AC 2010-411: STANDARDS EDUCATION: BRIDGING THE GAP BETWEEN CLASSROOM LEARNING AND REAL WORLD APPLICATIONS

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Mr. Olshefsky was appointed the Director of External Relations for ASTM International in June 2007. ASTM International is one of the largest voluntary standards development organizations in the world and publishes over 12,000 standards. In his new position, Mr. Olshefsky manages, supports, and promotes ASTM's international and academic initiatives and outreach. Most recently, he directed ASTM's Committee Services Department, as well as having served as the manager of several ASTM technical committees. Jim holds a Bachelor of Science degree in business logistics from The Pennsylvania State University. He had a 13-year career in the transportation field before joining ASTM in September of 1998, when he began as a manager in the Technical Committee Operations Division.

Standards Education: Bridging the Gap Between Classroom Learning and Real World Applications

This paper introduces the role of standards education in materials science and engineering curricula. Technical standards provide a common language for engineers to specify materials for use in design and for discussing material performance. Standards help in teaching engineering students how to structure and organize complex technical problems in useful and practical ways.

The paper will detail the origin and maintenance of technical standards and their importance and application in the workplace. Of particular focus will be best practices for integrating technical standards into the classroom, with examples from accredited universities that offer unique ideas on how to challenge students in the use and application of standards.

Curricula need to stay market-relevant, and standards education is a perfect medium to marry technical design to real-world issues. Knowledge and familiarity with standards can give students the edge they need to enter today's competitive technical and business environment.

Origins of Technical Standards

A standard can be defined as an agreed-upon way of doing something. The technical standards that we know today evolved from early standards for fundamental quantities of length, mass, and time. Standards are known to have existed as early as 7000 B.C., when cylindrical stones were used as units of weight in Egypt. One of the first known attempts at standardization in the Western world occurred in 1120. King Henry I of England ordered that the ell, the ancient yard, should be the exact length of his forearm, and that it should be used as the standard unit of length in his kingdom.[1] Today, standards are developed through a consensus opinion of international technical experts for materials, products, systems, and services.

Modern day standardization began with the onset of the Industrial Revolution in the 19th century and the increased need to efficiently manufacture and transport goods. In the U.S., several private voluntary organizations were formed to develop technical standards in this era:

- 1880 – American Society of Mechanical Engineers (ASME)
- 1884 - The Institute of Electrical and Electronics Engineers (IEEE)
- 1894 – Underwriters Laboratories (UL)
- 1898 – American Society for Testing and Materials (ASTM)
- 1910 – Society of Automotive Engineers (SAE)

Today there are some 600 private U.S.-based standards developers. The American National Standards Institute (ANSI), founded in 1918, is a private, non-profit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system. However, the decentralized standardization process based in the U.S. is largely managed through the cooperation of individual stakeholders from industry, government, and academia. For example, in the concrete industry, ASTM International (formerly known as the American Society for Testing and Materials) develops specifications and test methods for concrete materials and the American Concrete Institute (ACI) develops design and construction practices for concrete. This coordination is a result of a long-standing agreement between the organizations and is enforced by the technical experts participating in each body.

Development of Technical Standards

The technical standards written today by standards development organizations (SDO's) are developed using a consensus process to ensure open and equal access to interested parties. The "process" is a set of rules for preparing draft documents, receiving technical feedback, and ultimately achieving consensus on approval and publication of the document as a standard. Often, published technical standards remain voluntary, allowing users to choose the standard that is most technically relevant for their industry's application. A standard becomes mandatory when adopted or referenced by a country's regulation, or when quoted in a contract between a buyer and seller. Showing students regulations, codes or specifications requiring the standards they are applying, will help to make the connection to actual industry practice. (see section on "Application and Use of Technical Standards" for more information on code development)

There are two primary standards development processes where groups of people with knowledge and experience in a given technical area, also known as a technical committee, can do their work. In one process, a country, in the form of an official delegation, is the participant on the technical committee. In the other process, individual interests or individual companies are the participants on the technical committee.

The World Trade Organization's Committee on Technical Barriers to Trade adopted a set of principles to which an organization engaged in the development of international standards must comply. These principles have been captured in document "G/TBT/1/REV. 8. Section IX," titled "Decision of the Committee on Principles for the Development of International Standards, Guides and Recommendations with Relation to Articles 2, 5 and Annex 3 of the Agreement."[2] These principles include transparency, openness, impartiality and consensus, effectiveness and relevance, coherence and development dimension.

Several SDO's have developed a comprehensive set of electronic tools to assist technical committees in developing new standards or revisions to existing standards. These tools are designed to ease the task of developing a standard and accelerate the development process. The tools include electronic standards templates, internet balloting systems, standards tracking systems, and web-based collaboration areas.

Application and Use of Technical Standards

Technical standards are used to promote public health and safety, support the protection and sustainability of the environment, and improve the overall quality of life. Standards contribute to the reliability of materials, products, systems, and services and facilitate international, regional, and national commerce.

Large manufacturers use technical standards to ensure the quality of components originating in the supply chain. During the manufacturing process, technical standards are used to manage quality control, maintaining the consistent production of materials. Standards keep the costs of production low by limiting the range of choices a manufacturer has to produce a product, but at the same time standards set a base that can drive innovation and new technology. Standards help develop markets when consumers are confident that meeting a technical standard ensures a satisfactory level of safety and quality.

The 1996 National Technology Transfer and Advancement Act (NTTAA)[3] transferred the responsibility for the development of technical standards from the federal government to private sector consensus standards organizations when feasible and appropriate. The NTTAA also mandated that government agencies participate in the development process of the standards developers. Today, more than 6,500 voluntary consensus standards are incorporated by reference in federal law.

Local jurisdictions in the U.S. are free to adopt codes that regulate various aspects of the built environment. Technical standards are often referenced in codes to provide details on how a material, product, or assembly is to be designed, manufactured, tested, or installed to obtain a specific level of performance. Much like technical standards, codes are not legal documents until cited in a contract or called out in regulation by an agency or municipality, etc.

The International Code Council (ICC) is an example of a nonprofit organization that publishes building codes in order to provide model regulations that can be adopted by state and local government with the intent to protect public health and safety. In 2000, the ICC released a set of fully coordinated and compatible model building code regulations by consolidating what was previously contained in the model codes of three regional bodies in the U.S. The "I-Codes", as they are commonly called, replaced the model codes from the Building Officials and Code Administrators, International, Inc. (BOCA), the International Conference of Building Officials (ICBO), and the Southern Building Code Congress International, Inc. (SBCCI).

The ICC's "CP# 28-05 CODE DEVELOPMENT"[4] document details how the model codes are established. Anyone may participate in proposing changes to the codes, however only the governmental members may vote to approve changes or additions. As outlined in the ICC Bylaws, a governmental member shall be a governmental unit, department or agency engaged in the administration, formulation or enforcement of laws, ordinances, rules or regulations relating to the public health, safety and welfare.[5] Modifications to the I-Codes are considered according to a biennial code development schedule established by the ICC.

Building codes would be voluminous in length if an attempt was made to incorporate in-depth coverage on every technical detail into the codes themselves. As a result, building codes utilize the knowledge of technical experts to deal with specific subjects by referencing technical standards. Technical standards referenced in codes must meet criteria outlined by the code body. Standards must be developed through a consensus process and be written in mandatory language to insure that the application and intent of a standard is clear. The resulting referenced standards are considered part of the requirements of the code.

Best Practices for Integration of Standards Education in Curricula

ABET, Inc., formerly known as The Accreditation Board for Engineering and Technology, sets engineering accreditation requirements for the incorporation of standards in engineering curricula: "Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints."[6]

According to a survey conducted by The Center for Global Standards Analysis on Standards Education Perspectives in U.S. Schools of Engineering (2004), there are a very small number of university courses in the United States that are dedicated to the study of standards and standardization.[7] However, many standards developers provide tools and resources for teaching students about the standards development process that can be integrated into existing engineering curricula. ANSI maintains a "Standards Education Database" which lists online education and distance-learning resources.[8]

Many engineering students will require a basic introduction to the concept of standardization. Some students may believe that all standards are mandatory and there is no way to influence the content of standards, when the opposite is actually true. Students need to be made aware that technical standards have bottom-line business implications and can impact global trade, innovation, and competition. Technical standards are used by individual companies, research labs, and government agencies and guide product design, development, and market access.

Exposure to testing related standards in the third and fourth years of undergraduate study can help align educational concepts with real-world applications. An ordinary design assignment becomes interactive by requiring students to retrieve technical standards and apply them when applicable. Material science students need to have a basic understanding of several mechanical property tests and the use of standards to run valid tests. Examples of several important metals testing methods include:

- ASTM E8 / E8M Standard Test Methods for Tension Testing of Metallic Materials
- ASTM E10 Standard Test Method for Brinell Hardness of Metallic Materials
- ASTM E18 Standard Test Methods for Rockwell Hardness of Metallic Materials

Students need to be able to understand the range of materials covered by a given standard, its purpose, what specimens are used in the standard, and be able to explain in their own words why the standard is important.

Educators can show how a specific standard relates to a practical outcome through hands-on activities in the laboratory. The steps may include calibration and set-up of a testing apparatus, preparation of test specimens, recording the results of the test, performing any necessary calculations, writing a test report, and interpreting the results. A student who is being introduced to the language of standards for the first time may find interpreting the actual language of standards difficult to follow. Therefore, it may be necessary to prepare a simplified outline of the necessary steps to perform a complete test. Any simplification of a method should remain consistent with the original technical standard. In addition, some testing standards may take too long to perform or are too general for a given laboratory assignment. Educators may find that a simplification of the assignment may be necessary to complete the activity within time constraints. For example, ASTM D2435 Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading is the basic experiment to measure the settlement characteristics of a clay layer and takes approximately one week to perform. By having each lab group in a class perform a portion of the test and sharing the results, an entire data set can be developed for analysis.

Because it is likely that engineering students at an advanced or graduate level will work in engineering management, their focus should be on how standards provide the building blocks for quality control. For example, if a laboratory wishes to obtain a certification, it must demonstrate that it is following proper procedures in terms of management, calibration of equipment, documentation, and personnel training. Many of these aspects required for laboratory certification are outlined in specific technical standards for each industry. For example, ASTM C1077 Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation defines the duties, responsibilities, and minimum technical requirements of testing laboratory personnel and the minimum technical requirements for laboratory equipment utilized in testing concrete and concrete aggregates for use in construction.

There may also be a benefit to introducing students to the concepts of laboratory inspections and proficiency test programs, both of which involve standards as a means to determine if the laboratory is qualified to conduct the specified tests and may be required to obtain laboratory certification. The Cement and Concrete Reference Laboratory (CCRL)[9] is an example of a provider of laboratory assessments and proficiency testing programs for the cement and concrete industry.

Advanced students need to learn how standards will fit into the bigger picture of engineering practice. It is more likely that future engineers will need to know how to evaluate and use test results, instead of having the hands-on skill to perform a test in the laboratory or in the field. Additionally, students must know enough about the details of technical standards to specify testing for a project and potentially supervise testing in a laboratory management situation.

Key Examples from Accredited Universities

Following are summaries of how professors have successfully used technical standards in the classroom. The overviews and syllabi of selected courses are available in their entirety on the "Peer-to-Peer Resources" page of the ASTM International Students and Professors website.[10]

Rensselaer Polytechnic Institute's "Properties of Engineering Materials II"[11] is offered as a third year second semester course within the Department of Materials Science and Engineering. This course teaches the mechanical properties of metals, ceramics, and polymers from both the macroscopic and atomistic or micromechanical viewpoints, and includes an introduction to three-dimensional stresses and strains. Elastic behavior, plastic behavior, strengthening mechanisms, fracture, creep, and fatigue are all addressed. Three hours of lecture per week are combined with two hours in the laboratory. Students are required to have a basic understanding of several mechanical property tests and how to use technical standards to complete valid tests. Tensile test standards are performed in the laboratory and are used to calculate Young's modulus, yield stress, ductility, etc. This work helps the student to understand the components that give a metal strength and the sources of error in the testing procedures. The course concludes with an exercise that gives students the opportunity to select a random metal or metal alloy and strengthen it in the laboratory. This allows students to gain a basic understanding of the strengthening mechanisms in metals and the role of dislocation motion and structure as a result of strengthening processing.

Cleveland State University's "Behavior and Properties of Concrete"[12] is offered as a third year second semester course within the Department of Civil and Environmental Engineering. This course teaches the properties of hydraulic cements, aggregates, plastic, and hardened concrete; effect of admixtures and curing conditions; specifications and acceptance tests; placement, consolidation, finishing, and durability of concrete. The class meets twice a week for lectures only (no laboratory) and at least ten technical standards are presented. Examples include ASTM C39 / C39M Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens and ASTM C1074 Standard Practice for Estimating Concrete Strength by the Maturity Method. Students are expected to be able to discuss and evaluate test results and to be able to locate technical requirements in the standards. For example, as homework the students are asked to identify the ASTM standard and section for various testing requirements such as "… how many cylindrical test specimens must be prepared to develop a maturity-strength relationship" or "…when making concrete specimens in the field, what is the initial curing temperature range if the concrete specified strength is 6000 psi or greater." As a result of the work in the class using the actual technical standards, students are expected to be able to design special concrete types that would meet industry expectations.

Kettering University's "Properties of Polymers"[13] is offered as a fourth year course within the Department of Mechanical Engineering. This course begins with the thermo-mechanical properties of commodity thermoplastics and includes a review of structure/nomenclature. The course then addresses polymer shape and size, amorphous and crystalline states, glass transition temperature, melting temperature, rubber elasticity and viscoelasticity (creep). In the "Testing for Design" portion of the class, ASTM D1238 Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer is studied as a means to determine fluid properties and ASTM D2990 Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics is used to learn time dependent behavior. Materials selection and design projects are also included. The class meets twice per week for two, two-hour lecture sessions (no laboratory). Students are required to complete a project during the course where they are provided with a sample plastic product and information about the mechanical, chemical, and thermal environments experienced by the product in service, as well as modes of failure. Students must develop a standard test procedure for the product, correlate it to an existing technical standard, and relate the behavior of the product to mechanical and thermal behaviors of polymers. Additional questions are posed about specific polymer properties and their effect on potential performance and the manufacturing process.

Widener University's "Structures and Materials Laboratory"[14] is offered as a second year second semester course within the Department of Civil Engineering. This course covers basic laboratory test standards to measure the engineering properties of construction materials such as concrete, steel, timber, masonry, etc. The course also explores experimental analysis and the evaluation of behavior of structural elements and systems under various loading states. This is a writing-enriched course with emphasis on technical writing skills. The course consists of one one-hour lecture and one three-hour laboratory per week. Twenty-five percent of the final grade is based on a group design-build-test project. The requirements for the project come from the American Concrete Institute's Eastern Pennsylvania and Delaware Chapter Student Concrete Beam competition.[15] The students gain insights into the effects of tolerances in beam fabrication as well as concrete mix technology and structural design parameters, as outlined in the American Concrete Institute's 318 Building Code Requirements for Structural Concrete which incorporates technical testing standards by reference. The project is designed to challenge the ingenuity of the students and to foster communication and involvement among students, faculty, and industry.

The Massachusetts Institute of Technology's "Mechanics of Structures and Soils"[16] is offered as a third year first semester course within the Department of Civil and Environmental Engineering. The course objectives are to learn and apply methods of structural analyses for beams, columns, frames, cables and arches; to develop an understanding of the behavior and engineering properties of construction materials; to gain physical insights into material behavior through an integrated program of laboratory experiments; to learn and apply principles of soil mechanics used in the analysis of foundations, earthworks, retaining structures and slopes; and to develop an appreciation of techniques and approximations used in structural and geotechnical engineering. The course includes four hours per week of lectures, three hours of laboratory time, and one hour of recitation, and relies heavily on the textbook Geotechnical Laboratory Measurements for Engineers to explain both the underlying theory of the tests and the standard testing procedures. During the laboratory assignments, a handout outlines the proper procedure for performing a test that is a simplified version of a published technical standard used in industry. All simplified procedures and final laboratory reports are consistent with the requirements in the actual technical standard and the original standard is listed as a reference for further reading.

Conclusion

Standards provide a common language to discuss complex technical issues and can help bridge the gap between the classroom and real-world applications. Learning through the use of technical standards can often provide students with new perspectives and increased understanding of the relevance of standards to modern engineering practices. Awareness, exposure, hands-on use, and understanding of how standards fit into engineering practice are critical in helping future engineers adapt to the workplace. As one professor of civil architectural and environmental engineering put it, "Standards form a technical language that is essential for new engineers to understand. Progressing for the first time into the work of engineering is much easier if you understand the language and landscape of the technical standards that shape your industry."[17]

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[1] NBSIR 87-3576, "The ABC's of Standards-Related Activities in the United States", National Institute of Standards and Technology, Gaithersburg, MD 20899, May 1987.

[2] See http://www.astm.org/GLOBAL/images/wto.pdf
[3] See https://standards.gov/NTTAA/agency/index.cfm?fuseaction=home.main
[4] CP# 28-05 CODE DEVELOPMENT, See http://www.iccsafe.org/AboutICC/Documents/CP28-05.pdf
[5] Bylaws for the International Code Council, Inc., See http://www.iccsafe.org/AboutICC/Documents/bylaws0109.pdf
[6] ABET Criteria for Accrediting Engineering Programs, See http://www.abet.org/forms.shtml#For_Engineering_Programs_Only
[7] See http://www.standardslearn.org/Standards_in_the_classroom.aspx
[8] See http://www.standardslearn.org/trainingcourse.aspx
[9] See http://www.ccrl.us/
[10] See http://www.astm.org/studentmember/Peer_to_peer_courses.html
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