Incorporating Engineering Standards in the Major Design Experience

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Introduction

The ABET Criteria for Engineering programs require students to incorporate engineering standards in the culminating design experience.[1] The United States National Standards Strategy (NSS) calls for increased efforts to educate future leaders in engineering, business and public policy on the value and importance of standards.[2] There is a unique opportunity for the standards community to assist academe in incorporating engineering standards in undergraduate engineering curricula and at the same time accomplish one of the goals of the NSS.

The purpose of this paper is to outline the ABET requirement to include engineering standards in design and some ongoing activities in the standards community that can assist and support this. It will be shown that there are extensive materials readily available to assist faculty in including engineering standards in the major design experience. It will also be shown that engineering standards have broad policy implications and developing an awareness of these aspects can contribute to a student's general education.

ABET requirements

Criterion 4 of the Criteria for Accrediting Engineering Programs requires students to use engineering standards in the major design experience. Criterion 4 also requires that students consider realistic constraints that include most of the list of the 12 considerations included in the criterion. Several of the considerations specifically - environmental, health, and safety - are commonly the subject of standards, codes and technical regulations that influence design and manufacturing or construction.

For the purposes of trade, the World Trade Organization (WTO) Technical Barriers to Trade (TBT) Agreement defines technical regulations for products as standards with which compliance is mandatory.[3] The European Union's (EU) "New Approach" issues directives that define standards needed to ensure that the EU meets its objectives in the

areas of health, safety, and the environment.[4] For the EU, the standards are actually developed by the European standards organizations - the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC). Two of the other considerations in the Criterion 4 list are social and political and it is not too difficult to envision a design scenario where a student would be working on the design of a product to be sold in the European Union - i.e. where social and political considerations could be important.

Engineering standards

At the national and international level, what standards should students be familiar with and how can this be accomplished? Based on information at the Massachusetts Institute of Technology (MIT) library web site, mechanical engineering students are directed to search the national standards network to determine if there is an American National Standard (ANS). A standard becomes an ANS only if the standards developing organization (SDO) submits it to the American National Standards Institute (ANSI) for approval so not all standards students would need to consult will be ANS's. MIT maintains a collection of all ANSI approved standards in its library, along with those of ASTM International (ASTM) and the Institute of Electrical and Electronic Engineers (IEEE) (electronic access). It also maintains Society of Automotive Engineers (SAE) aerospace and ground vehicle standards.

The National Standards Network can be accessed at http://www.nssn.org/. Although NSSN originally stood for the national standards system network, it is now much broader and is a good starting point for students to research international standards as well. The MIT library can be expected to have a fairly good collection of standards suggesting that many students may find access to actual standards fairly limited although standards can sometimes be obtained through interlibrary loan and can always be purchased. Access to International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) standards is probably very limited for most students although some information on ISO and IEC processes is available on their web sites.

Based on sample materials on the National Council of Examiners for Engineering and Surveying (NCEES) web site, there are no questions on standards on the Fundamentals of Engineering (FE) exam. The only practice questions on the FE exam deal with ethics. At the Professional Engineer's (PE) level, there appear to be some questions dealing with codes and standards on the mechanical and electrical engineering examinations. For the civil engineering exam, a list of design standards is given which must be used to answer questions in the structural and transportation areas.

The National Standards Strategy looks at the broader picture particularly the role of standards and conformity assessment in global commerce and ensuring the competitiveness of U.S. industry. Standards developing organizations (SDOs) are mainly interested in training the professionals needed in future standards development work. In addition, the NSS standards strategy is looking for SDOs to provide educational

opportunities worldwide to facilitate participation in U.S. based standards activities. The WTO Technical Barrier to Trade Agreement expects countries to participate in standards activities important to its industry and the NSS calls for organized education activities to ensure broader more effective participation in standards processes and higher quality standards. There is a recognition in the NSS that there is a need to educate all on the benefits of standardization.

Incorporating Standards in a design project

Relevant standards should be consulted early in the design process and since it is reasonable to assume many companies will want their products to be accepted in the global market, students could be expected to look to see if their product is likely to be covered by an EU Directive. According to the most recent report by the U.S. Trade Representative, the European Union continues to be the U.S.'s largest trading partner and, as such, is a large market for US goods and services.

NIST has a number of publications that students can use to learn about EU Directives that could affect their design project. NIST Special Publication 951 gives an overview of the European process.[5] A table is included which shows the product fields affected by the new approach. Some areas covered by directives include: medical devices, construction products, machinery, and low voltage equipment.

A series of reports are available dealing with directives in different sectors which students could consult for details specific to their project area. These documents provide more detail than NIST SP 951 but are linked to this document. An example is the guide to the machinery directive.[6] The EU's essential requirements deal with health, safety, and the environment and this NIST report includes a discussion of health and safety issues specific to machinery. A discussion of the machinery directive would be a good way for students to gain an understanding of some of the considerations in Criterion 4 as they relate to the design of machinery. The Machinery Directive itself can be accessed at the EU legislation website.[7]

There are NIST guides for medical devices, the low voltage directive, and other sector-specific issues as well as more general guides dealing with issues such as product liability and product safety. All of these documents are available for downloading from the NIST site. These sector guides could be used to provide background for the major design experience in mechanical, electrical and biomedical engineering and the general guide for all areas. They provide a framework that could be useful in developing design constraints that address the considerations listed in Criterion 4. In addition, discussions can be built around the major design experience that are relevant to some of the outcomes listed in Criterion 3.

Public policy aspects

Gillen discusses preparation of the standards professionals of the future and the role of

standards in public policy.[8] In many cases, policy is sector specific so it is difficult to draw general principles. However, standards and technical regulations already play a dominant role in defining health, safety and environmental considerations nationally and internationally and these influences on design are not decreasing.

European Union policy is to define an approach for achieving desired outcomes - health, safety and environment - and direct the European standards organizations to write appropriate standards where international standards do not already exist, and ultimately to require designers to design products to meet those standards. Although products do not have to be designed to meet specific standards, doing so carries the presumption of conformity to the directive which is a requirement to market a product in the EU. Thus there is a strong incentive to design to appropriate standards. Clearly there is enlightened self-interest in writing standards that promote regional economic advantage while at the same time raising the bar for health, safety and the environment. From an international business perspective, the strategic implications of standards are increasing.

For example, the EU recently (fall 2002) held consultative meetings on a framework directive for eco-design of end-use equipment. The objective is a directive that harmonizes requirements concerning the design of end use equipment to ensure the free movement of these products within the EU and to reduce their impact on the environment. The proposed directive would apparently merge initiatives dealing with design of electrical and electronic equipment and energy and efficiency requirements.[9]

Sun Microsystems is concerned about a directive that would affect design of products they market in the EU. Their position is that these objectives of the EU would be better accomplished by working in an international standards-setting context and working more closely with industry.[10] In the IT area, where standards and products evolve rapidly and the U.S. market is clearly global, the incentives for understanding policy issues are clear.

What are the societies doing?

Several of the engineering societies have or are developing materials that can be used to provide basic background on standards and standardization processes. In addition to what the engineering societies are doing, ASTM International, ANSI and NIST have extensive resources that could be used as background for standards education.

The American Society of Mechanical Engineers (ASME) has an introductory publication that describes its standards processes.[12] This publication is general enough to be a good introduction for all students. ASME notes that over two hundred standards developing organizations are accredited by ANSI which means they abide by the principles of transparency, balance of interest, and due process in developing their standards. It is further noted that the members of standards committees are typically engineers knowledgeable in the technical aspects of the standard and notes that participants must agree to adhere to the ASME Policy on Conflict of Interest and the Engineer's Code of Ethics.

The Institute of Electrical and Electronic Engineers (IEEE) is a major standards developer and is reportedly reviewing what graduates in electrical and computer engineering should know about standards. Software engineering program criteria were recently added to the ABET Criteria for Accrediting Engineering Programs with the Computer Science Accreditation Board (CSAB) taking over from IEEE as the lead society for 2002-2003. Moore , in a very detailed treatment of the role of standards in software engineering, notes that standards for software engineering tend to be process rather than product standards.[13] It is interesting to note that in some disciplines there has been resistance to defining what might be termed process standards.

ASTM International (formerly the American Society for Testing and Materials) is not one of the technical societies that participates in ABET but it is a major SDO and it does have a very useful introduction to standards processes. Many, if not most engineering libraries, maintain collections of ASTM standards which students can consult. ASTM standards are used around the world as are the standards developed by other major U.S. SDO's such as ASME and IEEE.

What is ANSI doing?

In response to NSS Objective 11, the American National Standards Institute established an ad hoc education committee with representation from industry, government and academe. In support of the NSS, a free online introduction to standards course has been developed and is available on the web (See http://www.standardslearn.org); students and faculty should find this a useful introduction to standards. This online module could be used as background for a lecture on standards in the capstone design course or students could be directed to complete the course on their own - an exercise in life-long learning. Additional modules on standards development processes and international standards are under development by ANSI.

For understanding the standards processes themselves there are a number of ANSI courses available.[11] These courses are well above the level of what graduates need to know in terms of process. However, engineering graduates are expected to understand the context of their work and standards processes will come in here. Codes and standards are part of the professional component part of the curriculum

ANSI and NIST sponsored a workshop at Columbia University in September 2002 to bring together industry and academics, primarily in the telecommunications area, to begin to define a standards education and research agenda for higher education. This discussion continued at the ANSI annual meeting in October 2002 with defining a body of knowledge the focus of current activities. The ABET Criteria defines a need for undergraduate engineering education and there is agreement that resources to assist engineering programs in standards education already exist and are generally available to engineering programs. There is, however, a recognition that support and encouragement for faculty will be needed to ensure better integration of standards in the design experience. The approach in business and public policy is not well defined at this point and the interest

there appears to be mainly at the graduate level.

Other activities

Trade organizations are major standards developing organizations and some of them have materials that can provide sector-specific information on standards. For example, INCITS – the International Committee for Information Technology Standards – develops voluntary consensus standards in the area of information technology. As one example, they develop and maintain programming standards with C++ - an example that many students would be familiar with.

The federal government is a major user of standards and in the past has been a major standards developer. A number of federal agencies have significant standards activities that can be good sources of specialized information for students. For example, the Department of Energy has an introduction to standards which includes a great deal of general information as well information specific to energy.[14] NIST coordinates federal agency standards activities and is also is a source of basic information on standards.[15]

Finally, the Standards Engineering Society (SES) promotes the use of standards and standardization. Although its focus is on the standards professional, all of the papers from its annual conference and award winning papers from the Worlds Standards Day paper competition, are on its website and can be downloaded.[16] Students will find there a wealth of information on standards and conformity assessment.

Conclusions

The ABET Criteria for Engineering programs require students to incorporate engineering standards in the culminating design experience; this requirement is explicit in Criterion 4 but it is also implied in the list of 12 considerations that include health, safety and environmental. Health, safety and environmental considerations are commonly the subject of mandatory standards or technical regulations affecting design.

The National Standards Strategy is encouraging more education of engineers on the importance of standards and there are extensive resources available on most aspects of standards with much of it freely available on the web. As suggested in the introduction, this objective of the NSS and the requirements of Criterion 4 on standards is a unique opportunity for the standards and engineering education communities to work together.

The Engineering Societies, and ANSI, SES, and NIST already have materials that can be used by students as background in their design work or for faculty to develop one or more lectures appropriate to the design discipline. ANSI has an online introduction to standards and is developing additional courses that could be used by faculty as resources for lectures on standards in the capstone course or for self study by students. ANSI would welcome input from engineering educators on specific needs. There is a great deal of material on standards ranging from the very general and introductory to sector specific

and highly specialized that may be useful in capstone design courses.

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