Incorporating Standards in Capstone Design Courses

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Introduction

The ABET Criteria for Engineering programs require students to incorporate engineering standards in the culminating design experience; recent changes continue this requirement.[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] The NSS was developed by a diverse group of government and private sector representatives from industry, government, trade and professional societies, and consumer organizations. It is currently being updated and will likely call for increased education on standards and the increasingly important role they play in regulation and commerce at the global level. 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 standards in engineering design and ongoing activities in the standards community to assist and support this. It will be shown that there are extensive materials readily available to assist faculty members in including engineering standards in the major design experience including a new standards workshop that was offered for the first time at a regional ASEE meeting in fall 2004. It will also be shown that engineering standards have broader implications and that 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 incorporate engineering standards and multiple realistic constraints in the culminating major design experience. Criterion 3 requires that students consider realistic constraints from a suggested list of eight that includes environmental, health and safety – which are commonly the subject of standards, codes and technical regulations that influence design, manufacturing, construction or use.

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 considerations in the Criterion 3 list of outcomes 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.

Standards

At the national and international level: with what standards should students be familiar and how can this be accomplished? Based on information from the Massachusetts Institute of Technology (MIT) library web site, mechanical engineering students are first directed to search the national standards network to determine if there is an American National Standard (ANS). However, a standard becomes an ANS only if the standards developing organization (SDO) is accredited by the American National Standards Institute (ANSI) and subsequently submits the standard to ANSI for approval. Consequently, not all standards students could be working with are ANS's. In fact, 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. All of the above organizations are ANSI-accredited standards developers.

A useful resource for students and faculty members researching standards is the National Standards Network(NSSN) that can be accessed at http://www.nssn.org/ . Although NSSN originally stood for the national standards system network, the NSSN is now much broader in scope 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 but it appears that many non-MIT 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 in ensuring the competitiveness of U.S. industry. Standards developing organizations have a strong interest in training the professionals needed in future standards development work. In addition, the NSS 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 also a need to educate the public 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.

The National Institute of Standards and Technology (NIST) has a number of publications that students can use to learn about EU Directives that could affect design projects. NIST Special Publication (SP) 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 3 and 4 as they relate to the design of machinery. The directive 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 design experiences in mechanical, electrical and biomedical engineering, and in general be

illustrative if not applicable, guides for all areas. They provide a framework that could be useful in developing design constraints that are called for in Criterion 3 and in meeting the requirements for consideration of engineering design in the major design experience called for in Criterion 4.

General education 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 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 such policy issues are clear.

These examples are given to suggest that exploring some of these "soft" design issues in the capstone design course could contribute to the general education component of a curriculum. These experiences could also be structured to provide evidence for achievement of outcomes 3(h) and 3(j).

Professional societies

Several of the engineering societies are major standards developers. They have or are developing materials that can be used to provide basic background on standards and

standardization processes for students as well as for training professionals for standards work. The IEEE -Standards Association (IEEE-SA) is the leading developer of global industry standards in a broad-range of industries, including Power and Energy, Biomedical and Healthcare, Information Technology, Telecommunications, Transportation, Nanotechnology, and Information Assurance. According it its web site, ASME currently maintains 600 codes and standards dealing with mechanical devices. The American Society of Civil Engineers (ASCE) has committees which develop standards in a variety of civil engineering fields. All of these organizations have standards that are used internationally.

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 international standards developer and has been reviewing what graduates in electrical and computer engineering should know about standards. As part of this review, the electrical and computer engineering and engineering technology education communities reported their needs for knowledge and skills in the application of standards to engineering and engineering technology design and development in a survey conducted by the IEEE Educational Activities Board's Standards in Education Task Force in the late spring of 2004. The results of that survey (See http://www.ieee.org/organizations/eab/setf) motivated the development of on-line learning modules to provide a foundation to the use of standards in design and development by students and their faculty mentors in electrical and computer engineering and engineering technology. Pilot testing of the modules at two institutions will commence in the fall term of 2005. The architecture of the IEEE web site that will be made available as an open-access source in 2006 is depicted in Figure 1. The (core or base-line) tutorial is in the final stages of production, the first domain tutorial on the air interface (for wireless applications) has been scripted and submitted for production, and the first two case illustrations—a wireless router and a multimode mobile phone—have also been scripted and submitted for production. The initial releases of the glossary and of the reference guide have been prepared. The other elements of the web site, including the portal page and additional domain tutorials and case illustrations, are still in development. These initial elements of the web site will be demonstrated during the presentation of this paper.

ANSI's role

ANSI is a federation of companies, organization, government, and educational institutions and is not a standards developer but instead administers and coordinates the

U.S. voluntary standards and conformity system. In response to the current NSS Objective 11, ANSI established an ad hoc education committee with representation from industry, government and academe to address outreach to the public and university faculty members. In support of the NSS and to implement university outreach activities, ANSI developed a standards education portal www.standardslearn.org. A free introduction to standards e-learning course *Why Standards Matter* was developed as well as an additional course on U.S. standards development, both of which are available through the portal. Students and faculty members have found both courses a useful introduction to standards. ANSI e-learning courses could be used as background for

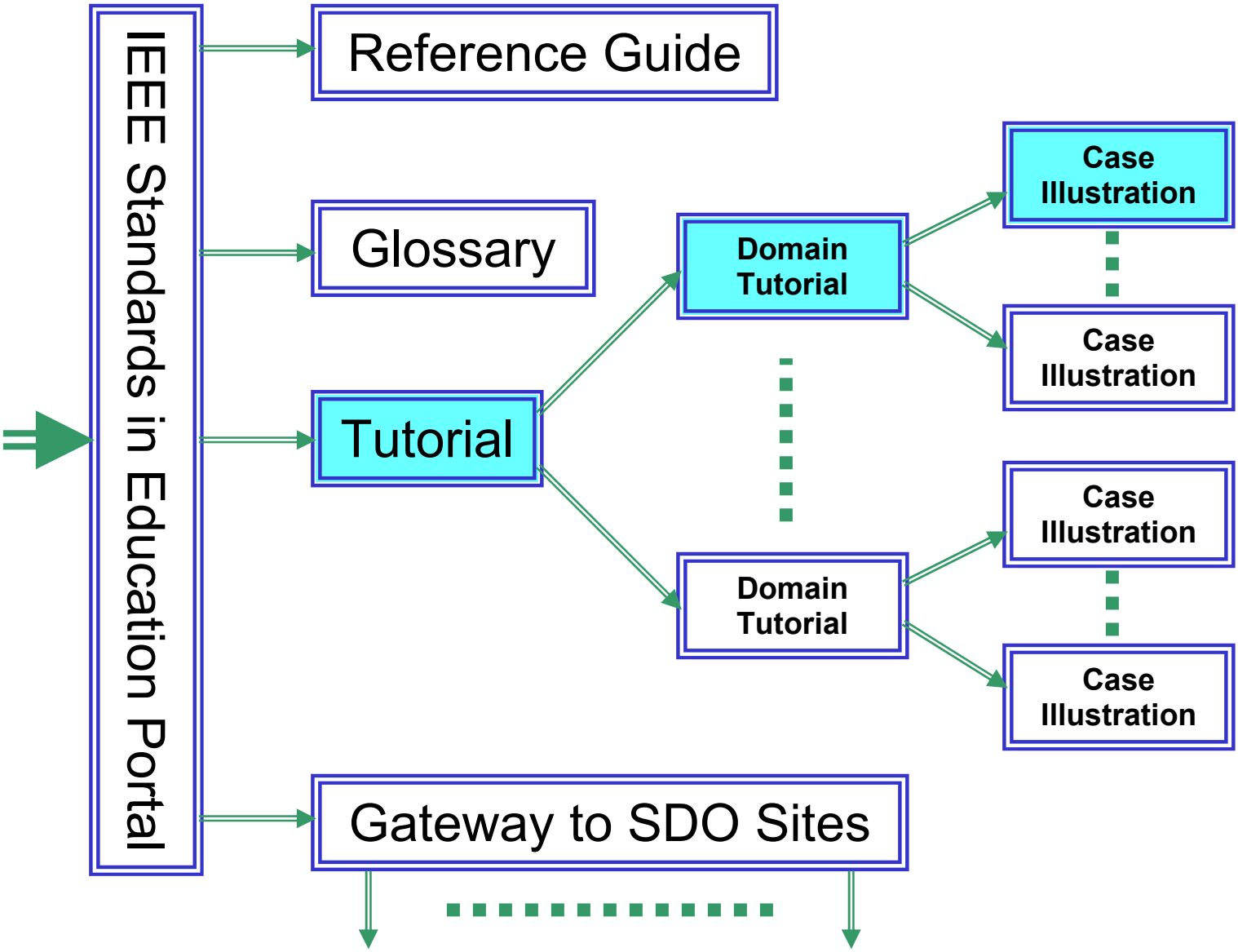

Figure 1. IEEE Standards in Design and Development Web Site Architecture

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. The course on U.S. standards development has a special module for faculty members and students using an example of an engineering technology student. An additional course on international standardization is under development by ANSI.

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 the defining of a body of knowledge as a focus of current activities. The ABET Criteria defines a need for consideration of engineering standards in undergraduate engineering education and there is agreement that a moderate number of 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 members will be needed to ensure better integration of standards in design experiences

A workshop was conducted at the fall 2004 ASEE Mid-Atlantic meeting where representatives from industry, government and academia provided insight into the world of voluntary standards and techniques for incorporating standards and conformity assessment-related topics in university curricula. Examples of current standardization issues – such as sustainable development; manufacturing and design issues; health and safety requirements; economic, social and political considerations – were highlighted and discussed from the perspective of instructional design. Educators walked away with a better understanding of the importance of standards and some ways to incorporate practical standards materials into their curriculum.

As part of the workshop, IEEE presented the results of the survey completed in spring 2004 along with a strategy for meeting the identified needs in the form of web-based tutorials and illustrative cases. Initial versions of a foundation tutorial, a domain (wireless) tutorial, and examples of illustrative cases were described and illustrated . Companion web-based reference and glossary modules were also described, as were additional domain tutorials and illustrative cases that are in development. Other issues disclosed by the survey were presented for discussion, in particular, the clear need for easy and affordable access to the standards products of the standards development organizations. The validation methodology, in the use of these educational materials at two academic institutions, was also noted.

The workshop was also offered at the spring 2005 ASEE Mid-Atlantic meeting at Fairleigh Dickinson University. Experience with the first workshop was very positive although attendees would like to see more examples of just how to incorporate standards in capstone design courses. The data from the spring workshop will be presented with this paper.

Other resources

Trade organizations are major standards developing organizations and some of them have materials that can be used to 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 with which many students would be familiar. A representative from INCITS who participated in the fall 2004 workshop reported that INCITS provides their standards at a low cost to students and faculty members. The American Petroleum Institute (API) recently announced that they will be providing free access to oil and gas standards for petroleum engineering students and faculty.

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 presentations 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 and faculty members will find a wealth of information on standards and conformity assessment on the SES website.

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 Criterion 3 in the list of eight suggested constraints that include health and safety and environmental issues. Health and safety and environmental considerations are commonly the subject of mandatory standards or technical regulations affecting design.

The National Standards Strategy encourages more education of all 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 3 and 4 that imply or require, respectively, standards is a unique opportunity for the standards and engineering education communities to work together.

The Engineering Societies, and ANSI, SES, NIST, and ASTM International already have materials that can be used by students as background in their design work or for faculty members to develop one or more lectures appropriate to the design discipline. As previously discussed, ANSI has online resources for learning about standards and

additional online courses that could be used by faculty members as resources for lectures on standards in the capstone course or for self study by student

The second faculty workshop on incorporating standards into capstone design courses is planned for spring 2005, and assuming continued success, we will be looking for other regions interested in including a workshop as part of their regional meeting.

The authors 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. Furthermore, more material focused on the use of standards in design and development processes as found in engineering and engineering technology programs is in production

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