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A Call to Action: Basic Technical Standards Education

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The engineering profession expects all students and new hires entering the workforce to have a basic understanding of and exposure to technical standards. A consensus exists among the business world that such education is necessary. Yet, engineering departments and academic institutions nationwide do not provide the quantity and quality of technical standards education demanded of engineers in the United States of America. Fortunately, the development of free, open-source, customizable modules is gaining popularity as a much-needed holistic solution to this problem. The call to action is here. The time to respond is now.

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Introduction

Technical standards are the backbone of the engineering profession. These formal documents establish uniformity across product criteria, testing methods, manufacturing processes, and best practices. They typically include the following sections: scope, references, definitions, significance and use, specifications, methods for testing or evaluation, maintenance, revision (of the standard), and appendices. An example of a technical standard is ASTM D638, "Standard Test Method for Tensile Properties of Plastics," from ASTM International (formally the American Society for Testing and Materials). This document details the test method used to define polymer tensile properties. This technical standard, like others, is developed by consensus from a team of experts. It is written to apply to a large audience and allows for repeatability and comparison between tests conducted in different geographic locations, by different uses, and with different instruments. Similar technical standards exist for the development of airplanes, food and beverage packaging, and pacemakers.

Historically, the lack of technical standards resulted in property damage, personal injury, high costs, and delayed efforts. Examples include the plethora of fires (i.e., 1893 World's Fair Fire) during the Industrial Revolution following the invention of electricity, the collapse of multiple bridges and structural developments pre-1900 (i.e., 1879 Tay Bridge Disaster) due to a lack of design criteria and construction methods, and the mismatched train track gauges between the eastern and western United States (i.e., Guage War) which hindered seamless transportation across the continent in the mid-1900s.

While the massive increase in technical standards development has worked to address these issues, similar issues persist. They demand the ongoing development and revision of existing standards. One present-day issue involves the lack of technical standards for electric vehicles. While cars are increasing in demand, there are few to no standards to advise autobody repair shops on the repair of damaged electric vehicles, to instruct the fire service on how to respond to lithium-ion battery fires, and to outline best design practices for installing fast-charging stations in commercial buildings.

Technical standards are an efficient and effective way to teach engineering design and engineering principles. The use of such documents is reported to encourage collaborative work and the recognition to engage in lifelong learning [1]. Technical standards education and training historically were provided via on-the-job training. Little has changed from apprentices learning standard practices in the late Middle Ages, through the Age of Enlightenment, to completing an engineering internship at the start of the 21st century; such education was rarely provided apart from the employer. Even within companies, those with winning technical standards strategies accredit their success to company mentors and trial and error rather than formal on-the-job training or an academic program [1].

Changing Times

However, times have changed. Academia is now responsible for introducing students to technical standards, and industry is responsible for providing specific customized technical standards education for each application and technical standards organization [2]. These changes in expectations are visible through the required inclusion of technical standards in engineering accreditation programs from ABET - Accreditation Board for Engineering and Technology, Inc., [3], to the National Society of Professional Engineers' *Code of*

Ethics for Engineers [4], and to the National Council of Examiners for Engineering and Surveying's *Fundamentals of Engineering (FE)* and *Principles and Practice of Engineering (PE)* exams [5].

Unfortunately, academic institutions nationwide are not positioned or incentivized to support this area of education [6]. They lack the expertise, resources, funding, and time to incorporate such education into their academic programs. As a result, technical standards education is largely absent in the classroom and far inferior to industry needs.

Challenges

Engineers and non-engineers identify with the statement, "Four-year academic engineering programs do not put sufficient emphasis on teaching technical standards" [7]. Insufficient technical standards education at the undergraduate level further compounds the industry's struggle to retain educated engineers. A course on technical standards basics is recommended for students, new hires, and new professional engineers with roughly the same distribution strongly agree to strongly disagree), favoring "strongly agree" [7]. The definition of "basics" used in the survey refers to the part of technical standards that is largely unchanging, such as the definition, the purpose, the history, the general contents contained within, and the development and revision process. While university students are commonly 18-22 years old, engineers taking the PE exam are 32-34 years old [8]. This information reinforces that while there is consensus that basic knowledge of technical standards is a critical component of an engineer's identity, this knowledge gap persists more than a decade after graduation.

Unlike a few decades ago, the industry is not prepared to provide the basic technical standards education that is not present in academic institutions. Fewer companies are encouraging employee involvement in technical standards activities as they associate it with a waste of time and money [1]. Professional engineering societies and organizations report challenges in recruiting and maintaining undergraduate student members despite increased efforts and programs focused on professional development, student competitions, and mentorship. The Society of Women Engineers reported a drop in collegiate membership from 20,594 (51% of total members) in 2019 [9] to 17,509 (40% of total members) in 2023 [10]. Many of these societies are member societies of ABET and are engaged in the technical standards development and revision process. Decreased exposure to professional societies (e.g., the American Society for Materials) can lead to decreased exposure to technical standards as these groups tend to have formal collaborations with global standards organizations (e.g., the American Society for Testing and Materials).

Furthermore, companies in the United States face added challenges when securing engineering talent with technical standards and knowledge compared to their foreign counterparts. Unlike the United States, other countries strongly emphasize technical standards education for engineers. Evidence of this is present in the global entities that lace technical standards into their agendas, frameworks, and policies. Many of these are described in the introduction of Li and Jin's work [11].

In some nations (e.g., South Korea), the basics of technical standards education are introduced as early as grade school regardless of students' interest in engineering due to the positive benefits (e.g., encourages group work) and exposure to safety concepts. This education continues throughout international students' graduate education [1]. The United States, on the other hand, struggles to provide basic technical standards education up to and within secondary and post-secondary education. This disparity between domestic- and foreign-born engineers creates a lag in technology and infrastructure advancements in the United States compared to European and Asian counterparts [1].

As society advances (e.g., digitalization, electrification, growing population), the need for new, revised, and highly specific technical standards increases. Two examples include artificial intelligence and cybersecurity standards. Undergraduate engineering students need to understand and use technical standards. This educational need is demonstrated through ABET criteria which require the exposure of undergraduate engineering students to technical standards in their first and second years and the integration of technical standards into senior design capstone projects [3]. Similar educational needs grow among professional engineers as engineering licensure requirements require basic technical standards knowledge [5]. The target for technical standards education, practical application, and cross-discipline experience is continually moving which magnifies the issue.

Recent Efforts

Engineering academics are doing their best to answer the industry's call to action. In the past two decades, individuals with extensive industry and technical standards experience (i.e., professors of practice) have been hired and recognized. Universities have worked to establish industry partnerships and collaborations. Professors have integrated more guest lectures and field trips into their courses, seminars, and senior design programs to discuss technical standards and applied learning.

Standards development organizations are outputting webinars, interactive education platforms, and outreach programs to educate the general population and relevant stakeholders on technical standards basics [12].

Professional organizations, engineering societies, and accreditation programs added technical standards language into rubrics and criteria. However, institutions are struggling to comply, and change is slow. Graduate programs are stepping up to fill the voids left by K-12 and undergraduate institutions by incorporating technical standards information into their courses and creating new courses from scratch [11], but this misses many students.

Professional organizations have achieved much success in developing content; however, these materials are not making their way to academics or into academic curricula. Many of these efforts are done in silos or fail to traverse enough barriers for large-scale adaptation. A stand-alone course at one university, single-day events, individual case study insertion into a senior design course, and one-time guest lectures have increased the availability and inclusion of technical standards in academic programs; however, these one-time-off efforts are not transversing the academic landscape at the need with which industry demands [12-17].

Potential Solutions

The first step towards creating a solution is to understand the current technical standards situation and challenges within the nation. Such a task is tough to do when funding agencies, department heads, and faculty bandwidth supports a piecemeal approach to a global issue. The landscape of basic technical standards education is incredibly variable from university to university, engineering program to engineering program, and senior design course to senior design course. A few engineering programs, like the University of Maryland's Fire Protection Engineering program, have integrated technical standards education in nearly every engineering course. In contrast, other programs and universities face simple challenges, such as accessibility and awareness, that delay and prevent them from making such progress. These issues are dissimilar across multiple categories (e.g., research activity, student population, geography), making it challenging to develop a unified approach. More research is needed on the existing challenges in implementing technical standards education into courses.

The second step is to deliver a desirable and relevant solution to the consumer – educators and students. Recently, two engineers developed free, open-source, customizable modules focused on the fundamental topics common to technical standards. Their product, the *Technical Standards in Engineering Program*, allows educators to easily adapt the modules based on engineering discipline, available time, and relevant content. It is as close to a holistic solution that exists at the writing of this paper [7]. Present in the literature for decades and supported by standards development organizations [1], the idea of customizable modules could revolutionize technical standards education if successfully executed. Educators and students should pilot test the program and provide feedback on the format and content. Technical standards instruction needs to catch up to the rapidly shifting landscape or catastrophe is inevitable. Everyone must play their part and heed the call to action.

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