependent on Science and Mathematics.	Dependent on Technology and Mathematics.

<u>Technology and Engineering Compared</u>

The comparison of engineering and technology indicate remarkable similarities. Many references use engineering and technology synonymously. Both engineering and technology treat solving practical problems as their philosophical nucleus. In fact, the "engineering design method" cited by Wright in his *Introduction to Engineering* text is the same problem solving method used in many technology books (1989). Engineering could be considered as a very refined area of study and professional endeavor of the broader discipline of technology. Herbert Simon suggested that science deals "with things the way they are" whereas, in technology [engineering], one deals "with things the way they ought to be."(1969).

Table 2 provides a juxtaposed comparison of technology and engineering.

TABLE 2
COMPARISON OF TECHNOLOGY & ENGINEERING

<u>TECHNOLOGY</u>	<u>ENGINEERING</u>
Involved with our human created and controlled world.	Involved with utilizing the materials and forces of nature for the benefit of mankind.
Concerned with "how to."	Concerned with "how to."

More directly involved.	Very specifically involved.
Guided by trial and error or skilled approaches derived from the concrete.	Guided by a more theoretical study with specific solutions recommended.
Concerned about the solution of problems and knowledge to that solution.	Concerned about the solution of problems and knowledge to that solution.
Used in combination with such words as: Application, Instrumental principles, Tools, Response to perceived needs, Effectiveness, Doing, Invention, Innovation, Empirical laws,Engineering, Design,...	Used in combination with such words as: Practicality, Vision, Ingenuity, Research, Design, Systems, Analysis, Application, Technology, Invention, Innovation,...
Its success or failure is usually determined by social acceptance and success in the marketplace.	Its success or failure is usually determined by social acceptance and success in the marketplace.
Action oriented & requires intervention.	Action oriented & requires intervention.
Systems oriented.	Systems oriented.
Making/doing things.	Building/producing things.
Dependent on Engineering, Mathematics, and Science.	Dependent on Technology, Mathematics, and Science.

Technology and Mathematics Compared

Mathematics provides us with the analytical tools needed to create, alter, build, and change our world and universe. Our civilization would scarcely exist without the technological processes and products developed as a by product of mathematical research. No one can build a wall or a constructed edifice without drawing on the techniques of geometric measurement developed by the Egyptian mathematicians. Classical mathematics, when rescued from the oblivion of the Dark Ages, helped ignite the adventurous spirit of the era of Columbus. The men who wrought the Industrial Revolution gained confidence in machines and what they could do from the partly mathematical, partly scientific investigations of Galileo and Newton.

It has been stated that both the essence of mathematics and the essence of technology is problem solving. The question is <u>how</u> each discipline goes about solving the problem and <u>what</u> type of problem each discipline solves.

How can technology and mathematics be compared? Table 3 provides a juxtaposed relationship between the two in order to help us see the similarities as well as the differences.

TABLE 3
COMPARISON OF TECHNOLOGY & MATHEMATICS

TECHNOLOGY	MATHEMATICS
Involved with our human created and controlled world.	Involved with patterns and their relationships.
Concerned with "how to."	Concerned with "analyzing or figuring out."
More directly involved.	Abstract.
Guided by trial and error or skilled approaches derived from the concrete.	Guided by analysis and logic.
Concerned about the solution of problems and application of knowledge to that solution.	Concerned with providing solutions to theoretical problems.
Used in combination with such words as: Application, Instrumental principles, Tools, Response to perceived needs, Artifacts, Practice, Effectiveness, Doing, Empirical laws, Invention, Innovation, Engineering, Architecture, Design,...	Used in combination with such words as: Analysis, Numbers, Shapes, Spatial relationships, Symbolic logic, Examine, Represent, Transform, Solve, Apply, Prove, Calculate, Estimate, ...
Its success or failure is usually determined by social acceptance and success in the marketplace.	Its success is <u>not</u> judged by social utility.
Action oriented & requires intervention.	Correct answer and predictability oriented.
Systems oriented.	Patterns, shapes, and numbers oriented.
Making/doing things.	Analyzing things.
Dependent on Mathematics and Science.	Dependent on Technology, Engineering, and Science.

The Symbiotic Relationships Between and Among Technology, Science, Engineering, and Mathematics

As it can be seen from the information presented in Tables 1-3, there is a symbiotic relationship between technology, science, engineering, and mathematics, with technology being held as the constant variable. Also, there is a very important interdependence among these areas of study.

In the book, *Engineering Fundamentals and Problem Solving*, the engineer is compared to the scientist as follows:

> *Both the engineer and scientist are thoroughly educated in the mathematical and natural sciences, but the scientist primarily uses this knowledge to acquire new knowledge, whereas the engineer applies the knowledge to design and develop usable devices, structures, and processes. In other words, the scientist seeks to know, the engineer aims to do.* (Eide, 1979)

In the words of Theodore von Karman: "Scientists explore what is; engineers create what had not been." (Beakley, 1982)]

Glegg contrasted the function of scientists and engineers as follows:

> *It seems fashionable to glamorize the position of the scientist and to imply that no other occupation is so rewarding in human, if not material, values. I do not think that this is true for several reasons. For instance, the engineer has the much wider horizon of possibilities. A scientist is lucky if he makes one real creative addition to human knowledge in his whole life, and may never do so.*
>
> *An engineer has, by comparison, almost limitless opportunities. He can, and frequently does, create dozens of original designs and has the satisfaction of seeing them become working realities. He is a creative artist in a sense never known by the pure scientist. An engineer can make something. He creates by arranging in patterns the discoveries of science past and present, patterns designed to fit the ever more intricate world of industry. His material is profuse, his problems fascinating, and everything hinges on personal ability.* (Glegg, 1969).

The study of technology and engineering is not possible without the study of the natural sciences. These in turn cannot be understood in depth without a fundamental understanding of mathematics because as Feynman has pointed out in his book, *The Character of Physical Law*, "Mathematics is not just another language. Mathematics is a language plus reasoning; it is a language plus logic. Mathematics is a tool for reasoning."

Science's main concern is analysis -- the breaking down of an entity into its most fundamental parts -- with the objective being the discovery of the laws of nature. Science is fundamentally reductionist in nature. With this in mind, taking a science course helps to develop one's convergent thinking processes. On the other hand, the primary essence of technology and engineering is synthesis or design in nature -- with the objective being the combining of separate elements into a whole. This is why the study of systems is a key component in the disciplines of technology and engineering. By studying technology and engineering, one develops his or her divergent as well as convergent thinking processes. This divergent/convergent thinking ability is crucial in learning how to solve practical problems as contrasted to just solving scientific, mathematical and other types of problems.

The future calls for well educated citizens who are able to use higher order thinking skills and creative abilities through the understanding and synthesis of technology, science, engineering, and mathematics to anticipate and solve the problems of tomorrow.

The Emergence of Technology as an Equal Partner With Science and Mathematics As a School Subject

There were a number of Commissions in the United States which evolved out of the 1980's which recommended the inclusion of technology education as a core subject in the schools of the future. The National Commission on Excellence report in 1983 summarizes well the depth and breadth of concern about current school and college conditions:

> *Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. . . .We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and as a people.(A Nation at Risk, 1983)*

Focusing particularly on elementary and secondary education in mathematics, science, and technology, the National Science Board (NSB) Commission on Precollege Education in Mathematics, Science, and Technology in the U. S. reported later in 1983:

> *Alarming numbers of young Americans are ill-equipped to work in, contribute to, profit from and enjoy our increasingly technological society. Far too many young Americans have emerged from the nation's elementary and secondary schools with an inadequate grounding in mathematics, science, and technology. . . .At a time when America's national security, economic well-being, and world leadership increasingly depend on mathematics, science, and technology, the nation faces serious declines in skills and understanding in these areas among all our youth. (Selby, p.157)*

With respect to new criteria for technology and science education, the National Science Board (1983) commission recommended in part:

> *Students must be prepared to understand technological innovation, the productivity of technology, the impacts of the products of technology on the quality of life, and the need for critical evaluation of societal matters involving the consequences of technology. Further, the nature of scientific inquiry and observation presents frequent opportunities for experiencing success. Such inquiry does not require unique answers. Students can rightly and successfully report what they have seen and found. This type of experience should be encouraged. (Selby, p.163)*

Cecily C. Selby, who was Co-Chair of this National Science Board Commission in Science, Mathematics, and Technology stated that the Commission recommended criteria for improving and changing instruction in the sciences with emphasis being placed on observation, student inquiry, and "hands-on approaches to learning." She also stated that:

> *The commission report recommends that technology should be included in the curriculum of kindergarten through grade 12 as a topic integrating science,*

> *mathematics, and other fields of study-not as a separate subject in the curriculum. . . .Coupled with objectives for the development of student skills must be a clarification of the essence of these subjects-what is the nature of the mathematics, science, and technology that should be understood? Study after study indicates that, through school and college (always, of course, with notable and most precious exceptions), we have been communicating science as a factual, difficult, textbook-bound subject governed by "known facts" and something rigidly defined as "The scientific method" -the keys to this kingdom being discipline centered courses which are as effective in locking students out as in inviting them in. (Selby, 1984)*

The National Science Board commission report, cited previously, recommended that the nation's educational systems, both formal and informal, should have the capacity:

1. *to continue to develop and broaden the pool of students who are well prepared and highly motivated for advanced careers in mathematics, science, and engineering;*
2. *to widen the range and increase the quality of educational offerings in mathematics, science, and technology at all grade levels so that more students would be prepared for, and thus have greater options to choose among, technically oriented careers and professions; and*
3. *to increase the general literacy in mathematics, science, and technology of all citizens for life, work, and full participation in the society of the future.*

Selby (1984) stated strongly that all these goals require new objectives for mathematics and science education and the addition of technology education---a newcomer to the liberal arts tradition.

The Committee on Education and Human Resources (CEHR) of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) states that all..."Citizens of the future must be equipped to make informed decisions in this age of rapidly developing knowledge, changing technology, sophisticated information, and communication systems. Accordingly, America's performance in science, mathematics, engineering, and technology must be second to none in the classroom and the workplace." (NASA, 1993)

Individual Discipline Subjects Vs. An Integrated Curriculum

If it is agreed that scientific, mathematical, and technological literacy is needed by everyone, how should this best be done through our educational system? What should be the academic boundaries of school science when compared to technology, mathematics, engineering, social sciences, and other school subjects? In many countries in the world, separate school subjects are usually taught at the secondary level while a more integrated approach to curriculum takes place at the primary or elementary school level. Even so, many teachers at the primary level teach subjects in disciplinary compartments or units with very little integration taking place. Some educators say that this approach is not reflective of life which is more multi-faceted and articulated.

In the Discussion Document of the National Committee for Science Education Standards and Assessment of the National Research Council (Oct. 1992, p. 4), it was recommended that in school science, "...the subject matter be generally limited to the natural sciences. The traditional disciplines--biology, chemistry, physics, earth and space sciences--are the intellectual territory from which the content of school science is drawn. Such a perspective dictates in large measure the structural organization (by discipline) of the science content. (Content as it is used here refers to the disciplines' intellectual products--concepts, principles, laws, theories, modes of reasoning, methods of inquiry, philosophical foundations, and historical development.)"

This National Research Committee on Science Education Standards and Assessment goes further to state that, "...understanding the complex interrelationships of science, technology. engineering, and society can only be attained when each is understood in its own right. Consequently, we believe that:

1. developing understanding of the concepts of society and culture is primarily the responsibility of the social studies curriculum;
2. developing understanding of the concepts of engineering is primarily the responsibility of the technology education curriculum; and
3. integrating these with science is the joint responsibility of the school science, social studies, and technology curricula." (National Research Council, 1992, p. 5)

Thus, this Commission is strongly recommending that science be taught as science by endorsed or certified science teachers (or in its historical disciplines such as biology, chemistry, physics, etc).

Another significant recommendation of this committee is that the concepts of engineering should be taught by the technology education curriculum in the primary and secondary school level, grades K-12. This will involve a major involvement and commitment of the engineering profession with technology education to develop and deliver this new curricular effort. Historically, engineering has had limited involvement with education at the primary and secondary school levels. This could provide a fertile ground for infusing engineering concepts at these levels. Also, it may provide a valuable recruiting tool for the engineering profession in the future. If this recommendation is to become a reality, collaborative efforts between engineering, technology education, and other school subjects such as science becomes a mandate. The leaders in the engineering profession must work with the leaders in technology education to forge new efforts to teach basic engineering concepts to all students in kindergarten through high school. If this alliance can be created, much will need to be done to develop a long term goal for what should be a direction and a vision for the intellectual content for the new "Engineering and Technological" curriculum. Both professions will have to work together to get the support of business, industry, governmental agencies, and others for this new pioneering educational effort. Crucial to the success of this alliance will be the creation of a new set of curriculum content standards for grades pre-K through 12 plus standards for developing exemplary teacher preparation programs (hopefully in conjunction with Colleges of Engineering in major universities). Efforts must also be undertaken by both the engineering and technology education professions to develop evaluation tools to assess whether students are properly learning the curriculum set forth in the standards. Historically, engineering has had limited involvement with education at the primary and secondary school levels. If engineering education could work with technology education to develop an alliance, it could provide a fertile ground for infusing engineering concepts at these levels. The alliance should provide a mechanism for greater appreciation and understanding of engineering and technology both as professions as well as disciplines. A more literate citizenry in the concepts of engineering and technology could assist this country in regaining its place as the world's leader in technology.

In another recommendation, the National Research Committee on Science Education Standards and Assessment stated that the integration of school science, mathematics, social studies, and technology curricular should be the joint responsibility of these school disciplines. This would be an excellent strategy at the primary school level using a thematic approach to the curriculum. An example of this can be found in the NASA funded program at Virginia Tech for primary school children titled, "Mission 21" which uses themes to encourage problem solving and creative thinking. Examples of these Mission 21 themes are shown in Table 4.

TABLE 4
MISSION 21 PROBLEM-SOLVING THEMES

Pre-K and K	Grades 1-2	Grades 3-4	Grades 5-6
Tools	Transportation	Machines	Communication
Toys	Explore	Discovery	Space Colonization
	Design	Community	Invention
	Space	Connections	Energy and Matter

In Mission 21, the elementary teacher is encouraged to use this material as an integrative web to tie together science and technology with mathematics, social studies, language arts, and humanities. Most themes can be used on a short term basis (for 2 days to 2 weeks) as a motivational approach to teaching. (LaPorte, 1992)

Another effort to integrate technology, mathematics, and science is the "Make The Connection" Project at Virginia Tech which has been sponsored by the Virginia Space Grant Consortium. This project conducted four workshops for 333 math, science, and technology teachers in Virginia along with their administrators to learn how to integrate these subjects together.

At the middle school level, there are already two research efforts funded by the National Science Foundation to integrate science, mathematics and technology. One of these is located at Illinois State University and it concentrates on integrating science, technology and mathematics at the 6th grade level. The second NSF funded project is at Virginia Tech and it has developed over 40 activities for the technology, science, and mathematics teachers to integrate their subjects at the middle school level (grades 6-8). This project is currently field testing these activities nationally. Other integrative approaches at the middle school level can be found in such innovative courses as "Innovation and Invention" and "Technological Systems."

A good model for the high school may be what Virginia is doing with some of its upper secondary school courses (usually grades 11 and 12) in "Introduction to Engineering" which are taught in secondary school programs by technology teachers.

The following recommendations are provided for the future:

1. A research agenda needs to be established on what are the norms for technological, mathematical, engineering, and scientific literacy.

2. The science, mathematics, engineering, and technology professions must together become actively involved together in developing joint curricular which assures that all pupils are technologically, mathematically, and scientifically literate and capable for the future.

3. The technology education profession must work closely with the science, engineering, and mathematics professions to assure that technology is placed in the school curriculum as a required subject.

4. In teacher preparation, the science, mathematics, engineering, and technology education professions must work to prepare teachers who are qualified to teach their subject matter areas either in an integrated fashion or as a single discipline.

5. Efforts must be initiated to provide a comprehensive in-service program for existing teachers to create a climate for effective change in the curriculum related to the integration of science, mathematics, engineering, and technology in grades K-12.

6. Governmental agencies, worldwide, need to be convinced that creative problem solving and discovery oriented student learning presented in technology education must be taught at all levels to all students.

7. The science, mathematics, engineering, and technology professions must become actively involved in developing quality standards and assessment for integrated curriculum.

Summary

In an article titled, "The Quite Path to Technological Preeminence" by the current United States Secretary of labor, Robert B. Reich states that if a country wishes to gain (or return to) technological preeminence in the global workplace, it must:

*Scan the globe for new insights,
*Integrate government-funded research and development with commercial production,
*Integrate corporate research and development with commercial production,
*Establish technological standards
*Invest in technological learning, and
*Provide a good basic education to all citizens. (Reich, 1990)

Reich goes further to say that "in addition to conveying basic skills, primary and secondary school curriculums must emphasize critical thinking--a capacity to identify problems, raise questions, and find structure in apparent disorder--rather than the mere regurgitation of facts." What better mechanism for this to be accomplished than through technology education working with science, engineering and mathematics in forging new, exciting, and relevant areas of learning for the future

This paper has laid the foundation for the importance of technology, mathematics, engineering, and science as school disciplines. Mathematics and science have a long term history as being required core subjects in the schools. It is strongly recommended that technology become a fundamental core school subject which is equal in importance with science and mathematics in the schools worldwide. Further, all pupils must be scientifically, mathematically, and technologically literate and capable to assist them in making wise decisions and choices as the trustees of the future.

Make no little plans. They have no magic to stir men's blood; and probably themselves will not be realized. Make big plans; aim high in hope and work. Remember that a noble, logical diagram once recorded,will not die.

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