AC 2011-2320: ENGINEERING IN TECHNOLOGY EDUCATION: A LONGITUDINAL VIEW, 1966-2011

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Engineering in Technology Education: A Longitudinal View, 1966-2011

For the past 15 years, the National Academy of Engineering (NAE/NRC) has strongly advocated including technology/engineering content in K-12 educatio1n. In 1996, the NRC's *National Science Education Standards* introduced the "Science & Technology" standard, which encouraged the study of technology within the science curriculum[1]. In 2000, NAE President William Wulf wrote the following in his Foreword to *Standards for Technological Literacy*: "Thankfully… the ITEA has distilled an essential core of technological knowledge and skills we might wish all K-12 students to acquire"[2]. Recommendation #1 in the NAE's *Technically Speaking: Why All Americans Need to Know more about Technology*[3] called for "the integration of technology content into K-12 standards, curricula, instructional materials, and student assessments in nontechnology subject areas." Similarly, the inclusion of engineering in K-12 curricula is the thesis of the NAE's *Engineering in K-12 Education*.[4] In July 2010, the NRC released an initial draft of *A Framework for Science Education*[5], which proposes engineering as new science subject matter alongside biology, chemistry, earth/space science, and physics. Paralleling the NAE/NRC initiatives, in 2010 the National Assessment of Educational Progress (NAEP) published *Technology and Engineering Literacy Assessment and Item Specifications for the 2014 National Assessment*[6], which will stimulate the addition of new technology and engineering content to the K-12 curriculum.

In *each* of these efforts, the role of the school subject known as "Technology Education" has been recognized and validated. In addition to describing the role of Technology Education in K-12 engineering education, *Technically Speaking* drew this conclusion: "the committee believes that the value of K-12 engineering curricula and of professional development for teachers of K-12 engineering would be increased by stronger connections to technological literacy, as described in such documents as the *Standards for Technological Literacy: Content for the Study of Technology*"[7].

Despite the rapidly emerging engineering in K-12 education agenda and the close relationship Technology Education has to that agenda and the technological literacy for all agenda, Technology Education remains a subject about which most laypersons and educators know very little. These circumstances beg a number of questions, such as:

- What, if anything, do an estimated 30,000 Technology Education teachers across the U.S. bring to the table as America moves forward with the engineering in K-12 education agenda?
- Will secondary engineering education employ labs to facilitate design-based engineering activity?
- If so, will those activities make use of an estimated 20,000 Technology Education Labs that currently exist?
- Or will school divisions reconstruct similar facilities as science education labs, at an estimated cost $12.5 billion[8] for the physical space, plus an additional $2 billion[9] to equip those duplicate labs?
- Do the Technology teachers (whose collective salaries represent an additional $1.5 billion/year investment) bring any grade-appropriate engineering expertise to the table?

- Or, will school divisions invest (enormously) in developing similar expertise and experience among existing science educators?
- Alternatively, will engineering be taught in science classrooms *without* lab-based engineering design-activities altogether?
- Will school divisions add substantial time to the science curriculum to add new engineering subject matter?
- Or, will science educators forfeit time from their existing science curriculum to make room for new engineering subject matter?

In light of these and related questions, this paper offers some relevant historical background, reports findings from four parallel national studies conducted over the past half-century of Technology Education teachers' engineering education-related beliefs and practices, and discusses some of the trends and implications of the reported findings.

Brief Historical Perspective

From the early 20th century through the mid-1980s, the field now known as "Technology Education" derived its content and purpose from the study of industry and craft—hence the name "Industrial Arts" (IA). The intent of industrial arts education, though never really achieved in public education, was to teach students in the early elementary through high school grades about the industrial culture that dominated the American landscape in the 20th century. In contrast to the commonly held belief that IA was only about vocational tool skills, the ideology on which IA was established in the l870s was a general education ideology in support of the notion that all boys and girls in the U.S. would benefit from the study of our industrial culture. Much the same ideology that now leads many to believe "K-12 engineering education" today would benefit all students, not just those seeking the postsecondary vocational engineering track.

The presentation of a paper titled "A Curriculum to Reflect Technology"[10] at the 1947 conference of the American Industrial Arts Association signaled a shift away from the study of industry and craft toward a new curriculum and content that would reflect the new "technological culture" in America, which was replacing the industrial culture that dominated the latter half of the 19th century and the first half of the 20th century. Four decades of that ideological shift and accompanying extensive curriculum experimentation led, in 1985, to the vote that renamed the national association "International Technology Education Association."

Concurrently, two radical curricular shifts began in Technology Education. The first curricular trend, which began in the early 1980s, was the infusion of digital technologies into the curriculum. For example, the IA/Technology Teacher Education program at Virginia Tech began teaching electronic publishing in 1981 with Apple computers and graphics tablets, which led to the teaching of digital multimedia with Macs in 1985, digital video and holography in 1992, and Web-based portfolios beginning in 1995. And, beginning in 1983, this teacher education program offered a "Computer Control and Automation" class in which students built an input/output card for the joystick port of a Commodore 64, which they programmed with BASIC to import data from analog/digital sensors, and output control code to servo-motors, which controlled "systems" they designed and constructed from scratch. Typical student team-designed/constructed working models of that (late 1980s) era included custom designed robotic devices, an electro-magnetic monorail system, an automated "smart house" automated launching devices, and automated testing equipment (a requirement for the manufacturing class). By the mid-1980s, those courses, along with courses in digital electronics, CAD, 3D modeling, and *elementary* technology education were required of all Technology Education majors at Virginia Tech, who began implementing those technologies in their own classrooms/labs upon graduation. The point being, while the field was known to most in that era (and even to this day) for the tools and instructional methods it had employed since the late 19th century, Technology Teachers were among the very first in all of education to infuse digital technologies and design-based instructional methods into the school curriculum. And, for the most part, these were grade-appropriate engineering-related technologies (tools for designing, constructing, and evaluating solutions to problems posed) that they were beginning to infuse into their Technology Education courses, rather than only the instructional technologies that many teachers were beginning to employ.

The second curricular trend, which emerged in the late 1980s, was the emergence of "modular" labs, and what became known as modular Technology Education. Commercially marketed modular labs rapidly transformed substantial numbers of middle school labs across the US from a traditional industrial arts labs to new-age labs dominated by digital tabletop technologies. It was impossible to think of these transformed labs as "wood shops." Initially (circa 1989) the typical lab transformation process involved the complete removal of *all* conventional equipment from the lab, followed immediately by the installation of carpeting, modular furniture, and (typically) 9-12 instructional modules chosen from about 2 dozen available modules that could be purchased at that time. Typical modules included airfoil design/testing using a tabletop wind tunnel and software, flight simulation, CAD, 3D modeling, digital electronics, virtual bridge design, and destructive testing of student designed/constructed trusses and bridges (e.g., http://synergistic-systems.com/tabid/91/Default.aspx?stem=8&searchtype=0&so=1&pb=1).

By the early 1990s, these facility transformations eschewed the completely carpeted lab design in favor of hybrid lab designs that located conventional tools and equipment in a small "prototyping lab" (about ¼ the size of the overall lab space) typically located behind a glass wall at one end of the larger lab. The prototyping lab allowed students to engineer solutions to design problems that Technology Education teachers were increasingly using with their students. Following the publication of *Standards for Technological Literacy (ITEA, 2000)* these modular labs were designed to mirror the "Designed World" standards found in *Standards for Technological Literacy*, which is to say, they were designed to introduce students to medical, agricultural, biotechnological, energy and power, information & communication, transportation, manufacturing, and construction technologies, through hands-on "table-top" activities. It was in the mid-1980s, concurrent with the (1985) name change to Technology Education and the ubiquity of digital technologies that the field began incorporate engineering content and method.

Several trends in the 1990s moved the technology education curriculum further in the direction of engineering. Early in the decade, the literature of the field downplayed the development of "tool skills," promoting, instead, the teaching of problem solving trough the "technological method."[11] Building upon ideas about design-based instruction imported from the UK in the late 1980s, these were the formative years of the field's efforts in transforming it's signature pedagogy from the "project method" that dominated industrial arts education in the 20th century, to a unique technological design-based pedagogy.

Concurrently, there were efforts across the field to identify and encourage mathematics and science content and method within the Technology Education curriculum and/or across the science, mathematics, and Technology Education subject areas. Numerous such projects were funded at the state and federal levels throughout the 1990s. The two publications of the ITEA that were intended for teachers—*The Technology Teacher* and *Technology and Children* were filled with instructional activities that featured connections among technology, science, and mathematics. The Technology Education divisions of state departments of education began publishing engineering curriculum guides for their Technology Education teachers. In 1992, the Virginia Department of Education published curriculum guides titled *Introduction to Engineering* and *Advanced Engineering*. The New York State Education Department followed suit with the 1995 publication of its *Principles of Engineering* course. Founded in 1996 by a NY state Technology Education teacher with massive support from a corporate engineering foundation, *Project Lead the Way* was easily the most successful curriculum initiative of the 1990s that promoted connections among mathematics, science, and technology. The partnerships PLTW established with a score of college and university of Engineering programs, and the eagerness with which Technology Education supervisors and teachers across the US adopted the PLTW curriculum, brought engineering and Technology Education closer together than ever before.

The most ambitious and influential Technology Education project of the 1990s was the *Technology for All Americans Project*, for which the ITEA was funded. Project staff, with substantial input from the field, and from the National Academy of Engineering, strived to develop a conceptual framework for the study of technology, which culminated in the *Standards for Technological Literacy*. Importantly, the NAE described the *STL* as "an "essential core of technological knowledge and skills we might wish all K-12 students to acquire".[2]

Purpose of this Longitudinal View of Engineering in Technology Education

There has always been a disconnect between the literature of educational reform and educational practice. Relatively few ideas found in the literature manifest quickly in teaching practice, widespread change takes decades or longer and many ideas never make it into practice. In this paper, therefore, we track selected variables that describe teacher demographics, teaching practices, teachers' beliefs regarding the purposes and content of Technology Education, and engineering concepts taught in Technology Education. We investigate those variables in order to help determine if and when significant changes in Technology Education teachers' instructional practices and beliefs relating to engineering have occurred.

Methodology Employed in the Four "IA / TE Beliefs & Practices" Studies

Each of the four studies used for this comparative analysis were descriptive studies of Industrial Arts (IA) / Technology Education (TE) teachers and programs. In each case, data were collected from a national sampling of IA / TE teachers/programs. The first study in the sequence was funded and conducted by the U.S. Office of Education. Schmitt and Pelley, (1966)[12] supervised the development and administration of a comprehensive instrument designed to assess IA education programs, teachers, students, and curriculum. In the fall of the 1962-63 school year, this instrument was mailed to 2,259 principals and 3,040 IA teachers in junior and senior high schools across America. The principals completed the first part of the instrument and the chair of the Industrial Arts Department completed the second part of the instrument.

The instruments used in the second, third, and fourth national studies of IA/TE beliefs and practices purposefully incorporated "teacher beliefs and practices" items that were used in the Schmitt & Pelley instrument, so longitudinal comparisons could be made. The instrument used in the 1980 study (Dugger, et al., 1980)[13] was mailed to a random sample of 1,404 IA chairpersons across the U.S., while the instrument for the 2001 study (Sanders, 2001)[14] was mailed to a random sample of 1,468 Technology Education chairpersons across the U.S.. In the 2009 study (Sanders, et al., 2009)[15] the instrument—still including "teacher beliefs and practices" items replicated from the original Schmitt & Pelley study for the purpose of longitudinal comparison—was made accessible via the Web to all 1,492 middle and high school members of the ITEA. Methodological details for each of these studies appear in the publications cited for each, found in the References section of this paper.

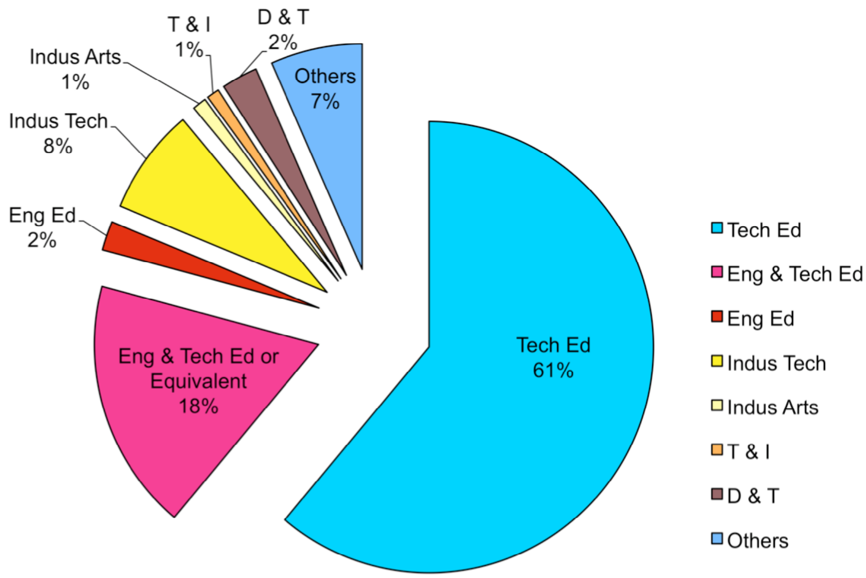
Findings

The data reported below depict selected findings from each of the four studies noted above that relate to the "engineering education." When we observed important differences or trends among the studies over time, we have noted and discussed (briefly) those trends. The "Discussion" section at the end of this paper offers broader observations based upon the collective set of findings relating to Technology Education teaching practices and beliefs, particularly as they relate to the emergence of "K-12 engineering education in the U.S.

Program Name

There wasn't much need for a "Program Name" item in the 1966 and 1980 studies, since nearly all programs were called "Industrial Arts" in that era. That item was added to the 2001 study, but since "engineering" had not yet begun to emerge in program names, program names with "engineering" in their title were not included in the options provided in the 2001study. In the 2009 study, however, middle and high school TE teacher members of ITEA were asked to identify the name of their programs, choosing from "Technology Education," "Engineering & Technology Education," "Engineering Education," "Industrial Technology," "Industrial Arts," "Trade and Industry," "Design & Technology," or "Other." Figure 1 depicts the distribution of their responses. While most (61%) continued to call their programs "Technology Education," 20% of the 2009 respondents were using "Engineering" in naming their programs[17]. Some of this may have resulted from the fact that some state departments of education had changed the program name at the state level from "Technology Education" to "Engineering & Technology Education," or "Technology & Engineering," or a similar title with "engineering" included. In March, 2010 (long after the data for this 2009 study were collected) 81% of the ITEA membership voted to change the name of the national association to the "International Technology and Engineering Educators Association." Thus, it is likely that the percentage of "Technology Education" programs in the U.S. that now include "Engineering" in their program name is substantially greater than 20%.

Figure 1. 2009 Study: Program Name



While the fact that many Technology Education programs are now using Engineering in their program names may come as a surprise to some, listings of course titles and instructional activities that have been commonly used since the late 1980s might help to understand this trend. Figure 2 provides a list of middle and high school Technology Education courses currently taught in Virginia[16]. Most of these course titles have been taught since the early 1990s. For example, Virginia first published its "Introduction to Engineering" and "Advanced Engineering" course guides in 1992. While course titles vary from state to state, these course titles are reasonably typical of those found in other states. Many of these course titles suggest age/grade-appropriate "engineering" or "engineering technology" content though additional evidence relating to "engineering learning outcomes" resulting from these courses would be helpful and more convincing. The *NAEP 2014 Technology and Engineering Literacy Assessment*, currently in development, should provide the first comprehensive measure of this sort.

Figure 2. Technology Education Course Titles Taught in Virginia

Middle School Technology Education Courses Taught in Virginia

- Introduction to Technology
- Inventions and Innovations
- Technological Systems

High School Technology Education Courses Taught in Virginia

- Advanced Drawing and Design
- Advanced Engineering
- Advanced Manufacturing Systems
- Aerospace Engineering
- Aerospace Technology I & II
- Architectural Drawing and Design
- Bioengineering
- Biotechnical Engineering
- Biotechnology Foundations
- Civil Engineering & Architecture
- Communication Systems
- Computer Control & Automation
- Computer Integrated Manufacturing (PLTW)
- Construction Technology
- Digital Electronics (PLTW)
- Digital Visualization
- Electronics Systems I, II, & III
- Energy and Power
- Engineering Analysis and Applications
- Engineering Concepts and Processes
- Engineering Design & Development (PLTW)
- Engineering Drawing and Design
- Engineering Explorations
- Engineering Practicum
- Geospatial Technology I & II
- Graphic Communications Systems
- Imaging Technology
- Information Tech in Production Systems
- Introduction to Engineering Design (PLTW)
- Introduction to Engineering
- Manufacturing Systems
- Materials and Processes Technology
- Power and Transportation
- Principles of Engineering (PLTW)
- Principles of Technology I & II
- Production Systems
- Technical Drawing and Design
- Technology Assessment
- Technology Education--Disabled
- Technology Education--Disadvantaged
- Technology Foundations
- Technology Transfer

Figure 3 is a list of typical modular instructional activities that have been very popular in middle school Technology Education Programs across the U.S*., since first introduced in 1985.*[17] Each module is a self contained, hands-on instructional activity that students typically work on in pairs. Students are introduced to and directed through the activity by a video presentation typically digitally streamed from a server in the Lab and written instructional materials provided as part of the instructional module. Over the past 20 years, “modular” instruction has become very popular in Technology Education across the U.S. In the 2001 Technology Education study, 48.5% of respondents reported using “vendor-made modules,” and 72.5% of respondents reported using “teacher-made modules” in their instructional practice. Some would argue that many of these activities are age/grade appropriate engineering education. Their relationship to engineering may be evident from their titles, which are reasonably descriptive of the nature of the activity they represent.

Figure 3: Pitsco Instructional "Modules" Titles Commonly Taught in Middle School Technology Education Programs since 1989.

- Alternative Energy
- Applied Physics
- Architectural Design
- Bio-Engineering
- Biotechnology
- CAD & 3D Modeling
- CNC Machining (Lathe/Mill/Router)
- Computer Graphics & Animation
- Digital Design
- Digital Multimedia
- Digital Video / Video Production
- Electricity & Electronics
- Energy, Power, & Mechanics
- Engineering Bridges & Towers
- Engine Systems
- Flight & Flight Simulation
- GPS Systems
- GIS Systems
- Material Science
- Mechanisms
- Package Design
- Plastics & Polymers
- Research & Design
- Robotics / Automation
- Rocket Science
- Webworking

Comparative Results from Four Surveys of Technology Education Teachers – 1966-2011

Program Philosophy—General Education vs. Vocational Education

Respondents were asked to indicate if their programs followed a philosophy associated with general education or vocational education. This dichotomy has been an issue in the field since its inception in the 1870s. "Vocationalists" are those who believe the purpose of their program is primarily to prepare people for work. Historically, that usually meant work in the trades, such as cabinetmaking or machinist or draftsman. Today, job preparation is more likely to be computer-aided designer, or a pre-engineering graduate who might earn a two-year degree in a technical field or enter a university engineering program. Most holding the vocational preparation philosophy teach in high schools and take pride in preparing students for jobs upon graduation from high school.

In contrast, those who think of Technology Education as general education believe that all boys and girls would benefit from Technology Education courses. Many of those teachers are in middle schools, where in many schools, all boys and girls are required to enroll in a Technology Education course. The "technological literacy for all" mantra that has appeared in the IA/TE literature since the 1960s is wholly consistent with the general education philosophy.

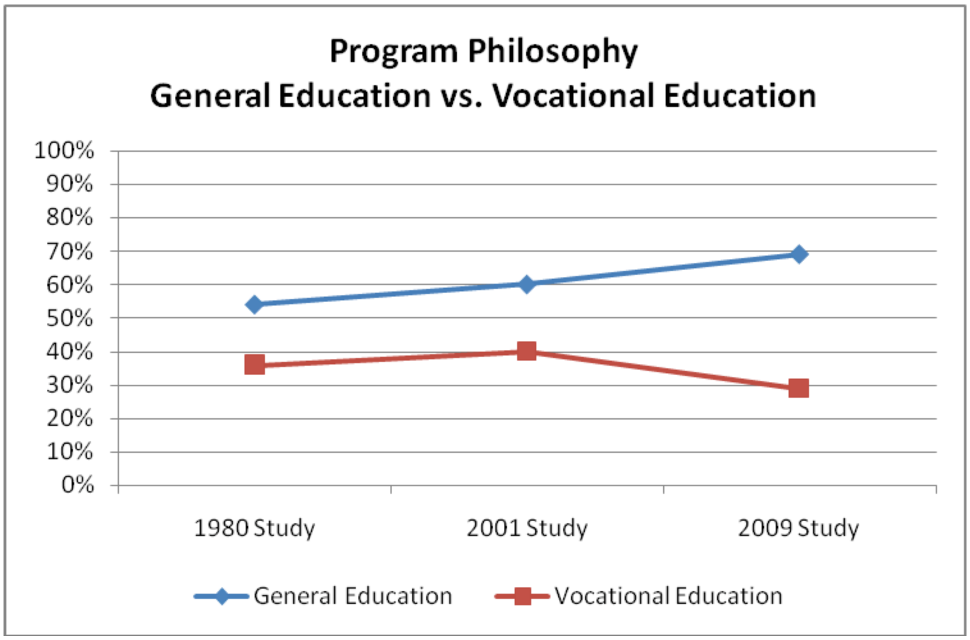
These philosophical differences are already plainly evident in the K-12 engineering education movement. The Engineering is Elementary curriculum is intended to benefit all boys and girls, though not overtly attempting to place elementary students into an engineering track. But the Project Lead the Way (PLTW) and other high school pre-engineering courses aim to prepare students for admission to a university engineering/engineering technology program, which represents a vocational objective.

As shown in Table 1,Technology Education teachers have increasingly adopted the general education philosophy since 1980, a trend that is consistent with the push for "technological literacy for all" espoused by the Technology for All Americans Project and others in both the Technology Education and Engineering Education communities.

Table 1. Program Philosophy—General Education vs. Vocational Education

	1966 Study[12]	1980 Study[13]	2001 Study[14]	2009 Study[15]
General Ed	NA	54%	60%	69%
Vocational Ed	NA	36%	40%	29%
Undecided				2%

Figure 4.



Teacher Demographics: Gender, Ethnicity, and Aging

Three trends in TE teacher demographics appear from comparing findings over the last five decades. First, although it remains the case that far fewer women than men teach Technology Education, the percentage of women teaching Technology Education has continued to increase since 1980. There are now more women teaching Technology Education than ever before. In 1980, only 1% of Technology Teachers were female. That percentage increased to 10% by 2001 and 18% of the 2009 respondents were women. If K-12 engineering education is perceived to be for all, increasing the percentage of female secondary engineering educators should be a high priority.

A second trend is the under-representation of minority populations among Technology Education teachers. Although minorities represented about 25% of the U.S. population in 2000 and about one third of the U.S. population in 2008[18] only 6% of the teacher respondents in 2001 and 2009 studies were non-Caucasian. Whether the goal is technological literacy for all or K-12 engineering education for all, it would be appropriate and desirable for the distribution of teacher gender and ethnicity to mirror the gender and ethnicity distributions of the student populations in the K-12 education.

A third trend is the aging of the Technology Education teaching workforce. The average teaching experience rose from 9.5 years in the 1966 study to 11.5 years in the 1980 study and then to 17.5 years in the 2001 study. In the 2009 study, more than 21% of all respondents had greater than 25 years of teaching experience and about the same percentage (19.5%) were older than 55. Only 13.1% were 30 years old or younger. The age and years of experience among Technology Education teachers partly explain why some programs have lagged behind the curricular trends in the field toward digital technologies and design-based pedagogy. Tables 2 and 3 indicate that Technology Education teachers represent a relatively old and experienced workforce.

Table 2. Teachers' Age Distribution, 2009 Study[15] (N=577)

Age Range	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	>65
# **%**	17 (2.9)	59 (10.2)	52 (9.1)	63 (10.9)	68 (11.7)	86 (14.8)	118 (20.3)	84 (14.5)	21 (3.6)	8 (1.4)

Figure 5.

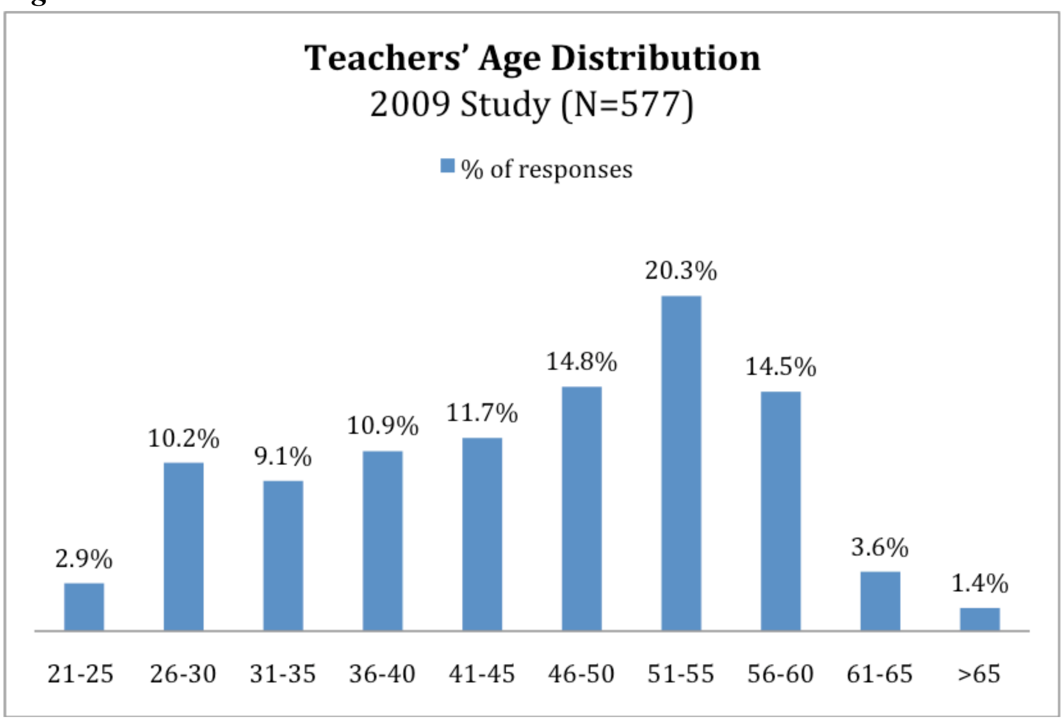
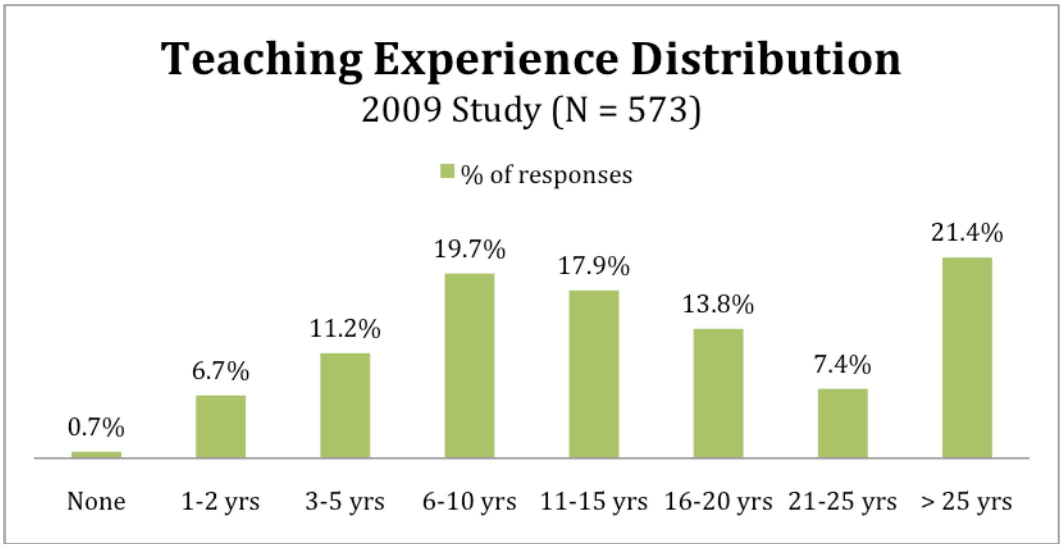


Table 3. Teaching Experience Distribution, 2009 Study[15] N = 573

Years of Teaching	None	1-2	3-5	6-10	11-15	16-20	21-25	> 25
	4 (.7)	39 (6.7)	65 (11.2)	114 (19.7)	104 (17.9)	80 (13.8)	43 (7.4)	124 (21.4)

Figure 6.



Purposes of Technology Education

The initial Schmitt & Pelley (1966) study asked teachers to rank 10 different statements that described possible purposes for IA education. Each of those 10 statements were retained in each of the subsequent surveys, but the number grew to 17 purpose statements over the 4 studies, as new purposes were added to the instruments. For example, "develop technological literacy," was added to the 2009 study, to reflect that emerging purpose. Specifically, respondents in each of the surveys were asked to rate the importance of the purposes using a 5-item Likert scale (1-Unimportant; 5-Very Important). Since all of the original 10 statements appeared on each of the surveys, any of those original 10 purposes *might have* continued to appear among the top-rated purposes in any or all of studies that followed the Schmitt Pelley study. Table 4 depicts the top five purposes of IA/TE across each of the four studies.

Teachers' perceptions of the purposes of their Technology Education programs have undergone a significant shift over the past 45 years. In the IA era, the highest-ranked purpose was developing "skill in using tools and machines." In contrast, the top ranked items in the 2001 and 2009 studies were both about problem solving. Simply put, teachers in the IA era valued tool skills above all else, but by the turn of the century, teachers were valuing the development of problem solving abilities as the primary purpose of Technology Education, followed closely by "technological literacy" and "understand the application of science and mathematics." Taken together, the top ranked purposes (development of problem-solving skills and technological literacy, the use of technology to solve problems, and understanding the application of science and sound like a pretty good foundation of goals for the teaching engineering concepts and methods. It is not a stretch to suggest that one might characterize these top-ranked purposes as *educating students about the application of technology, science and mathematics to solve problems/satisfy human wants and needs*, which also might resonate as a description of the purpose of K-12 engineering education for all. The point is that Technology Education teachers' beliefs about the purposes of their instruction would seem consistent with the emerging K-12 engineering education goals.

Table 4. Top Five Purposes of Technology Education—1966-2009

<table>
<tr><th>Rank</th><th>1966 Study[12]</th><th>1980 Study[13]</th><th>2001 Study[14]</th><th>2009 Study[15]</th></tr>
<tr><td>1</td><td colspan="2">Develop skill in using tools and machines</td><td colspan="2">Develop problem solving skills</td></tr>
<tr><td>2</td><td>Discover and develop creative talent</td><td>Provide technical knowledge and skill</td><td colspan="2">Use technology to solve problems and satisfy need and wants</td></tr>
<tr><td>3</td><td>Develop worthy leisure time interests</td><td>Discover and develop creative talent</td><td>Make informed educational and occupational choices</td><td>Understand the application of science and mathematics</td></tr>
<tr><td>4</td><td>Provide technical knowledge and skill</td><td>Develop worthy leisure time interests</td><td>Understand the application of science and mathematics</td><td>Develop technological literacy</td></tr>
<tr><td>5</td><td colspan="2">Develop problem solving skills</td><td>Develop an understanding of the nature and characteristics of technology</td><td>Make informed educational and occupational choices</td></tr>
</table>

Table 5 presents TE teachers' ratings for all 17 purpose statements. Worth noting is the fact that the three lowest ranking purposes statements were vocational in nature. As engineering education makes it way into K-12 education this dichotomy between general and vocational education will remain a key issue.

Table 5. TE Teachers' Ratings of 17 Purpose Statements, 2009 Study[15]

Purposes of Technology Education	2009 Study	
	Rating	Rank
Develop problem-solving skills	4.80	1
Use technology (knowledge, resources, & processes) to solve problems & satisfy needs/wants	4.39	2
Develop technological literacy	4.29	3
Understand the application of science and mathematics	4.26	4
Make informed educational and occupational choices	4.06	5
Recognize that problems and opportunities relate to and often can be addressed by technology	3.97	6
Identify, select, and use resources to create technology	3.97	6
Provide technical knowledge and skill	3.93	8
Discover and develop creative talent	3.93	8
Develop an understanding of the nature and characteristics of technology	3.91	10
Develop skill in using tools and machines	3.83	11
Evaluate the positive and negative consequences of technological ventures	3.82	12
Develop consumer knowledge and appreciation	3.61	13
Understand technical culture	3.56	14
Provide pre-vocational experiences	3.31	15

Develop worthy leisure time interests	2.92	16
Provide vocational training	2.70	17

The Content of Technology Education

In the 2009 study, respondents were asked to rate (on a five point Likert scale (1=unimportant, 5=very important) the importance of 17 content areas[17], which were derived directly from *Standards for Technological Literacy*[22]. Here again, the top-ranked concepts: 1)Troubleshooting, R&D, invention, innovation and experimentation; 2) application of design processes; 3) attributes of design; core concepts of technology; and engineering design—would seem to provide a good foundation for K-12 engineering education. Though admittedly the deck was stacked with content identified in *Standards for Technological Literacy,* all of which is arguably consistent with K-12 engineering education, the fact remains that teachers rated nearly all of the content areas as important. The three newest content areas—biotechnologies, agricultural technologies, and medical technologies—were rated the lowest priorities[17]. Given the relative importance of those three technological areas globally, it would seem their relatively low ranking in this study is likely the result of their being historically absent from the Technology Education curriculum.

Table 6. Teachers' Ratings of the CONTENT of Technology Education, 2009 Study[15]

Content Areas (as stated in *Standards for Technological Literacy*	ITEA	
	Rating	Rank
Role of troubleshooting, R&D, invention, innovation, & experimentation in problem solving	4.16	1
Application of design processes	4.12	2
Attributes of design	4.03	3
Core concepts of technology	3.91	5
Engineering design	3.96	4
Connections and relationships among technological fields and other fields	3.88	6
Effects of technology on the environment	3.71	7
Information/communication technologies	3.66	8
Characteristics and scope of technology	3.62	9
Manufacturing technologies	3.62	9
Role of society in the development and use of technology	3.56	11
Use and maintenance of technological products and systems	3.54	12
Construction technologies	3.53	13
Influence of technology on history	3.45	14
Energy and power technologies	3.37	15
Cultural, social, economic, and political effects of technology	3.35	16
Transportation technologies	3.29	17
Assessment of the impact of products and systems	3.23	18
Biotechnologies	2.20	19
Agricultural technologies	2.10	20
Medical technologies	2.03	21

Discussion

There is currently far more interest and momentum behind the idea of engineering in K-12 education in the U.S. today than at any previous time in history. Technology Educators have been knocking on that door for a long time. But since the publication of *Standards for Technological Literacy* (ITEA, 2000), the movement to include engineering content in K-12 education has been greatly strengthened and enhanced by a host of others. In particular, the National Academy of Engineering has bolstered the cause with publications cited earlier in this paper, as well as by sounding the message continuously since drafting the Foreword to the *STL* in 2000. Thomas Friedman's best-selling *The World is Flat,* the new *NAEP 2014 Technology & Engineering Literacy Assessment*, and the NRC' new *Science Education Framework* are among the myriad of factors that have attuned the broader public to the idea of "engineering in K-12 education."

The success of materials such as the *PLTW* and other high school Technology Education "pre-engineering" curricula and the *Engineering is Elementary* curriculum make it clear that there is more opportunity for engineering in K-12 education now than has ever been the case in the past. But if engineering content is to be infused more broadly across the K-12 spectrum, there are substantial challenges that must be broadly addressed. Key among the challenges in moving forward with this idea are: 1) finding room for engineering content in the overcrowded school curriculum; developing robust instructional materials for the K-12 spectrum; and preparing educators to implement robust technology and engineering instructional materials at across the K-12 spectrum

This paper sought to examine data from four national studies of Technology Education teachers' beliefs and practices over nearly five decades, as well as related evidence of "engineering education" efforts from the Technology Education community, to see if the trends in Technology Education over the past decades speak "favorably" (or not) with regard to Technology Education's role in future efforts to implement engineering in K-12 education. Generally speaking, I think the findings from our review describe the changing ideas of Technology educators with regard to the nature of Technology Education content and curriculum that position the field to play an important role in what some (e.g., the NAEP, and the ITEEA) are increasingly referring to as "technology and engineering literacy for all."

The juxtaposition of these four studies allowed us to identify some demographic trends and point to some new directions. The Technology Education teaching workforce has been gradually becoming more diverse, likely the result of significant numbers of baby-boomer white male teachers retiring, concurrent with gradually increasing numbers of women (who now account for about 18% of Technology teachers, compared to 1% three decades ago) and minority faculty entering and remaining in the profession. Overall, the field is still dominated by white men, but the increasing percentage of female and minority teachers in Technology Education is nonetheless an important and encouraging trend for a field that seeks to promote technology and engineering literacy for all.

Technology Education teachers' changing perception of the *purposes* of Technology Education is another important trend. As the data indicate, TE teachers now rank technological problem solving and the application of science and mathematics as the most important purposes of

Technology Education, whereas they saw the development of tool skills as the primary purpose of their instruction during the Industrial Arts era. Clearly, present day Technology educators hold very different beliefs about Technology Education than did their IA counterparts in the post-World War II years. Their emerging interest in problem solving instruction and the application of science and mathematics in over the past two decades is wholly consistent with the growing and interest in K-12 engineering education. This shift in values explains why many of today's Technology Education teachers have been eager to take on engineering courses and design-based instruction.

Technology Education's turn to engineering content and curriculum seems to be creating a new vocational pre-engineering track at the high end of the bell curve. Technology educators teaching the PLTW or other pre-engineering curriculum are targeting academically capable students, effectively taking the vocational high road, in contrast to the vocationalists in the IA era, who taught marketable technical skills to students seeking to enter the workforce upon high school graduation. In effect, the field now has three tracks rather than the two that it maintained throughout the 20th century: 1) the general education track (technological literacy for all); 2) the vocational skills track (which, though contrary to the philosophy underlying both IA and TE—assisted in providing academically challenged students with marketable technical skills for the purpose of securing employment upon graduation from high school); and 3) a new engineering vocational track (for academically capable students seeking post-secondary engineering education). This pre-engineering track, perhaps best known through the PLTW Curriculum—founded, developed, and implemented by Technology Education teachers—has emerged in the past decade, and already accounts for about 15% of the respondents in the 1999 study, and coincides with the engineering profession's unprecedented interest in the K-12 engineering education.

While this study documents a significant increase in the use of "engineering" in program names, engineering content and method are by no means infused throughout Technology Education. Moreover, it documents Technology Teachers' strong interest in incorporating a wide array of engineering content into their courses and curriculum. But many challenges remain to be addressed if this transition to engineering-infused curricula is to occur. For example, Technology Education faculty typically have had little formal engineering education and have completed limited postsecondary mathematics and science coursework, and many K-12 education infrastructure components such as laboratories, instructional materials, and teaching facilities would need to be developed and installed.

Yet, there are an estimated 30,000 Technology Education teachers across the U.S. who provide key components of the infrastructure needed to implement engineering education in K-12 education. These components include: time in the school curriculum; physical facilities that lend themselves well to engineering design-based instructional activities; technical expertise; and as this study indicates, a substantial and increasing desire to implement more engineering, mathematics, and science content and methods in their programs. It's a scenario of opportunity and challenge. Despite the contributions Technology Educators have been making to technology and engineering education in recent decades, there is an immediate need for the development and implementation of new instructional materials, large-scale professional development associated with engineering education, and a new teacher education infrastructure capable of preparing K-12 technology and engineering educators for the 21st century.

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[8] The *34th Annual Official Education Construction Report* (2007) estimated $211/square foot for the median cost of building middle school facilities. The ITEA recommends a *minimum of* 3,000 square feet for a middle school lab in their 2010 *Facilities Planning Guide.* With an estimated 20,000 labs used by 30,000 teachers, the math works out to about $12.5 billion of existing Technology Education labs, *not including* the value of the remarkable array of expensive equipment found within each of those 20,000 labs.

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