A Century of Perspectives that Influenced the Consideration of Technology as a Critical Component of STEM Education in the United States

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ABSTRACT

Technology and engineering education is recognized as a way to integrate disciplines, such as math and science, using hands-on learning activities to solve problems. Doing so helps students become technologically literate and work productively in society. Historically, many different views evolved regarding the need for instruction related to technology and technical processes. Numerous systems and methods were devised to achieve this goal in the United States. During the early part of the 20th century, a number of education professionals theorized about the implications of technology as it related to the study of industry.

These leaders eventually declared technology as integral to their field. Especially during the period of economic growth that followed World War II, many considered the study of technology, and the man-made world, a vital concern in the curriculum of industrial education. Increased foreign competition, characterized by events such as the launching of the first Soviet "Sputnik," resulted in private support and government initiatives for improvement in education, particularly math and science, but eventually in other content areas, including industrial education.

In the 21st century, the study and integration of technology is accepted as a key component in the Science, Technology, Engineering and Mathematics (STEM) movement. Familiarity with the evolution of general education related to technology in the United States helps us understand the rationale behind the inclusion of technology in the STEM acronym. This historical review identifies key perspectives and practices that led to the inception of technology education at the end of the 20th century – which, in turn, contributed to the integrated STEM movement. But what is the impetus for including "technology" in STEM education? What is the role of technology and engineering in STEM education?

Keywords: STEM, education, technology, engineering, history

The Influence of Technology Identified within Industrial Education

As early as 1917, Charles Bennett referred to the effects of technology on people in his book *Manual Arts*, containing this excerpt:

> … industrial development has been so rapid and so varied in our country–it has affected every man's life to such an extent that if he is to retain sufficient mastery of his environment to make it serve his needs, he is forced to acquire considerable practical knowledge of the materials, principles, and processes of industry. (1917, pp. 14-15)

This rationale for the study of industry was based upon the need for people to adapt to changes caused by society's industrial growth. Bennett's reference to mankind's "mastery of his environment to make it serve his needs" could be considered plausible as an explanation for technology.

John Dewey authored strong opinions about the growth of industrial education throughout his lifetime, during which the United States entered the Machine Age. The industrialization of the late 19th century and acceleration of technology Dewey witnessed had a decided impact on his educational philosophy. In *Democracy and Education*, Dewey stated:

> Industry has ceased to be essentially an empirical, rule-of-thumb procedure, handed down by custom. Its technique is now technological: that is to say based upon machinery resulting from discoveries in mathematics, physics, chemistry, bacteriology, etc. . . . As a consequence, industrial occupations have infinitely greater intellectual content and infinitely larger cultural possibilities than they used to possess. The demand for such education as will acquaint workers with the scientific and social bases and bearings of their pursuits becomes imperative, since those who are without it inevitably sink to the role of appendages to the machines they operate. (1916, p. 314)

In the book, *John Dewey's Pragmatic Technology*, Hickman said of Dewey: "… he sought to demonstrate that the methods and means by which technological inquiry take place *are* the methods and means by which all knowing, in its 'honorific' sense, is generated" (1990, p. 4).

The "industrial-social theory," influenced by Dewey and posited by James Russell and Gordon Bonser, was intended to provide intellectual investigation of a wide range of endeavors typifying the industrial processes that provided for basic human needs and were thus technological in nature. Consider this passage from the 1923 Bonser-Mossman definition of industrial arts: "… *a study of the changes made by man in the forms of materials to increase their values, and of the problems of life related to those changes*" (Bonser & Mossman, 1923, p. 5). C. Lemons wrote, "this definition may be the first documented reference to the technological society as a purpose for teaching industrial arts" (1988, p. 59).

In 1934, Maris Proffitt described what he considered essential "functions of industrial arts." Among the functions suggested by Proffitt was the following study of material cultures:

> A study of material cultures of American society in a perspective of great world civilizations will reveal a fundamental origin of industrial arts. This origin refers to elements of utility, efficiency, and beauty in things that have been developed and used by man throughout history. This origin more than any other distinguishes industrial arts as a broad subject of study. (Cited in Anderson, 1940, p. 234)

Proffitt's reference to a "fundamental origin of industrial arts" seems to be a search for a professional motive and the second sentence of this passage is comparable to modern definitions of technology as physical elements.

In 1935, A. Swope viewed industry as incidental to the principles of science. He reasoned that "it is conceivable that we may as a nation depart on some other avenue of adventure than the application of scientific principles which were formulated two or three generations ago to industrial life primarily." Swope also believed that we would progress beyond industrialization and he felt that "our training in school might be the means of adapting the child to see beyond these horizons" (cited in Lemons, 1988, p. 56). Swope was confident that technological advancement would occur, and he suggested that educators could address the needs of students related to such change.

In January 1940, The *Phi Delta Kappan*, printed a special issue dedicated entirely to the topic "Industrial Arts in General Education." In this issue, Albert Siepert, William Warner, and other leaders of industrial arts education attempted to clarify the mission of industrial arts. Siepert, the Dean of Education for the Bradley Polytechnic Institute in Peoria, Illinois, authored the initial article titled "Philosophy," in which he stated:

> If industrial arts teaching is to acquaint the school pupil with the products of industry, if the purpose is to orient the individual whose life is to be spent in a world so much dependent upon technology, then first-hand experience appears to be essential. (1940, p. 235)

Here again, Siepert identified the substantial influence that technology can have on society and the individual. His predominant point was that by providing "hands-on" experiences, industrial arts readily facilitated learning that would prepare students for life in a technological society.

The Curriculum to Reflect Technology

The aftermath of World War II, including the rapid economic growth and advancement of technology caused by that event, contributed to a new perspective on the instruction of industrial arts. For several years following the war, various leaders in the profession encouraged teachers to modify their programs by, as Meyer put it, "grasp[ing] the technological bull by his educational horns" (1951, p. 16). Discourse of this nature was motivated by a momentous effort that not only focused on the concept of technology, but also provided a means to develop programs with an emphasis on technology within the context of industry.

In April, 1947, a new interpretation of industrial arts, initially referred to as "The New Industrial Arts Curriculum," was imparted by William Warner, Joseph Gary, Carlton Gerbracht, Harold Gilbert, John Lisack, Paul Kleintjes, & Kenneth Phillips. Warner, who had served in the war, introduced this new plan at the eighth annual American Industrial Arts Association (AIAA) convention held in Columbus, Ohio. For Warner, it was the next logical step in the advancement of his philosophy and practices. In *A Curriculum to Reflect Technology*, Warner and his protégés defined industrial arts as follows:

> *Functionally*, industrial arts as a general and fundamental school subject in a free society is concerned with providing experiences that will help persons of all ages and both sexes to profit by the technology, because all are involved as *consumers*, many as *producers*, and there are countless *recreational* opportunities for all. (Warner, Gary, Gerbracht, Gilbert, Lisack, Kleintjes, & Phillips, 1965, p. 41)

Dwight Curtis wrote a review of Warner's conference presentation that was printed in the June 1947 issue of *The Industrial Arts Teacher*. He commented, "the presentation by Dr. Warner, and the interpretations that followed, completely redefined the position of industrial arts in general education in the public school, and solicited both re-evaluation of the present program and consideration of the implementation of the new" (p. 1).

Delmar Olson said of this effort, "it was too far ahead of the times to gain general acceptance, but like all advance thinking it has had its impact on the profession" (1963, p. 15). Warner, himself, had a different feeling about the acceptance of the project as evidenced by the following, which he wrote retrospectively:

> The result, as herein reported, was featured at the AIAA Convention of 1947 which I revived in Columbus, Ohio, following World War II, and where we were fearful of the outcome until the discussions which followed, when our findings were not only accepted, but praised on all sides. (Warner et al., 1965, p. 5).

Eventually, "The New Industrial Arts Curriculum" became known as *A Curriculum to Reflect Technology*, with content "derived via a socioeconomic analysis of the technology and not by job or trade analysis as of old…." (Warner et al., 1965, p. 41). It included six subject matter classifications: Power, Transportation, Manufacturing, Construction, Communication, and Management.

Thomas Latimer summarized:

> For the most part, it remained a proposal, probably because Warner did not have the funds to promote and enhance it nationally. The plan was probably too far ahead of its time . . . .
>
> Even though the curriculum was never totally implemented, today there are many elements of *The Curriculum to Reflect Technology* present in educational systems throughout the United States. (1981, p. 48)

Indeed, there is evidence of the influence of Warner's Curriculum in the content of programs nationwide. However, there were many other efforts to identify technology as integral to industrial arts during the late 1940s and through the 1950s.

Appeals for a New Approach to Industrial Arts

In 1948, at the ninth annual AIAA conference held in Washington DC, a resolution on "The Impact of Technology" was authorized by the Association. From that resolution comes the following excerpt:engineering education.

> Whereas, certain of the school subjects such as industrial arts have not kept pace through adequately orienting all Americans to cope with the problems involved, now therefore, be it RESOLVED, that the industrial arts profession as represented by the AMERICAN INDUSTRIAL ARTS ASSOCIATION and its affiliates, as well as all the federal, state, and local agencies concerned, be stimulated to interpret and implement the issues, the subject matter, and the means involved, in order that all Americans may more readily adjust to and enjoy the potentialities of a good life made possible through an ever-expanding technology. (AIAA, 1948, p. 2)

Also in 1948, Walter Williams, Jr., Professor at the University of Florida and Vice President of the AIAA, declared "Industrial Arts Faces a New Era." In an article for *The Industrial Arts Teacher*, Williams observed:

> For a time the true educational concept of industrial arts was lost, and its position was relegated to a secondary place in the scheme of general education. Now, under

> the pressure of a complex technological society the narrow view of the manual arts concept is fast giving way to a more comprehensive and flexible interpretation of industrial arts or technology. That a crucial need exists for technological literacy is apparent. . . . (p. 1)

Gordon Wilber, the ninth President of the AIAA, was another educator with timely insight. He referred to the influence of technology in his book *Industrial Arts in General Education*, when he defined industrial arts as "…those phases of general education which deal with industry–its organization, materials, occupations, processes, and products–and with the problems resulting from the industrial and technological nature of society" (Wilber, 1948, p. 2). Wilber also expressed the conviction that education was critical to the development of technology by stating: "if society did nothing more than transmit its culture there would be no progress or improvement. Education has the further objective, therefore, to provide for extending and improving the way of life" (p. 6). This could be accomplished, he believed, through instruction that challenged the critical thinking skills of students.

In 1951, Harvey Meyer, Associate Professor at the University of Florida–Gainesville, asked of his peers, "Industrial Arts - What Next?" Meyer knew that "every boy and girl, regardless of present interest or future occupation, is forced to an acquaintanceship with the products of technology." As a result he felt that, "work with materials and toward a grasp of technology needs to be a part of the experience of every boy and girl" (p. 15).

Meyer recognized that "as teachers of industrial arts, a field yet young in education, we have groped for truth and sought our role in leading youth toward a real and functioning technological literacy." Meyer continued, stating:

> Our problem is not that of substituting something new for something old. It is not to discard the *classics* in the interest of the technics–or this will destroy both. Our task is to provide the cultural matrix of the arts, the sciences, and the humanities so that the equally cultural technologies can find their rightful place and make their vast and vital contribution. (Meyer, 1951, p. 16)

Through the 1950's, Meyer maintained an interest in the role of technology in industrial arts and had begun to consider technology as fundamental to the profession. The following passage from his article, titled "Creed, Deed, and Need," is an example of how his thought had progressed:

> *As has been pointed out in these pages before, basic science can do a great deal in the initial stages of any development; but in the final analysis, it is technology that puts the findings of basic science to work.* Unless the children in our schools and the young people entering college have a real and vibrant grasp of what is involved in technology, it is indeed doubtful if they can take full advantage of the technological progress now so imminent and so necessary. (Meyer, 1959, p. 17)

In 1954, John Whitesel, a former president of the AIAA, was elected president of the American Council on Industrial Arts Teacher Education (ACIATE). As the newly elected president, he expressed hope that industrial arts professionals could redefine "the contributions of industrial arts in a modern program of education, and redesigning the program of industrial arts in an effort to make the fullest contributions possible in the light of present day technological needs" (1954, p. 9). The following year, Burl Osburn, the twelfth President of the AIAA and Department Head of Industrial Arts at the State Teachers College in Millersville, Pennsylvania, addressed the National Education Association Assembly held in Chicago on July 4, 1955. His speech, "Industrial Arts in Modern Education," clarified the status of Industrial Arts for members of other NEA organizations.

> We can begin to see, therefore, that as method industrial arts education is the directing of experiences in the transmission and improvement of man's control of forces and materials for the enhancement of personal-social living. As a subject it is concerned with the processes of producing goods and their personal and technological effects. (p. 8)

Here, the method of industrial arts was identified as an effort to guide learners toward bettering their lives and their environment.

In 1958, at the annual meeting of the National Society of College Teachers of Education and the American Association of Colleges for Teacher Education, the ACIATE sponsored a symposium titled "Industrial Arts Teacher Education for a Technological Era." Many well-respected individuals participated in a major session on the topic of "Curricular Innovations for an Age of Technology." This session dealt with such concepts as quality control, mass production, group experiments, and the idea of providing service to science and other subject areas. This symposium occurred shortly after the Soviet Union launched its "Sputnik" satellite in 1957. President Dwight Eisenhower established the National Aeronautics and Space Administration (NASA) in 1958 and challenged Americans to respond to the "space race" by becoming leaders in science, technology, engineering, and math.

Early Curriculum Efforts Organized Around Technology

In the late 1950s, Donald Maley organized what became well known as *The Maryland Plan*. This plan initially concerned itself with instructional methods developed through an analysis of human needs. By the 1960's this plan grew into a major curriculum project based on three assumptions:

> 1. Industrial arts is a cultural experience dealing with a comprehensive and in-depth study of one of the most dominant forces (technology) in the contemporary society.
> 2. Many of the content items for industrial arts have persisted throughout the history of mankind as matters of vital importance and primary cultural focus in the evolving societies.
> 3. There is an increasing void in education with respect to the understanding of industry and technology as dominant cultural factors. (Cited in Cochran, 1970, pp. 80-81)

The critical focus on the development of the learner was the primary instructional emphasis of *The Maryland Plan*; however, the content base was drawn from both industry and technology. According to this plan, the study of the organization, materials, occupations, processes, and products of industry remained constant in the subject matter. Yet, technology was considered the core around which industry had grown. Regarding *The Maryland Plan*, Cochran stated:

> The rationale for such a program was based upon the fact that the secondary school curriculum was dominated by mathematics and science, and the significant role of technology in the society was being overlooked. As a result, a concerted effort was made to develop a program based upon the integration and application of mathematical, scientific, creative, and manipulative abilities of youth. (1970, p. 80)

The appreciation of past technologies was to be enhanced through activities utilizing an anthropological approach. Students would also identify and confront the problems of living in an industrial and technological society. Essentially, *The Maryland Plan* blended the positive aspects of both the industry-based and the technology-based positions. That this was intended is apparent in Maley's later definition of industrial arts published in 1973:

> Those phases of general education which deal with technology, its evolution, utilization, and significance; with industry, its organization, materials, occupations, processes, and products; and with the problems and benefits resulting from the technological nature of society. (Maley, 1973, pp. 2-3)

Also, *The Minnesota Plan for Industrial Arts Teacher Education* was published in 1958. This proposal, developed at the University of Minnesota, contained recommendations for improving the preparation of industrial arts teachers. Suggested changes involved a revision of the industrial arts subject matter to include individualized instruction in three "cores of experience:" science-mathematics, technology, and design. Meyer expressed a highly favorable opinion of *The Minnesota Plan* as follows:

> They develop in this curriculum such items as industrial orientation, materials, a great deal of design, studies of power, studies of wave motion, chemistry and metallurgy, and in general depart rather radically yet apparently quite soundly from the normal and traditional industrial arts program. This is something we need to explore. (1959, p. 17)

Also, Olson said this plan "should be considered as one of the significant contributions to teacher-education curriculum development in the second half of the century" (1963, p. 16). *The Minnesota Plan* contributed dramatically to the revision of industrial arts teacher education programs across the nation.

Original Technology-based Programs

During the 1960s, primarily two people guided the focus on technology as a theme for curriculum development in industrial arts. Delmar Olson and Paul DeVore each based his identification of content for industrial arts, to some degree, on separate analyses of technology. In 1957, Olson completed his graduate studies at The Ohio State University. His dissertation, *Technology and Industrial Arts: Derivation of Subject Matter from Technology with Implications for Industrial Arts*, included a proposal for an industrial arts curriculum "derived from an analysis of contemporary industry and reflective of technology. . . ." Published through the backing of the honor society Epsilon Pi Tau, this proposal was considered as a plan, for the first time, by participants in the 1959 Virginia Industrial Arts Association conference (Olson, 1957, pp. 15-16).

In 1963, Olson, a professor of industrial arts at Kent State University, authored the book *Industrial Arts and Technology,* which improved upon his dissertation and focused on the need for a major change in the curriculum. In his book, Olson specified six functions of industrial arts derived from the technological culture and man as the creator and user of technology. Olson identified the sources that influenced the selection of his functions, likening them "to the outcomes of industrial arts as seen by Bonser and Mossman" and "the purposes of industrial arts as expressed in the *Ohio Prospectus*" (p. 165). In his article "Curriculum Movements in the 1960's," Daniel Householder (1979) said of Olson's plan: "his six functions for industrial arts: technical competence, occupational orientation, consumer competence, recreational liberation, cultural appreciation, and social competence, required a thorough understanding of technology" (p. 120).

Ronald Todd has stated: "Olson was the first to grapple with the difficult problem of identifying the new content structure of industrial arts if it were, indeed, to reflect technology" (1991, p. 20). Olson's analysis of technology, in *Industrial Arts and Technology*, was particularly noteworthy for the following explanation of the relationship between industry and technology:

> Now study is defined as careful examination, investigation, inquiry, and research in order to determine the facts. And a science is defined as systematized knowledge derived from study, observation, experiment, and test. A broad interpretation of industry considers it as the system of enterprises for the development, production, and utilization of material goods and services by which a people gain control over their physical environment. Through rather logical deduction, then, technology becomes the science of industry. (1963, p. 55)

Olson's consideration of technology was rational and quite thorough. Yet, as unique as this approach was, Olson maintained the model of industrial arts as a study of industry. "Consequently," stated Olson, "we study industry to learn about technology, its techniques, skills, processes, products, services, and occupations" (1963, p. 55). Olson's early reasoning was revolutionary, but it did not break the mold that was the basis for traditional industrial arts programs.

Later in his career, Olson made it clear that he considered technology a body of knowledge equal to other content areas in general education. In 1971, he authored an article titled, "Technology, Environment, and Industrial Arts" in which he stated:

> Industrial Arts education now takes responsibility for a basic, fundamental education, which every American needs because he lives in a technological environment. To interpret means to bring out the meaning of, and to do this technology becomes the discipline and the curriculum for industrial arts education…. We call it a new industrial arts. (p. 15)

In 1973, Olson, then Coordinator for Graduate Study in Industrial Arts at North Carolina State University, authored a publication titled *Technol-o-gee*. In it, he stated, "industrial arts, a discipline in general education, is the study of the technology" (1973, p. i). He also wrote: "industrial arts being a discipline serves a multi-faceted role among the academics as it functions within the context of general education with its body of knowledge representing the technology. It has its own identity, integrity, and responsibility" (1973, p. 6).

Though Olson originated the concept of analyzing technology to determine the functions of industrial arts, it is evident that his early analysis of technology was to be utilized primarily within the context of a study of industry. However, Paul W. DeVore, a former student of Olson's, contemplated the role of technology in industrial arts on a much broader scale.

DeVore taught industrial arts at the secondary level, later joined the faculty of Grove City College, and in 1956 was hired by the State University College, Oswego, New York. By 1960, he had become the director of the reputable industrial arts division at Oswego.

While at Oswego, DeVore's thinking about technology intensified. In 1964, the first annual report on the national convention of the AIAA, titled New Directions for Industrial Arts, was published. At that conference, DeVore made a presentation titled Technology: A Structure for Industrial Arts Content. In this address, he stated, "the efforts of the profession have failed to establish this area of education as an intellectual discipline" (DeVore, 1964b, p. 78). This statement was backed by his earlier effort to determine exactly what comprised an intellectual discipline. In Technology: An Intellectual Discipline, DeVore posited the following definition of a discipline:

An intellectual discipline:

1. has a recognizable and significant tradition, an identifiable history.
2. has an organized body of knowledge which has a structure with unity among the parts…
3. is related to man's activities and aspirations and becomes essential to man by addressing itself to the solution of problems of paramount significance to man and his society,
4. identifies as a part of its tradition and history a considerable achievement in both eminent men and their ideas, and…
5. relates to the future of man by providing the stimulation and inspiration for man to further his ideals and to reach his goals. (DeVore, 1964a, p. 10)

DeVore found that technology fit the criteria to be considered an intellectual discipline in all but one aspect. The exception was that, to that point, no structure had been established for the organization of the content, or body of knowledge, for the study of technology. Thus, he proposed that technology be organized into seven areas: construction, communication, manufacturing, transportation, research and development, organization and management, and craft and service industries (DeVore, 1964a, p. 15). These organizers were similar to the classification scheme by Olson in the industry analysis from *Industrial Arts and Technology*.

On the final page of *Technology: An Intellectual Discipline*, DeVore issued a challenge to his colleagues in the profession. He wrote:

> Those engaged in industrial arts education face a challenge. The challenge is simply stated. Educate the youth of today for a culture dominated by technology.
>
> This is the challenge and the opportunity. To accept the challenge and to take advantage of the opportunity industrial arts educators need only address themselves to the study of the organized body of technological knowledge. (1964a, p. 15)

DeVore's perception of technology as a discipline was not without its critics. Anderson and Olstadt commented:

> Those in industrial arts who feel that technology is the more appropriate body of knowledge have not analyzed all of the knowledge associated with technology. They have not structured the understanding necessary to understand technology. They have, rather, categorized different types of technology. This is not an unnecessary step or an unimportant activity. It is, in fact, one of the first steps necessary in the development of a body of knowledge. What has been developed is a vertical approach to the study of technology. (1971, p. 248)

Amidst the nationwide development of curriculum, DeVore's proposal also came under fire for not supplying a clear means to implement his new schema. In response, he prepared taxonometric principles to determine areas of technology that could apply to the structure of industrial arts. DeVore also explored methods for implementing the study of technology in public schools. Much of that work was accomplished during the 1965-66 academic year, when he took a sabbatical–which he spent at the University of Maryland.

The following year, DeVore moved on to West Virginia University, where he was allowed a great deal of freedom to study technology. In 1968, he authored a monograph, titled *Structure and Content: Foundations for Curriculum Development*, based on his work while at the University of Maryland. In his taxonomy, DeVore broke the study of technology into two broad elements – technical and cultural-social – that each led further into a series of hierarchical elements. The second level of the hierarchy for technical elements consisted of production, communication, and transportation.

In *Structure and Content: Foundations for Curriculum Development*, DeVore voiced his support of the study of "man and technology" as an alternative foundation for the industrial arts curriculum. The study of man and technology was to be primarily "concerned with man as the creator of technology regardless of national origin" (1968, p. 2).

DeVore pointed out that technology studies would be suitable to the goals of general education and would be an area of knowledge readily addressed as a discipline. This new approach was also expected to provide a meaningful relation between technology and the historical, anthropological, social, and economic aspects of our culture. DeVore further asserted that a discipline is essentially a body of knowledge that meets the following criteria: it must be dynamic, cumulative, theoretical, structural, and integrative (1968, pp. 4-5). DeVore later declared:

> The study of the creation and utilization of adaptive means, including tools, machines, materials, techniques, and technical systems, and the relation of the behavior of these elements and systems to human beings, society, and the civilization process is the field of study known as technology. (1980, p. xi)

It is important to recognize that this entire schema relied on the assumption that society would accept the premise of three bodies of knowledge (the humanities, the sciences, and the technologies) being integral to the development of general education programs (DeVore, 1968, p. 16).

Technology Identified as the Future Direction within the Profession

In 1972, the ACIATE sponsored an ad hoc "Committee for the Study of the Future." One goal of the Committee was to generate a yearbook dedicated to the topic of futurism and the future of industrial arts. This was achieved in 1976 with the publication of the 25th yearbook titled *Future Alternatives for Industrial Arts*. Chapter five, "Implications for Industrial Arts," was of direct interest to the profession. The authors, DeVore and Donald Lauda, cited eight implications the study of the future would have for industrial arts. The first declared, "if industrial arts is to contribute to the study of the future, then the most appropriate discipline base is the study of technology" (1976, p. 142). Other implications involved necessary changes in facilities, instructional strategies, teacher preparation, and a clear definition for the content and structure of "technology education."

That was a strong indication toward a desire to change the name of industrial arts. But it was not the first time such a suggestion was made. In 1966, William Warner said, "there is no question about our need for a new professional label because neither 'Industrial Arts' nor 'Industrial Education,' are descriptive or explicit enough to fill our needs in the decades ahead" (p. 8). Regarding the term "technology," Warner stated: "it is very palatable and certainly generic, but because of this, can be claimed by many others, so our use of it must be done with care" (1966, p. 8). This early consideration of a name change for the AIAA did not culminate in any action since a majority of leaders at that time were opposed to such a change.

As a graduate student at the University of Maryland, Kendall Starkweather established himself as a forward thinker. In 1975, he completed his doctoral dissertation titled *A Study of Potential Directions for Industrial Arts*

Toward the Year 2000 A.D. It was based on the views of 10 experts of futuristic studies within the industrial arts profession and concluded the following:

1. A new name should be created for the discipline appropriate for a profession seeking to interpret technology and industry in a post-industrial society.
2. Programs will move in the direction of applying technology to solve the major problems facing mankind.
3. Technology will begin to be studied from an international base.
4. New areas of content will begin to emerge (e.g., plastics, ceramics).
5. Traditional areas (e.g., wood, metal, drawing) will be grouped into broader areas of study such as materials and processes.
6. Industrial arts will become more interdisciplinary and systems oriented.
7. Course content will have an emphasis on environmental considerations.
8. Post-industrial development will influence content with emphasis on technical knowledge, research, data retrieval, design, and technological change.
9. The affective domain and value systems will receive more attention. (Cited in Lauda, 1979, p. 237)

By virtue of employing a Delphi methodology, the conclusions from Starkweather's dissertation were effectively a compilation of the best existing ideas related to the development of a new approach for industrial arts. Each statement was well formed and helped to define the characteristics of the technology-based approach for instruction, serving as a forecast of things to come. Most of these conclusions became realities largely as the result of the strong convictions of Starkweather and the leaders who contributed to his study.

In 1979 and 1980, three separate meetings referred to as the Jackson's Mill Industrial Arts Curriculum Symposium provided the opportunity for 21 members from the vanguard of the profession to meet and deliberate on the direction of the industrial arts field. The significance of the *Jackson's Mill Industrial Arts Curriculum Theory*, the report from this symposium published in 1981, was the eventual consensus among differing points of view (Snyder & Hales, 1981). For those who supported an industry-based view, it was difficult to give up "industry" as the key organizer even though they had identified technology as a major concern for the study of industry. The fact that those who favored that approach accepted technology as the motive underlying industrial arts education was significant. It represented a paradigm shift that, for many, required a great leap of faith.

In 1984, Starkweather (then Executive Director of AIAA) and the Association Board of Directors solicited a vote of the Association membership on the possibility of a name change. The vote required a two-thirds majority of the voting membership favoring a change of the name.

In April 1985, at the San Diego Conference, AIAA President William Dugger announced that organization would henceforth be known as the International Technology Education Association (ITEA). Also that year, Dugger directed a writing team from Virginia Polytechnic Institute and State University to rewrite standards to reflect the direction of technology education. The *Standards for Technology Education* provided a systematic arrangement of criteria to simplify the assessment of comprehensive technology education programs (Dugger, Bame & Pinder, 1985). The primary goal of technology education, preparing students to be technologically literate, involved more than the mere understanding of what technology is and/or the acceptance of it. It involved many questions on the relevancy of the technology and its applications. Beyond the content, the learning process was also critical to the development of the student. "Thus the curricular role of technology education can and must be one that provides for an integrated, holistic approach to education in the 21st century" (Technology Education Advisory Council, 1988, p. 3).

Integration of Disciplines

During the 1990's, a number of approaches were devised for the delivery of technology education. Foster & Wright recognized that many plans were developed "from an organizational standpoint" and gave examples such as "career-awareness" in elementary schools, "the modular approach" that became popular for middle or junior high, and "tech-prep" for high school programs. They stated, "technology education has also been viewed as constructive methodology for teaching important content from other school subjects" and identified approaches that had an "integrative theme" (1996, p. 15).

One of those (promoted by LaPorte & Sanders in 1993) known as the *Technology/ Science/ Mathematics Integration Project* was funded by the National Science Foundation (NSF) and designed to integrate disciplines at the middle school level. A later report by LaPorte & Sanders concluded, "more than at anytime before in the history of education, the stage is now set for a closer working relationship among technology, science and mathematics" (1995, p. 209).

Dennis Herschbach (2009) also identified the trend toward integrating math & science occurring around this time and that many science-related organizations were promoting science literacy. In 1990, the American Association for the Advancement of Science published *Science for all Americans*–and the third chapter was titled "The Nature of Technology." That chapter addressed ideas "sorted into three sections: the connection of science and technology, the principles of technology itself, and the connection of technology and society" (p. 25). Spurred by international studies that showed low achievement levels by American students, this report investigated how the nation could begin reforming its system of education in science, mathematics, and technology.

In 1996, the ITEA followed up with *Technology for All Americans: A Rationale and Structure for the Study of Technology*–a report based upon work funded through grants from NSF and NASA. This project stressed the need for technological literacy and that understanding technological systems "usually requires a knowledge from a variety of fields, especially science, mathematics, and technology" (p. 19). The stated goal of the Technology for All Americans Project, led by William Dugger, was "to offer those who are interested in technology education a clear vision of what it means to be technologically literate, how this can be achieved at a national level, and why it is important for the nation (p. 49).

Prior to the turn of the century, significant discussion related to the coalescence of Science, Technology, Engineering and Math education occurred across many channels and within a wide range of related agencies and organizations, such as the National Council of Teachers of Mathematics and the American Society for Engineering Education. Although numerous groups were considering this amalgamation, Judith Ramaley is commonly credited with coining the acronym STEM (Koonce, Zhou, Anderson, Hening, & Conley (2011). As assistant director of education and human resources at the National Science Foundation, she was unhappy with the acronym SMET in use at NSF since the 1990's. So, in 2001, she simply rearranged the letters and the emerging concept was branded (Christensen, Nov.13, 2011). Science, Technology, Engineering, and Math were now joined in the form with which we are now so familiar. However, as Mark Sanders pointed out, even though "some have suggested that STEM education implies interaction among the stakeholders. It doesn't." (2009, p. 21). Although a lot of funding has since been directed toward STEM education, and that doesn't mean all recipients are working together toward the same objectives.

David White pointed out that the "T and E" of STEM education "appears to be a stumbling block to producing meaningful STEM experiences to K-12 students"… because "many educators that are not in the fields Engineering and/or Technology are intimidated with (the associated) processes" (2014, p. 5). It is possible for one teacher to integrate concepts across all segments. Still, though a single teacher may have the ability, and desire, to teach across disciplines, they might be limited by the facilities, or tools and materials that are available to them. Optionally, working as a team, with teachers representing each discipline, toward common learning objectives can be an effective way to ensure that students are getting truly integrated STEM learning experiences.

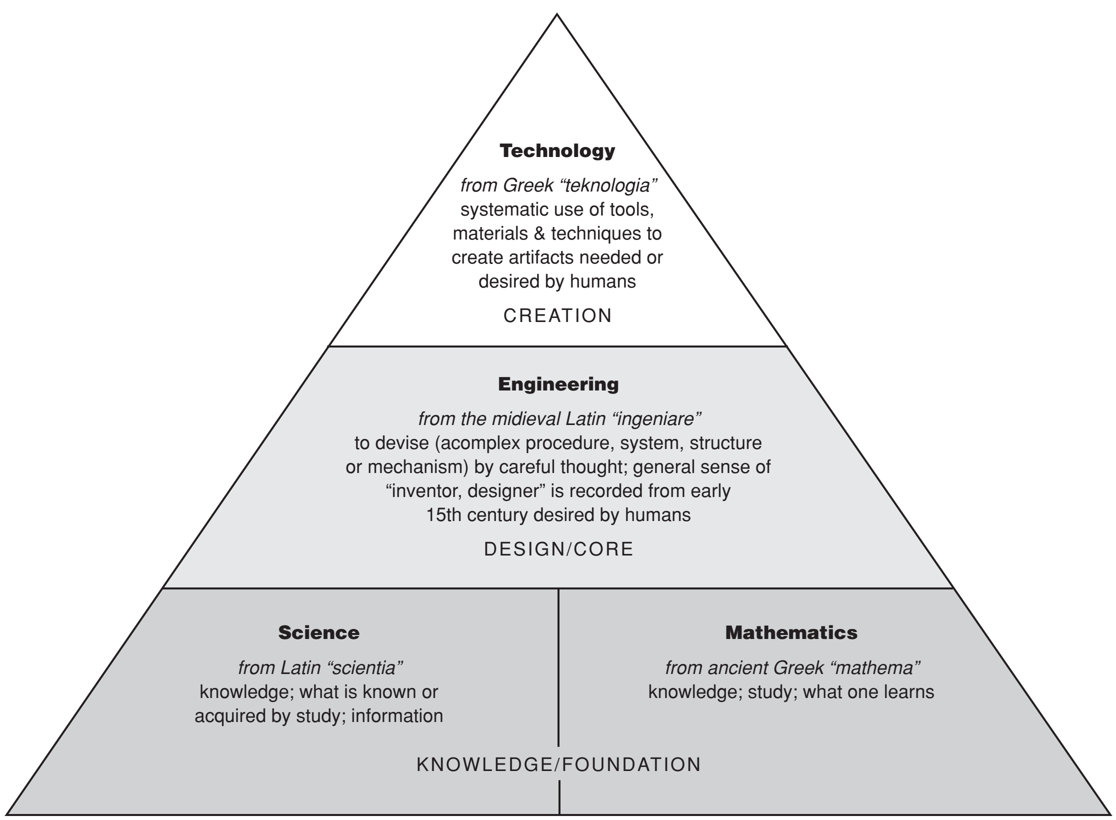
The Role of Technology in STEM

STEM curricula's authors agree on the concept that it is beneficial to integrate the disciplines of science, technology, engineering, and mathematics. However, the integration of the disciplines must be substantial. The STEM initiative intends to avoid the traditional paradigm of separating subjects and, instead, blends them in a concrete, applied approach. The technology discipline has traditionally been recognized as an educational program with emphasis on the application and use of tools, materials, and techniques. Students "learn by doing" – using hands-on practices. Engineering involves design and planning for the application of math and science to build things.

Figure 1 identifies the role of each discipline in STEM that is based on the etymological origins of their titles. This organization of disciplines should not be perceived as a hierarchy. In the world around us, each discipline works in concordance with the others. For example, discoveries in math and science can inform engineering or, perhaps, generate new materials. In turn, developments in engineering and technology might create tools and techniques that shape materials to produce new artifacts, or devices, which can enable further discoveries. Also, between engineering and technology, the creation of "prototype" artifacts often reveals design flaws that need to be re-engineered. Once identified, these flaws can typically be explained by the principles of math and science.

Similarly, these disciplines can also work together harmoniously in education. An overemphasis on preparing "knowledge workers" (those who are proficient in math and science) may reduce the opportunity students have to work with real tools and materials to create technological artifacts. In contrast, those students focused exclusively on technology and developing skillful techniques often don't appreciate the mathematical and scientific principles that correspond to the work they do. STEM education can help technology-oriented students better understand this foundational knowledge. Engineering provides a bridge between the foundational knowledge and technological development through thoughtful planning and design. Technology and engineering can help make science and mathematics come to life through application. All the STEM disciplines are entwined like the threads in a steel cable.

Figure 1. STEM disciplines organized based on etymological indications. This should not be perceived as a hierarchy. Each discipline works in concordance with the others.



CONCLUSION

STEM education includes learning across all grade-levels and post-secondary programs. It is focused on developing scientific and technological literacy, teaching the engineering design process, as well as addressing innumeracy–the inability to utilize mathematical concepts and methods. Throughout the evolution of technology and engineering education, the discipline has applied hands-on, experiential learning methods to the design and creation of technological artifacts. Incorporating this methodology to solve problems that are inherently math and science oriented helps motivate learners, as well as increase their interest and abilities related to concepts they might not be drawn to otherwise.

The role technology and engineering plays in the broad spectrum of the STEM movement may not be straightforward for many STEM educators. Even through the past century, it took many people's perspectives and ideas to come to a consensus regarding the essence of the role of technology in education. Perhaps, through the review of this history, one can better understand the true nature of the field and come to appreciate the significance of integrating technology and engineering concepts into STEM education.

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