

Importance of Standards in Engineering and Technology Education

Ahmed S. Khan, Amin Karim

Abstract—During the past several decades, the economy of each nation has been significantly affected by globalization and technology. Government regulations and private sector standards affect a majority of world trade. Countries have been working together to establish international standards in almost every field. As a result, workers in all sectors need to have an understanding of standards. Engineering and technology students must not only possess an understanding of engineering standards and applicable government codes, but also learn to apply them in designing, developing, testing and servicing products, processes and systems. Accreditation Board for Engineering & Technology (ABET) criteria for engineering and technology education require students to learn and apply standards in their class projects.

This paper is a follow-up of a 2006-2009 NSF initiative awarded to IEEE to help develop tutorials and case study modules for students and encourage standards education at college campuses. It presents the findings of a faculty/institution survey conducted through various U.S.-based listservs representing the major engineering and technology disciplines. The intent of the survey was to gauge the status of use of standards and regulations in engineering and technology coursework and to identify benchmark practices. In light of survey findings, recommendations are made to standards development organizations, industry, and academia to help enhance the use of standards in engineering and technology curricula.

Keywords—Standards, Regulations, ABET, IEEE, Engineering and Technology Curricula.

I. INTRODUCTION

A. Who Are the National and International Stakeholders of Standards?

IN today's global economy, the importance of the formal study of standards has been highlighted by the new demands of international trade. A number of national and international organizations provide guidance for developing and implementing standards to ensure product safety, such as

- American National Standards Institute (ANSI)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- Association of Electrical, Electronic and Information Technology, Germany (VDE)
- Canadian Standards Association (CSA)
- European Commission of the European Union (CE)
- Federal Communications Commission (FCC)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Transportation Safety Board (NTSB)
- Underwriters Laboratories (UL)
- US Food and Drug Administration (FDA)

Ahmed S. Khan is with DeVry University, United States (e-mail: askhan@devry.edu).

At the national level, the ABET Criteria for Engineering programs also require students to incorporate engineering standards in their design experience [1]. The National Standards Strategy for the United States (NSS) demands increasing the endeavors to educate future leadership in engineering, business, and public policy, on the role, value and importance of standards [2].

At the international level, Prof. Shiro Kurihara has proposed a Three-Wave Model for the spread of international Standardization [3]. The first wave is driven by scientists, engineers, and technologists; during this phase standards for technologies, products, manufacturing processes, and services are defined. The second wave started approximately two decades ago because of the application of network and digital technologies in communications.

The main stakeholders in this phase are the corporate and business leaders who are interested in the development of standards and procedures for interoperable technologies to facilitate world trade. This phase takes approximately five years and is not suitable for products with shorter lifecycles. The third wave is driven by government and consumers and typically involves standards for services and for product maintenance to improve customer safety and satisfaction. This phase has necessitated the development of global standards and regulations in other areas, such as accounting, law, health, environment and safety. The three waves are interrelated, and input from each phase is fed back to the other phases leading to continuous improvement. In summary, the role of standards is: (i) significantly expanding since the creation of the Internet and the World Trade Organization (WTO), (ii) leading to an increased impact on business and society, and (iii) creating many more stakeholders.

B. What Are the Standards Skillsets that All Graduates Must Know?

In 2003, a group of industry engineers and educators formed Standards in Education Task Force within IEEE to find the knowledge and skillset in standards that engineers and technologists must acquire before graduation. The process included faculty and student surveys to identify the current state of standards education. The task force made the following recommendation [4]:

1. Engineering and technology graduates should receive a comprehensive introduction on standards. This includes information on how standards are developed, how they impact the development of product, process, or service and how they benefit a country's economy.

2. Graduates should be familiar with key standards organizations in their disciplines and study standards or regulations in the context of an engineering case study.
3. Graduates should be able to identify and apply relevant standards in solving the expectations of an engineering design.

The IEEE task force also coordinated the development of educational materials to help engineering and technology programs incorporate standards education.

C. What Are the Fundamental Dynamics of Standards?

Harding [5] observes that students need to develop an understanding of the interplay of three fundamental dynamics of standards: Technology, Economics, and Politics. In this regard, students need to learn:

- a. How standards play a part in their career;
- b. How to think critically about standards development and technology solutions;
- c. About the pace of standards development in terms of technical change;
- d. How standards help drive innovation;
- e. How standards development process provides good technical solutions;
- f. Why standards are flexible.

D. What are the Needs of Undergraduate and Graduate Students?

Harding (2012) [5] further notes that the state of standards education at the university level is diverse. There are different needs at the undergraduate and graduate levels:

- a. Undergraduate students require a basic level of understanding that standards and standards organizations exist.
- b. Students can use standards at the project level.
- c. Graduate students use standards related to specific fields of interest.
- d. Graduate students can explore the standards development process and the intersection with business interests.

E. What Are Practical Factors that Hinder the Inclusion of Standards in the Curricula?

Some of the practical factors which hinder the inclusion of standards to the curricula are [5]:

- a. Institutions are overwhelmed by the quantity of currently required materials;
- b. Professors believe that they do not know enough about standards to teach the subject effectively or assess student work;
- c. Required materials for teaching standards do not exist.

Harding [5] observes that in addition to these, there is also a philosophical barrier, i.e., university education focuses on teaching the fundamental concepts and theories of engineering, and many professors believe that standards do not fit well in the foundation courses.

F. What Is the State and Status of Standards Education in Academia?

To gauge the state and status of standards education in academia, a faculty survey was conducted through ETD listserv, which has membership of more than 3800 faculty members. The following is a summary of results and recommendations based on faculty input and feedback.

II. SURVEY RESULTS

- Question 1: Do you teach standards and regulations in your curricula?

Out of 149 respondents, 71% said yes and 29% replied no.

- Question 2: Do students in your senior design course incorporate industrial standards and regulations in their senior design projects?

Sixty-six percent of respondents said yes and 34% answered no.

- Question 3: Which organizational resources are available for your students to access standards documents?

One hundred forty-nine respondents answered and 2 respondents choose not answer this question (Fig. 1).

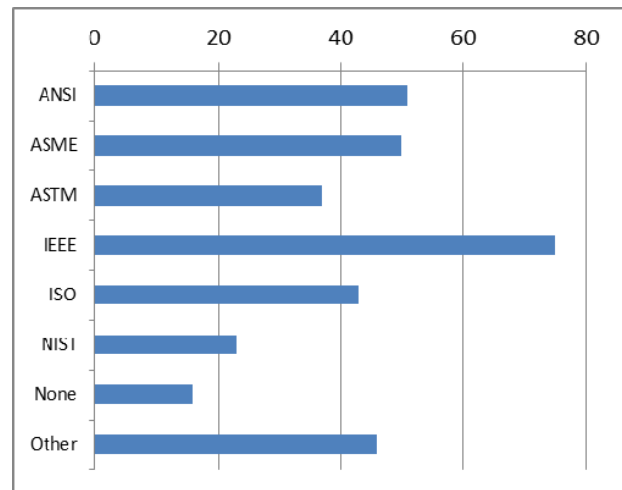


Fig. 1 Types of Organizational resources available for students to access standards documents

- Question 4: What are the impediments to teaching and learning about technical standards?

One hundred forty-two respondents answered this question (Fig. 2) and 9 respondents skipped this question. The responses in terms of their percentages are listed below:

- Lack of text books that provide the fundamentals and examples of application of technical standards (62%)
- Cost of access to technical standards documents (56%)
- Lack of faculty expertise on application of standards (49%)
- Lack of access to technical standards documents (42%)
- The "other" (21%) responses include: limited time, too many standards to teach, lack of faculty time, standards are continuously changing, and standards use complex

language, and lack of standards knowledge by faculty and administrators.

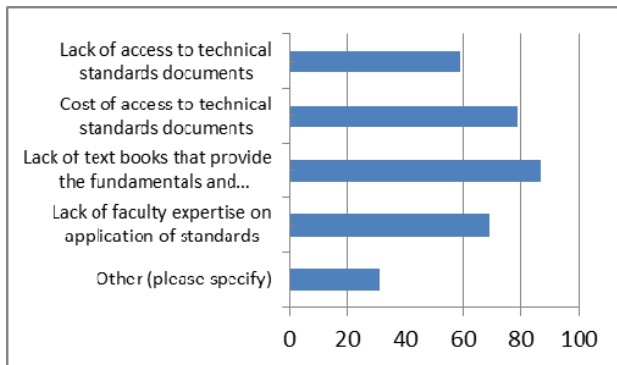


Fig. 2 Response distribution of impediments to teaching and learning of standards

➤ Question 5: What is your department affiliation?

One hundred fifty-one respondents answered this question.

Fig. 3 shows respondents' departmental affiliation. The other categories contain areas representing Civil engineering, Agricultural engineering, Manufacturing engineering, Construction engineering, Chemical engineering, Industrial engineering, and Aviation.

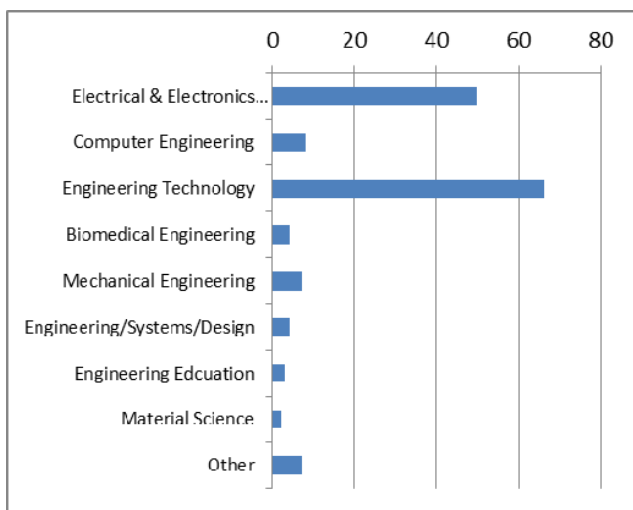


Fig. 3 Departmental affiliation of respondents

➤ Question 6: How can standard development organizations (SDOs) such as the IEEE, ASME, ASTM, and others help in mitigating the impediments to teaching and learning about standards?

A summary of selected responses is reproduced below:

- Creating a web resource with the summary of these Standards instead of the full blown standard.
- Please provide resources to help faculty teach about Standards and regulations (across multiple engineering disciplines).

- Offer free student licenses that "time out" like the Software companies provide for students (i.e. AutoCAD, Solidworks, etc.).
- Provide technical standards for educational purposes at a reduced cost to the students Work with publishers to encourage authors to add related standards to the textbook.
- Facilitate the access to at least the latest draft of the working document (before it becomes a standard). This way it would be possible to use an "almost standard" document in the classroom, without incurring in any cost.
- Most standards are too complicated to teach in a traditional course. The only way for the students to learn the standard is when they have to study the standard as part of a capstone design

➤ Question 7: Which textbooks or reference books or resources are being used to teach standards in your curricula?

A summary of selected responses is reproduced below:

- Machinery's Handbook; Print Reading for Engineering & Manufacturing Technology by Madsen & Madsen; Technical Drawing with Engineering Graphics by Giesecke et al.
- We require the students to purchase the respective Technical standards plus a textbook
- Fundamentals of Geometric Dimensioning and Tolerancing, 3rd Ed.
- NEC, NFPA & IEEE Color Book Series
- Library resources and word of mouth only
- Fundamentals of GDT by Krulikowski and Technical
- Drawing 101 with AutoCAD by Smith and Ramirez are both based on ASME Y14.5-2009 standard and are very helpful. However, the cost of an educational site license of this software is too steep.
- Most Text-books are obsolete...!! Each faculty/ Professionals should develop content and curricula to Select Text-books and /or resources.
- I mostly use items from my 18 years as an engineer prior to teaching in academics.
- Dr. Maan Jawad's textbooks on pressure vessels and plates and shells.
- IEEE 802 family of standards
- Get these standards from a web search
- NEC code book. Others as needed for Senior Projects (capstone experience).
- Machinery's Handbook; ASTM standards (available through library site license); sample MSDS (available Online); various other open-access online resources that "interpret" the content of specific standards such as UL-94
- Engineering Materials Properties and Selection, Budinski, 9e Machinist Handbook
- Basic Construction Materials" by T.W. Marotta, 7th Ed. had a wonderful selection of ASTM standards. Obviously someone at ASTM decided Marotta couldn't do this anymore so the 8th edition doesn't have it. Now students go to the library and make copies of the standards they need

- Real life scenarios are so much more practical, and applicable, than most of the theoretical textbook items.
- Question 8: Do you have any recommendations/suggestions for improving the teaching of standards and regulations in engineering and technology curricula?

A summary of selected responses is reproduced below:

- Our program adopted ASME Y14.5-2009 for the creation of mechanical engineering drawings. Teachers in every course are required to use this standard so it has become the departmental standard for teaching dimensioning and tolerancing. We have seen that students whose portfolios reflect an understanding of this standard fare well in job
- Interviews especially among organizations that also employ standards.
- Students benefit from developing their own quality assurance and quality control processes, based on standards, and defending their reasoning. This helps them clarify their thinking, identify their assumptions, notice causal relationships, and evaluate potential contradictions in the standards -- and also in the relationships between
- Technical standards, ethical/moral standards, environmental standards, community standards, etc.
- Perhaps establish a repository and reference process for those resources that interpret standards for users. If faculty can't afford to access the actual standard, they could use help in verifying its general content.
- Broad-based initiatives to promulgate standards usage among engineering and technology faculty members.
- Assignments which require students to search for relevant standards for specific applications. These can be short assignments and be much targeted in nature.
- Teaching more design techniques motivates students to seek technical standards in circuit component selection and circuit construction.
- Require students to conduct a standards search for applicable standards for their capstone projects.
- Poll your sponsoring companies to see which
- Standards are most important to them
- Stress presenting real applications using standards and good textbooks
- Make them more part of the syllabus requirements. ABET should ensure this happens.
- The applicability of standards in ECE courses varies by sub discipline within ECE. It is easier in the area I work in (power) than it is others. Some Ethernet standards also see use.
- Make it as interactive as possible, Have students go out into their own environment and collect standards that are found in the product information all around them. Structured as a standards scavenger hunt, the standards collected can then be used for exploration and discovery as related to other technical course content.
- We need to create the connections between teaching Standards and teaching other course material, likely through project-based pedagogy.
- Include recommendations related to teaching standards and regulations in program accreditation requirements
- Develop learning activities to explicitly improve reading comprehension with nonfiction, especially technical material. Chris Tovani's books are an excellent resource, full of exercises and best practices.
- Explicitly teach students to evaluate standards, in order to expose the hidden assumptions they often make about criteria for goodness. Students should be able to judge why the standards choose the tradeoffs that they do, and to assess whether a standard is appropriate for a situation - or whether it is overkill, or possibly inadequate.
- The freshman today needs more basic background classes. Nobody fixes their car so they don't know what a screw or a screwdriver is but the ALL want to be engineers cause that what people say we need (STEM programs)
- We typically have student teams develop inter-group Interface standards that all teams must respect, as part of the design process. So even if we are not using actual industry standards, we are following the standard processes for negotiating and agreeing on standards.
- It is difficult to train an engineer in a 120-hr Curriculum when 60-hrs are taken up with history, government, physical education and other subjects that are taught in high school.
- Need to determine which standards are most important to the local employers and either have access to these standards through the Library or through the course.
- Make sure the instructors have used them in their careers to perform actual professional engineering designs so that they know how they get implemented and how good or bad some of them are.
- Capstone courses are a natural place for consideration of standards and should include use of relevant standards.

III. IMPLICATIONS FOR PRACTICE/RECOMMENDATIONS

Based on the survey results and participants' feedback, the following recommendations are made for enhancing the teaching and learning of standards into the curricula and senior design projects.

1. The standards development organizations can help academia to better incorporate standards education in the curricula by:
 - a. Making standards available online to students and faculty at no cost.
 - b. Conducting standards education training programs for faculty.
 - c. Developing and disseminating standards education materials that can be incorporated into existing courses. Materials may include tutorials, case studies, webinar lectures by industry professionals on the basics of standards, and instruction on how to read and use a standard.
 - d. Developing and disseminating ancillary materials that provide guidance for faculty on incorporating standards education and evaluating output of student in standards education-related activities.
 - e. Sponsoring educational contests and events to encourage hands-on application of standards in student work.

2. Academia and industry should collaborate for:
 - a. Sponsoring authors to write/revise textbooks on standards and/or chapters on standards in textbooks for various engineering disciplines.
 - b. Developing examples of how to use standards in various foundation and senior design courses.
 - c. Conducting workshops and industry seminars on standards education for students and faculty.
 - d. Providing advisers to guide students on their senior projects based on standards.
 - e. Developing standards-based elective courses for undergraduate and graduate programs.
 - f. Providing internship opportunities for students in standards development organizations.

IV. CONCLUSION

This paper highlighted the state and status of standards education in engineering and technology curricula by discussing the faculty survey conducted through the ETD listserv. It also made recommendations for improving the teaching and learning of standards in the engineering and technology programs via a collaboration of academia and industry.

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Dr. Ahmed S. Khan is a Senior Professor in the College of Engineering and Information Sciences at DeVry University, Addison, Illinois. Dr. Khan has more than thirty-four years of experience in research, instruction, curricula design, development, evaluation, implementation and program accreditation, management and supervision.

Prof. Amin ul Karim, is the former national Director of the College of Technology and Health Sciences, DeVry University, Downers Grove, IL. Prof. Karim is a past Chair of the Electronics and Computer Engineering Technology Department, Heads Association of the American Society for Engineering Education and served as a TAC of ABET evaluator for engineering technology programs. He is a member of the Standards Education Committee for IEEE.