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Technology Education in the United States

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報　告

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Technology Education in the United States†

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Technology education has a long history in the United States as manual training in the 1870s, industrial arts through most of the twentieth century, and now as technology and engineering education in most states. Federal legislation has helped define and finance technology programs while organizations such as the International Technology and Engineering Educators Association, National Academies, National Science Foundation, National Assessment Governing Board, and National Aeronautics and Space Administration have shaped content and pedagogy. There are many opportunities in the U.S. such as Integrative STEM Education, growing informal education experiences in makerspaces, and expanding elementary technology education, but there are also challenges such as teacher shortages, the role of engineering, and the dynamic nature of emerging technologies and educational practice.

Key words：Technology Education, United States

1. Historical Review of Technology Education in the United States

Technology education in the United States has a relatively short but rich history. The European Industrial Revolution of the eighteenth and nineteenth centuries greatly influenced the technology education programs in the U.S. today (Ritz, 2006). “These were the eras where practical activity was included in the school curriculum to establish contexts to make learning meaningful” (Ritz, 2006, p. 19). Legislative acts and educational leadership over the past 150 years provided the means to establish, promote, and fund the field of manual arts, which was later named industrial arts, then technology education, and presently technology and engineering education. During the industrialization period of the United States, Congress enacted legislation supporting mechanical and industrial arts. Over the years, mechanical and industrial arts programs evolved into technology education. The evolution of technology education continues today as engineering design and science, technology, engineering, and mathematics (STEM) education become more prevalent in U.S. schools. This section will provide a brief history of the origins of technology education, addressing key legislative acts and events.

Technology education in U.S. schools found its roots in 1862 when the United States Congress passed the Morrill Act. This act donated public lands to several states and territories, which could be sold or leased to fund the creation of at least one college, “to institute this new vocational curriculum to emphasize agriculture and mechanical arts” (Sarkees-Wircenski & Wircenski, 1999, p. 35).

The foundation of United States technology education programs can be attributed to two educational leaders, Calvin Woodward and John Runkle, who learned about the Russian Method of applied instruction at the 1876 Centennial Exposition in Philadelphia, Pennsylvania (Reed, 2017a). In the late 1870s, Calvin Woodward, mathematician and dean of the polytechnic school at Washington University in Missouri, created the Manual Training School in St. Louis. Meanwhile, John Runkle, president of the Massachusetts Institute of Technology (MIT), introduced manual training into the curriculum for instructional purposes that

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actively engaged students (Reed, 2017a). In 1904 the manual arts field evolved into industrial arts, aligning better with the changes in industry practices. The field, however, "maintained the active learning environment advocated by Woodward and Runkle" (Reed, 2017a, p. 2).

In 1917, the United States Congress passed the Smith-Hughes Act (a.k.a. the Vocational Act), which created federal and state boards of Vocational Education (Sarkees-Wircenski & Wircenski, 1999). Industrial Arts was subsequently firmly established in the American school system.

Dr. William E. Warner, in his *A Curriculum to Reflect Technology* identified and described how society, industry, and technology were evolving and that it was necessary for education to address those evolutionary changes (Warner, 1947). Warner's document suggested a curriculum management organization consisting of "Power and Transportation, Construction, Manufacturing, Communication, and Consumption" (Warner, 1947, p. 6). Warner's (1947) document was an influential piece of literature that guided the areas of technology education taught in the U.S. Delmar Olson (1957) suggested Warner's curriculum include "Research, Innovation, Design, Experimentation, and Testing" (Lewis, 2004, p. 29). Lewis (2004) also noted that, "because so much was new with what Warner, and then Olson, were proposing as curriculum direction for the field, engineering had to lay fallow, as manufacturing, construction, transportation, power and energy, and communications took hold" (p. 29).

Refining the works of Warner, Olson, and others, the *Jackson's Mill Industrial Arts Curriculum Theory* recognized and addressed "changes taking place in our world" (Snyder & Hales, 1981, p. 1). Addressing the interrelationship of philosophy and classroom practice, *Jackson's Mill* organized industrial arts curriculum into communication, construction, manufacturing, and transportation. The *Jackson's Mill* document illustrated the interrelationship of philosophy and classroom practice for a changing technological world.

As technological advances continued within society, industrial arts leaders began to advocate for a paradigm shift, so the field would reflect technology as the content base, not merely industrial practice (DeVore, 1964). In 1973, the American Industrial Arts Association president, Paul W. DeVore suggested that "the name of the association be changed to the American Technology Education Association…to reflect cultural reality" (Foster & Wright, 1996, p. 15). Clark (1981), in his article *The Industrial Arts Paradigm: Adjustment, Replacement, or Extinction?* wrote "Industrial Arts/Technology Education (IA/TE) is in a crisis – a crisis caused largely by the increasing changes that are occurring within society and technology" (p. 1). Similar articles helped usher into existence what we now know as technology education. In 1985, the name of the American Industrial Arts Association was changed to the International Technology Education Association (ITEA). ITEA published documents such as *A Conceptual Framework for Technology Education* (ITEA, 1991) to help guide the profession during this time of transition. Additionally, the Council on Technology Teacher Education (CTTE), an affiliate council of ITEA, published its 1986 yearbook, "Implementing Technology Education," to help teacher education programs with this transition. (To access all CTETE yearbooks, visit https://vtechworks.lib.vt.edu/handle/10919/5531).

Industrial arts/technology education has had academic standards since the 1920s, but the creation of modern standards that reflected technology as a content base occurred in the 1990s (Reed, 2017b). In 1996, ITEA published *Technology for All Americans: A Rationale and Structure for the Study of Technology* (ITEA, 1996). This document "provided the foundation for *Technology Content Standards* and established the guidelines for what each person should know and be able to do in order to be technologically literate" (ITEEA, 2007, p. 208). The document iterated the fact that "There are strong philosophical connections between technology, engineering, and architecture" and that "these professions need to work with technology educators to develop alliances for infusing engineering and architectural concepts" (ITEA 1996, p. 29). The document also stressed the need for "structure" (ITEA, 1996, p. 14) and a standards-based curriculum to "achieve technological literacy for a nation" (ITEA, 1996, p. 42).

Considered the most influential technology education document to date, ITEA published *Standards for Technological Literacy: Content for the Study of Technology* in 2000 and provided updates in 2002 and 2007 (ITEEA, 2007). As companions to *STL*, ITEA published *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards (AETL)* (ITEA, 2003). These publications were a result of the *Technology for All Americans Project* (TfAAP), funded by the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA). This project has provided decades of curriculum development, teacher training, and research. In addition to English, *STL* has been translated into at least six other languages: Mandarin Chinese, Estonian, Finnish, German, Greek, and Japanese (Dugger & Moye, 2018).

The U.S. Congress continues to legislate acts that support Career and Technical Education (CTE) programs in the U.S. Technology education is one of seven content areas that falls under the purview of CTE. The seven recognized CTE areas are Agricultural Education, Business and Information Technology Education, Family and Consumer Sciences Education, Health Sciences Education, Marketing Education, Technology Education, and Trade and Industrial Education. The primary federal legislation funding CTE in the U.S. is the Carl D. Perkins Act, which was initially passed by congress in 1984 and reauthorized in 1990, 1998, 2006, and 2018.

Many technology educators in the U.S. (Olson, 1957; Lewis, 2005; Wicklein, 2006; among others) began to advocate that engineering, especially engineering design, should be a central focus of technology education. In 2008, the Council on Technology Teacher Education (CTTE) dedicated its yearbook to this topic: "Engineering and Technology Education" (Custer & Erekson, 2008). Mounting research and association opinion prompted ITEA to change its name to the International Technology and Engineering Educators Association (ITEEA) in 2010. Many state associations affiliated with ITEEA have also changed their names to reflect a focus on technology and engineering (e.g., Virginia Technology and Engineering Education Association, VTEEA).

Technology and engineering education faces many challenges in the U.S. today. However, one thing is certain: U.S. public and elected leaders realize that technology and engineering education programs provide students what they need for the future (NAEP, 2013; PDK, 2017). Technology and engineering education is constantly evolving. We cannot predict what technologies will be used in the future, nor can we determine the environmental impact or the socio-cultural effects of those technologies that do not yet exist. What we can do is to follow the recommendations of documents such as *Technically Speaking: Why All Americans Need to Know More About Technology* (National Research Council, 2002) and *Tech Tally: Approaches to Assessing Technological Literacy* (National Research Council, 2006) that advocate for all students and adults to learn about technology in authentic ways that involve three dimensions: technological knowledge, capabilities, and critical thinking and decision making.

2. Current Status of Technology Education

Researchers have conducted studies over the past two decades to determine the status of technology and engineering education in the U.S. (Sanders, 2001; Moye, 2009; Moye, Dugger, & Starkweather, 2012; Moye, Jones, & Dugger, 2015). As the technologically driven world and work requirements become more dependent on technology- and engineering-literate citizens, educational requirements must continue to evolve. This section will discuss four significant trends in U.S. technology and engineering education: Integrative STEM Education, the National Assessment of Educational Progress, the teacher shortage, and two significant areas of growth: informal education and elementary technology and engineering education.

Technology education in the U.S. has been a leader in the development and use of STEM education before

STEM education became well known in the broader educational context (LaPorte & Sanders, 1995; Sanders, 2009). There are still many problems with the implementation of Integrative STEM Education. For example, many states require teachers to be "highly qualified," and often only in one subject, which can limit STEM education (Reed, 2018). However, technology and engineering education continues to be a leader in Integrative STEM Education, primarily through the work of ITEEA. ITEEA's STEM Center for Teaching and Learning™ (STEM CTL™) focuses on curriculum, professional development, assessment, and research with many of its activities guided by a consortium of state members. Access to STEM CTL™ materials such as the Engineering byDesign™ (EbD™) curriculum, as well as a STEM resource page, can be found on the ITEEA website (https://www.iteea.org/). These resources are based on *Standards for Technological Literacy* (ITEEA, 2007) but are also developed using other key STEM standards such as *Next Generation Science Standards* (NGSS Lead States, 2013) and *Common Core State Standards* (NGA & CCSSO, 2010).

ITEEA works closely with other organizations to foster Integrative STEM Education. Advance CTE, the Association of State Supervisors of Math (ASSM), the Council of State Science Supervisors (CSSS), and the International Technology and Engineering Educators Association (ITEEA) recently partnered with Texas Instruments to outline three principles to drive STEM education policy:

- Principle 1 - STEM education should advance the learning of each individual STEM discipline. This principle asserts that each separate domain within Science, Technology, Engineering, and Mathematics needs to be recognized as critically important foundations to enable more complex learning within and among the STEM disciplines. The teaching of individual content and skills within each STEM discipline is required as a natural learning progression in the preK-12 grades.
- Principle 2 - STEM education should provide logical and authentic connections between and across the individual STEM disciplines. This unlocks educators from following a rote script of teaching individual STEM discipline content to actively engage ALL prek-12 students in open-ended real-world problems and challenges to intentionally teach an I-STEM Education approach, defined as:

> "the application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels." (Wells & Ernst, 2012/2015, as adapted from Sanders & Wells program documents, 2010).

- Principle 3 - STEM education should serve as a bridge to STEM careers.

The *STEM⁴: The Power of Collaboration for Change* (STEM⁴, 2018) document provides recommended actions for each of these principles to help facilitate access and equity in STEM education.

A second trend in the U.S. involves standardized testing. The literature tells us that students learn better by doing hands-on activities while addressing, and solving, real-world problems (Moye, Dugger & Starkweather, 2018; NSTP, 2018; STEM⁴, 2018). This method of learning has been a cornerstone since the early origins of manual arts. However, in the broader educational context, standardized testing through short-answer response items has become the primary assessment method. "For more than 150 years, students' academic success has been measured by standardized tests" (Moye, Dugger, and Starkweather, 2018, p. 3). However, a national survey found that Americans felt that the current "testing doesn't measure up" (PDK, 2015, p. K3). In a subsequent PDK survey, American adults felt that schools should prepare students for the workplace and life, not just academic tests (PDK, 2017). The same 2017 PDK study found that taking technology and engineering courses and developing students' interpersonal skills are the two most important aspects of school quality (PDK, 2017). These sentiments are not new. In 2013, the National Assessment Governing Board (NAGB) created the National Assessment of Educational Progress— Technology and Engineering Literacy (NAEP-TEL) Assessment. In 2014 the NAEP-TEL Assessment was administered to 21,500 eighth grade students across the United States. A baseline of students' technological literacy had been established, but the results were less than desirable. In fact, it was reported that U.S. student learning of technology and engineering was "left to chance" and that "U.S. middle schoolers lack in-depth experience with technology and engineering" (CTEq, 2016, p. 1). The NAEP-TEL was again administered in 2018 to eighth grade students and, among others, the results revealed two interesting findings. First, significantly more eighth grade students took technology and engineering courses in 2018, compared to 2014 (Figure 1). Also, eighth grade students scored significantly higher on the 2018 assessment compared to 2014 (Figure 2). Additional research is needed but, based on those two data points, it could be inferred that the overall scores improved because more students took technology and engineering courses.

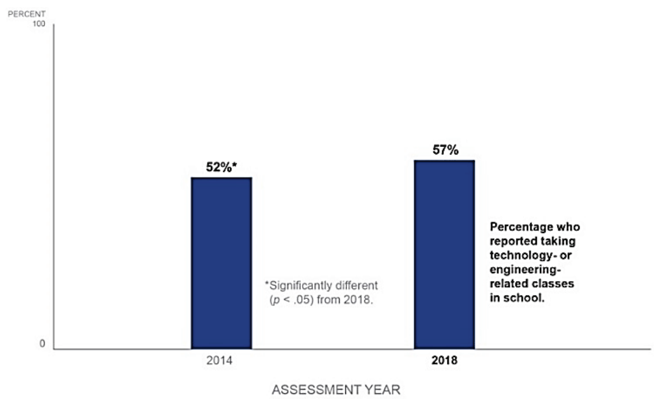

Fig. 1: Percentage of eighth grade NAEP TEL test takers in 2014 and 2018 reporting taking a technology or engineering class. Retrieved from https://www.nationsreportcard.gov/tel_2018_highlights/

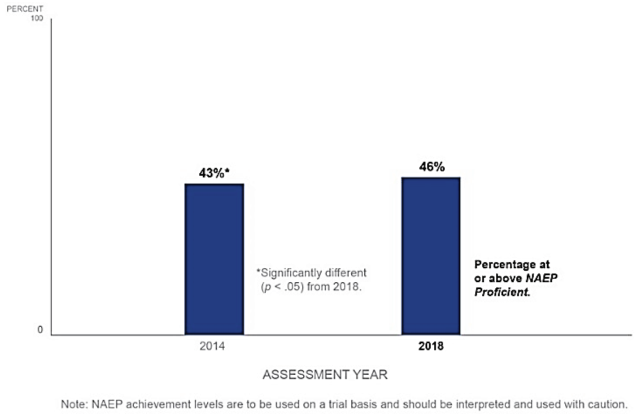

Fig. 2: Percentage of eighth grade NAEP TEL test takers in 2014 and 2018 that scored at or above the proficient level. Retrieved from https://www.nationsreportcard.gov/tel_2018_highlights/

A third significant trend in the U.S is the teacher shortage. The number of new technology teachers in the U.S. has been declining for quite some time (Moye, 2009). Ironically, this comes at a time when the U.S. public feels students should be taking more technology and engineering courses (PDK, 2017). Moye (2016) reported, "even though the supply and demand of technology and engineering teachers could be considered one of the most significant challenges facing the profession, there seems to be very little accurate data on this topic (p. 32). This situation is not only for technology teachers, but teachers in many disciplines. Overall, in the U.S., the teacher shortage is real, large, growing, and worse than anticipated (Garcia & Weiss, 2019). Since 1969, Phi Delta Kappa surveys have asked U.S. adults if they would like their children to become teachers. Initially in 1969 only 25% of parents indicated that they would not like for their children to become teachers. By 2009 that number had increased to 30%. Less than a decade later, 54% of parents preferred that their children not become public school teachers (PDK, 2018).

The fourth significant trend in the United States involves two areas of growth: informal technology and engineering education and elementary technology and engineering education. Informal technology and engineering education is best illustrated in the school library/media centers creating makerspaces where students can learn about technology and engineering by engaging in hands-on, technical activities. These activities often allow for unstructured exploration and are intended to get students interested in STEM at an early age, mostly at the elementary (Kindergarten-Grade 6) level. The technology education community is helping with these efforts through publications such as *Safer Makerspaces, Fab Labs and STEM Labs: A Collaborative Guide!* (Roy & Love, 2017) and by showing how these makerspaces can aid in recruiting for formal technology and engineering courses (Reed, 2018).

Additionally, there has been a growing interest in elementary technology and engineering education by classroom teachers who typically integrate technology and engineering education across the curriculum. ITEEA's Elementary STEM Council (ESC) and *The Elementary STEM Journal* continue to expand and support the growing elementary population. Activities such as the Virginia Children's Engineering Convention have grown annually and are increasing awareness and, more importantly, the number of students engaged in technology education (Reed, 2017a). See http://www.cpe.vt.edu/vcec/ to learn more about the Virginia Children's Engineering Convention.

3. Future of Technology Education

The technology and engineering education profession in the United States works in multiple ways with the goal of encouraging student involvement and development of their technology and engineering literacy—in fact, their overall STEM literacy. Today, education must be interesting and focus on improving students' critical-thinking and problem-solving skills (STEM[4], 2018). Futuring is difficult because "emerging research will continually shape teaching and learning, and the changing nature of technology continually shapes the discipline" (Reed, 2007, p. 21). The primary challenge is to recognize the needs of students and to fuel their desire to eagerly participate in their education. Students' success, of course, is the focus of any future planning. This section discusses three activities in U.S. technology and engineering education that will impact future directions: revision of *Standards for Technological Literacy* (ITEEA, 2007), defining the scope of engineering, and planning for the future.

Moye, Jones, and Dugger (2015) found that the majority of technology (and engineering) education programs offered in United States public schools followed ITEEA's *Standards for Technological Literacy: Content for the Study of Technology* (STL) (ITEEA, 2007). While guiding technology programs for almost two decades, the standards need an update. ITEEA is currently working to revise the standards to address technological, educational, and societal changes that have occurred since *STL* was first published. An initial survey was conducted in fall 2018 to solicit input on *STL*, including the format and possible deletion or addition of standards. Preliminary planning work to revise STL started in the spring of 2019.

The role of engineering will continue to be defined by whether the profession should proceed with a proper noun approach (i.e., to prepare students as engineers) or a verb approach (i.e., to teach students through engineering design practices) (Reed, 2018). Projects such as *Advancing Excellence in P12 Engineering Education* (AEEE; Strimel, Grubbs, & Huffman, 2018) and *Engineering for All* (Hacker, Crismond, Hecht, & Lomask, 2017) illustrate how both approaches can, and probably should, be utilized. This follows a historic duality in U.S. technology and engineering education: whether the discipline is general education for all students or career preparatory for specific technology and engineering occupations (Reed, 2018).

The final futuring activity involves research and strategic planning. ITEEA adopted a strategic plan in 2015 (see https://www.iteea.org/About/Mission.aspx) to help guide the profession. ITEEA's Board of Directors made this a living plan that is revised annually by task forces, affiliate councils (e.g., CTETE, CSL, ESC, TEECA), and other leaders. The current strategic plan is undergoing revision with the goal of releasing an updated version in the fall of 2019. Additionally, the authors of this manuscript are currently conducting a nationwide study to determine critical issues and problems facing technology and engineering education in the United States. The intended result of the study is to aid in future strategic planning. The scheduled completion date is spring 2020 but, as with the ITEEA strategic plan, ongoing research will be needed to ensure that technology and engineering education remains a leading-edge discipline within the United States.

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