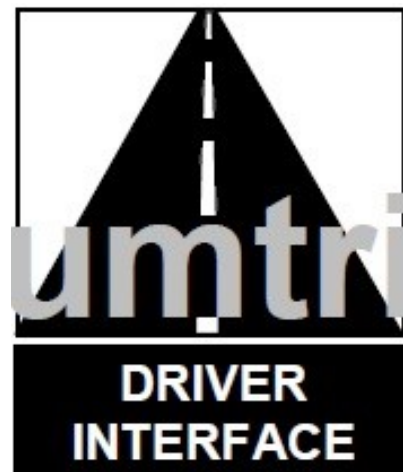


Getting Research into Practice via Standards: Standards 101

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16. Abstract <p>This paper concerns 2 problems that have a common solution. First, ABET criterion 5 (Curriculum) requires that students complete a project that requires the incorporation of standards. Second, faculty and students often produce journal articles and conference papers that do not translate research into practice, and yet getting research into practice is a core engineering goal. This is what standards do.</p> <p>Underlying these problems is a lack of incentives to refer to and contribute to standards, which partially occurs because of a lack of knowledge of them. Accordingly, to incentivize faculty and students to make the connection between research and practice (by referring to and contributing to standards), 2 changes are suggested to the author requirements for engineering journal articles and conference papers. First, keywords should be added after the abstract to identify the standards (or guidelines, best practices, policy documents, etc.) affected by the research. Second, the consequent revised language for the standards should appear in the body of the proposed publication. Admittedly, for basic research, these requirements will not apply.</p> <p>To provide the knowledge of standards to support the proposed change, materials in this paper and elsewhere describe what faculty and students will need to know (Standards 101). That includes information to make (1) faculty and students aware of the importance of standards, and to describe (2) the types that exist (definitions-focused, methods-focused, etc.), (3) how and where to find them (e.g., using IHS Markit, Techstreet, or the ISO online browsing platform), (4) what makes for a good standard (e.g., table of contents, readability, references, sourced definitions), and (5) how standards are developed by ISO (to maximize the utilization of faculty and student research). Extensive lists of web-based search tools for standards (e.g., ANSI, ISO, ITU, NIST, SAE) and web sites with instructional materials on standards (e.g., ANSI, ASTM, IEEE) are provided to support finding standards and learning more about them.</p>					
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What is a standard?

The Accreditation Board for Engineering and Technology (ABET) 2016-2017 Criteria for Accrediting Engineering Programs, in their requirements for academic departments, states, *“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”* (Accreditation Board for Engineering and Technology, 2015, page 5). See also Harding and McPherson (2009).

What then, is a standard? ISO Guide 2:2004, page 10 (section 3.2) defines a standard as a *“document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. ... Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.”* Sometimes standards are referred to as technical standards. Standards are developed to support trade (of goods and services) and travel (of people), both nationally and internationally. The number of standards is vast, with International Standards Organization (ISO) alone publishing more than 21,000 standards. As examples, there are standards for (1) the design of intermodal shipping containers (ISO 668, International Standards Organization (2013)) that affects the design of ships, cranes, trucks, railroad cars, bridges, and other infrastructure, (2) local area networks (such as IEEE 802 (Institute of Electrical and Electronics Engineers, 2016)), (3) bolts (e.g., ISO 262, International Standards Organization, 1998), and (4) even how to make a fruitcake (MIL-F-1499F, U.S. Department of Defense, 1980).

Beyond the ISO definition of a standard, there are many other documents that can be functionally equivalent to a standard to varying degrees – best practices, code of practices, technical specifications, standard procedures, and other terms that follow. For example, ISO collectively refers to many type of documents as standards, which includes actual standards (defined previously), technical specifications (published for immediate need and which could become a standards), technical reports, publicly available specifications (similar to technical specifications but with a maximum life of 6 years), international workshop agreements, and guides (which support standards development and implementation) (Wikipedia contributors, 2018a).

The Society of Automotive Engineers publishes standards (“broadly accepted engineering practices or specifications for a material, product, process, procedure or test method”), recommended practices (“practice, procedures and technology ... intended as guides to standard engineering practice. Their content may be of a more general nature, or they may propound data that have not yet gained broad acceptance”), information reports (“compilations of engineering reference data or educational material useful to the technical community”), and material specifications (“compilations of engineering reference data or educational material useful to the technical community”) (Society of Automotive Engineers, 2017, p. 37).

How Are Standards Enforced?

Except for standards that are passed by the government as regulations, most standards organizations have no direct enforcement powers, so compliance is “voluntary.” However, it is not unusual for governments to adopt them (and enforce them). For example, many countries have regulations that require imported products to meet “accepted international standards,” sometimes called type approval (Wikipedia contributors, 2018b). Companies do not want to unduly limit their international markets for goods and services.

In the U.S., incentive originates from the National Technology and Transfer Act of 1995 (American National Standards Institute, 2006). Section 12d states, “all Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments” (American National Standards Institute, 2016).

Compliance can also be achieved as a consequence of litigation concerning product defects. One of the first questions an opposing attorney will ask is “does this product meet all accepted, industry, national, and international standards.” Having to answer no often means losing the lawsuit, which could put the company in financial jeopardy.

What is the Problem to Be Solved?

In addition to the ABET requirement, **A major problem within science and engineering is getting research into practice, which is what standards do.** In industry, the design of products and services often begins with identifying the relevant standards, which rarely is the beginning for faculty and student research.

Khan, Karim, and McClain (2013), based on 149 responses to an IEEE listserv survey, reported that the 4 leading impediments to learning about standards were the (1) lack of textbook examples, (2) cost of access to standards, (3) lack of faculty expertise in their application, and (4) lack of access to them. Getting standards into textbooks is beyond what this paper can achieve. However, each of the other issues is addressed in this paper. Specifically, the goal of this paper is (1) to make faculty and students aware of the importance of standards, what they contain, and cover related topics and (2) describe how standards can be found (along with a suggestion to address cost), and (3) provide incentives for faculty and students to link their research to standards. Think of addressing these goals as Standards 101.

Getting research into practice, specifically standards, will benefit (1) faculty and student researchers, whose research would be cited, (2) standards developers, because there would be a stronger research basis for their standards, and (3) the engineering community at large, because they would have better standards to use as a basis for design and testing.

How Can Faculty and Students Be Incentivized to Include References to Standards in Their Research?

One solution is to **change the evaluation criteria for submitting papers to journals and conferences. That change would require authors to provide revised text for standards relevant to their research in the body their submission.** Admittedly, for basic research, there are no immediately apparent applications. However, imagine a study was conducted that examined how forest fire fighters were trained, and it found that training hours should be allocated differently than is the current case. The resulting research article should cite the current training standard and suggest new language for the paragraphs that describe how time should be allocated. Under current submission requirements, when information about applications is requested, the authors comment generally about improved training, but do not offer specific changes. Therefore, nothing changes as a consequence.

Furthermore, the standard number and section revised should be listed in the keywords following the abstract. The authors of standards would benefit from this change, because a pre-standards-meeting Google search would reveal new relevant research to include in standards being developed. Having their research cited in standards would also benefit faculty and students by increasing their citation count.

For this change to occur, faculty and students will need to know more about standards -- what kinds there are, who produces them and how, how to find them, etc., all covered in the remainder of this report (Standards 101). Removing the knowledge roadblocks makes the proposed requirements feasible.

Standards 101 - What kinds of standards are there?

To find a relevant standard, one needs to know what type of standard to seek, which depends upon the content of the research. **Typically, a standard contains information from the categories that follow.** (For an alternative scheme, see ISO Guide 2 (International Standard Organization, 2004).)

Definition – These standards list a set of terms and define them, and sometimes how those terms are measured and/or provide representative values. Standards relating to SI units (Taylor and Thompson, 2008) or driving performance measures and statistics -- SAE 2944 (Society of Automotive Engineers, 2015) are examples. Standards in this category advance a field by getting terms to be used in a consistent manner. What would engineering be like if there was no agreement as to what a meter was or what to call it?

Classification – These standards divide materials, products, systems or services into groups that have similar properties. SAE J403 (Society of Automotive Engineers, 2014), which classifies steels based on their chemical composition, is a good example.

Methods/Process – These standards describe how something is to be done – the measurement of engine horsepower (SAE J1349, Society of Automotive Engineers, 2011), if a driver interface is distracting (U.S. Department of Transportation, 2012), or determining the hardness of materials

(ASTM E18-16, American Society for Testing and Materials, 2016). Methods standards can also have acceptance/rejection criteria. The development of the criteria is contentious when there are no high-level policies to establish meta-criteria for fundamental characteristics, not something that low-level technical committees should establish. Does safe mean not unsafe, somewhat safe, or something else? Is the standard of proof – some evidence, the balance of the evidence, beyond a reasonable doubt, or something else? (See Green, 2001.) The topic of standards policy is one ripe for contributions from faculty and students.

Management – These standards are similar to those for methods, but at a much higher, often organizational, level. ISO 9000 (International Standards Organization, 2015) is a management standard.

Physical Design – These standards specify the dimensions, mechanical properties (e.g., maximum load), electrical properties, or other physical properties of an object or system. For example, electrical connectors would be useless if a plug could not fit into the receptacle intended for it.

Performance Design – Sometimes the distinction between physical standards and performance standards can be confusing. As an example, a physical standard for a motor vehicle bumper could specify its mounting height and dimensions, and in an extreme case, nothing else. In a performance standard, only the load pulse to be absorbed would be described, and nothing else. Performance standards can provide flexibility in how the goals are to be achieved, but in some instances, desired functionality cannot be achieved without physical constraints.

Literature Reviews – These standards typically summarize the literature on some topic (e.g., older drivers) and contain many references. Their goal is to provide information to support the development of other standards. In some cases, they are not standards, per se, but technical reports. Student literature reviews are extremely valuable to standards developers if they are comprehensive and replete with technical details and numerical values.

Framework Standards – Framework standards only provide a summary of a collection of standards. For example, ISO/IEC 25000 provides an overview of the SQuaRE (Systems and software product Quality Requirements and Evaluation) project (International Standards Organization, 2005) and ISO 25060 (International Standards Organization, 2010) provides the resulting framework for the Common Industry Format for Usability.

Standards 101 - Who Develops Standards (and Whose Should Be of Interest?)

Standards can be developed by **governments, international standards organizations, regional standards organizations, national standards bodies, professional societies, sector based-standards organizations, and companies**. The 3 major international standards organizations (**ISO, ITU, IEC**) interact through the World Standards Cooperation (WSC) organization. Organizations whose primary purpose is to develop standards (e.g., ISO) are referred to as standards setting organizations (SSO). The message here for faculty and students is that **for any particular topic, there is likely to be more than 1 standards organization relevant to their research, and faculty and students need to have a sense of the organizations on which to**

focus their search. See Table 1. See also <https://www.consortiuminfo.org/essentialguide/whatisansso.php>.

Table 1. Active and Important Standards Organizations

Type	Example Organizations	Coverage & Other Information
international standards organizations	International Standards Organization (ISO)	162 national standards bodies belong; 323 technical committees (almost anything: information technology, screw threads, road vehicles, mining, fire safety, air quality, cosmetics; see https://www.iso.org/technical-committees.html for a list)
	International Telecommunications Union (ITU)	agency of the UN; information and communication technology (examples: wireless technology, broadcasting, Internet access, voice/data/video communication; see https://www.itu.int)
	International Electrotechnical Commission (IEC)	all electrical, electronic and related technologies (examples: cyber security, energy efficiency, plugs & sockets, functional safety, Internet of Things; see https://www.iec.ch/)
regional standards organizations	European Committee for Standardization (CEN)	national standards bodies of 34 European countries; all topics; see https://www.cen.eu/work/areas/Pages/default.aspx)
national standards bodies (every country has one)	American National Standards Institute (ANSI)	all topics covered; houses technical advisory groups (TAGs) that represent the US at ISO; https://www.ansi.org/ ; ANSI accredits standards organizations for the U.S. and hosts standards activities; significant activity on standards education and training;
	British Standards Institute (BSI)	significant activity on standards education and training; all topics covered; houses technical advisory groups (TAGs) that represent the UK at ISO; https://www.bsigroup.com/
	Deutsches Institut für Normung e.V. (German Institute for Standardization, DIN)	all topics covered; see https://www.din.de/en for more information
professional societies	American Society for Testing and Materials (ASTM)	examples include petroleum, steel, construction, cement and masonry, paint, plastic, fasteners, rubber, textiles; see https://www.astm.org/Standards/category_index.html ; active training program
	American Society of Mechanical Engineers (ASME)	boilers and pressure vessels, piping, drawings, valves, and fittings; see https://www.asme.org/about-asme/standards

	Institute of Electrical and Electronics Engineers (IEEE)	world's largest technical professional organization; all topics related to electrical and electronics equipment, computing, and systems that use them; https://www.ieee.org/standards/index.html ; standards activities are significant and handled by IEEE Standards Association
	Society of Automotive Engineers (SAE)	motor vehicle design and testing; sae.org
private company	Underwriters Laboratories (UL)	electrical characteristics of products, fire safety; https://www.ul.com/
sector-based organization	National Electrical Manufacturers Association (NEMA)	electrical boxes, wire and cable, motors, transformers, medical imaging; see https://www.nema.org/pages/default.aspx
companies	Apple	user interface design, rules for application program interfaces (APIs)

As context, the organizations of greatest interest are accredited standards development organizations (SDOs), those that have *open and transparent processes*. (See https://www.standardsportal.org/usa_en/resources/sdo.aspx for a list of organizations and the ANSI process.) *Open* organizations encourage *participation*, for example, by allowing nonmembers to participate in meetings. *Transparent* organizations have few restrictions on *communications*. The dates and locations for meetings are made public, and so too are the rules, and potentially, discussions, and votes. Being open and transparent reduces the influence of conflicting commercial or political interests. The nature of an organization is important because **standards from SDOs have considerable impact and they are most accepting of research from faculty and students.**

Of the organizations in the previous table, those that have been most active in standards education are ISO, ASTM, ANSI, and IEEE. **Faculty and students interested in learning more about standards should examine the web sites in Table 2.** As part of a project funded by National Institute of Standards and Technology (NIST), a series of PowerPoint decks and YouTube videos were created for classroom use, along with 2 papers (including this one) that should be quite informative to faculty and students (Green, 2018). (See Charter, Hoskins, and Montgomery, 2018, for related information).

Table 2. Web Sites with Educational Information on Standards

Source	URL
ASME	https://www.asme.org/about-asme/standards/standards-certification-member-training-resources https://www.asme.org/wwwasmeorg/media/ResourceFiles/AboutASME/Who%20We%20Are/Standards_and_Certification/ASME_Codes_and_Standards-Examples_of_Use_for_Mechanical_Engineering_Students.pdf
ANSI	https://www.standardslearn.org/ https://www.ansi.org/education_trainings/committee_educ); https://www.ansi.org/education_trainings/overview?menuid=9
ASTM	https://www.astm.org/TRAIN/training-e-learning.html
CEN	https://www.cencenelec.eu/standards/Education/Pages/repository.aspx
IEC	https://www.iec.ch/standardsdev/resources/training/training_module.htm see also: https://www.iec.ch/standardsdev/resources/training/
IEEE	https://standards.ieee.org/content/ieee-standards/en/about/standards-education/index.html
ISO	https://www.iso.org/education-about-standards.html their repository is considerable but emphasizes economic benefits https://www.iso.org/sites/materials/teaching-materials/education_materials-higher-edu.html https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/teaching_standards_en_-_lr.pdf
SAE	Technical Standards Board (TSB) Standards in the Classroom Advisory Group https://www.sae.org/works/committeeHome.do?comtID=TSBSCAG See how to use and access standards (https://www.sae.org/works/postDiscussion.do?comtID=TSBSCAG&docID=&forumID=25153&start=0&msgOrder=aesc&resourceID=458287&inputPage=showAll) and case studies (https://www.sae.org/works/workareaResources.do?comtID=&forumID=25153&start=0&msgOrder=aesc&resourceID=458287&inputPage=showAll)
U. of Michigan Transportation Research Institute	contact the author (Paul Green); PowerPoints and videos to appear at: www.umich.edu/~driving , on a NIST site to be determined, on YouTube, and possibly elsewhere; topics include SAE standards, human factors standards, automotive human factors standards, human-computer interaction standards. See also Green (2008), Jeong and Green (2013).

Readers may also find Choi and DeVries (2011) and Danish Standards (2015), among many sources, to be helpful. Useful overviews of standards activities also appear on standardsmichigan.com. Beyond the specific objectives of this project, faculty and students (and administrators) could find the activities of ISO/PC 288 (Educational organizations management systems) will find ISO Standard 21001:2018 (Educational organizations -- Management systems for educational organizations -- Requirements with guidance for use) to be of interest. Note that 288 is a Project Committee, which is formed “to prepare individual standards not falling with the scope of an existing technical committee” (https://www.iso.org/sites/directives/2018/consolidated/index.xhtmll#_idTextAnchor063).

Interestingly, the U.S. is neither a participant or an observer on this committee. It appears the work of this committee will be transferred to ISO TC 232 (Learning Services Outside Formal education; Marinkovic, 2018, personal communication).

Standards 101 - How Are Standards Developed and How Is Research Part of the Process?

Understanding how standards are developed provides insights into where and when input from students and faculty can be most useful. The process by which standards are developed varies slightly from SDO to SDO, but in essence is requires **a consensus agreement at the lowest level committee or subcommittee that a proposed standard is needed, a task force to generate a draft, multiple cycles of comments to develop an acceptable draft, and then further editing, and additional votes at higher committee levels to gain consensus and eventual publication.**

For example, if an international standard was desired to define terms and methods for driver fatigue, the discussion would occur within ISO Technical Committee 22 (Road Vehicles), Subcommittee 39 (Ergonomics), Working Group 8 (Transport Information and Control Systems). As context, TC 22 has 12 subcommittees and Subcommittee 39 has 4 working groups, so this topic is one of many these groups will address. TC 22 has published 882 standards and has another 263 under development. In TC 22 are 30 participating countries (who vote on standards) and another 45 who observe.

In this example, an international working group (about 6 people) assesses the need for this standard, identifies experts to work on it, and proposes a New Work Item, which starts a 3-year development clock for the standard. Those experts should have a comprehensive knowledge of the relevant literature, which is not always the case. A draft standard should eventually be developed as a result of face-to-face meetings about twice per year and communications via email at other times. As task forces and working groups meet in conjunction with related working groups and subcommittees, they report upward what they are doing. At each level above them there is a discussion of drafts, sometimes return of a draft for modification to a lower level, but usually a vote and movement upwards to the subcommittee, technical committee, and ISO secretariat, who edits and publishes the standard. The result of this process is a series of documents – a working draft, sometimes a subcommittee draft, a committee draft, a final draft international standard, and finally the standard itself. The earlier in this sequence that research becomes known to ISO, the more likely it will be considered. In addition, most organizations review every standard every 5 years after publication, with the ideal time for input being 1 year before that 5-year cycle ends (years 4, 9, 14, etc.). However, if the journal article or conference paper is captured by Google Scholar and includes the standard name, it should be found and considered at some point. For those who are interested in being proactive, the chairs of standards committees and subcommittees (usually with email addresses) are listed on SDO web sites. For those interested in the ANSI process, see American National Standards Institute (2018).

As an aside, a major problem with some of these committees is the lack of faculty members on them. In the U.S., faculty at the major research universities are evaluated based on how much research funding they bring in and how many scholarly publications they write. Standards do not count as scholarly publications, discouraging faculty participation. Also, company and government representatives are funded by their employers to do this work. Faculty are not.

Standards 101 - Where Are Standards to Be Found?

The common approach used to find material on the web is to “google it.” For standards, the search term could be the topic of interest + “standards.” Those searches are often not successful because they also find documents that discuss the topic, not the standards desired. As an alternative, one can use commercial cross-SDO search platforms for standards such as **IHS Markit and Techstreet**, but they also return links to books and other publications. (See Leachman and Pezeshki, 2015 for frequency of use data.)

The author’s strategy is to **start with the ISO online browsing platform**, then check ANSI, and then knowing the topic, determine which standards organization should be writing relevant standards (and search their web sites). **Again, reinforcing the previous section, knowing the coverage of various SDOs helps determine where to search for standards.** Table 3 lists the URLs for the primary SDOs. The most extensive set of SDO links is on the Society for Standards Professionals web site (<https://www.ses-standards.org/page/44>). There are about 80 SDOs listed and at the present time there are about 240 ANSI Accredited Standards Developers (Bogatz, 2018, personal communication).

Table 3. Location to Search to Find Standards

Type	Organization	URL
commercial	DocumentCenter	https://www.document-center.com/
	IHS Markit Standards Store	https://global.ihs.com/
	Techstreet	https://www.techstreet.com/pages/about_techstreet.html
SDO	ANSI	https://webstore.ansi.org/ (includes ANSI, ISO, IEC, ASTM) IBR (Incorporated by Reference) Standards Portal (https://ibr.ansi.org/) https://www.standardsportal.org/usa_en/resources/sdo.aspx (URLs of many standards organization)
	ASTM	https://www.astm.org/Standard/standards-and-publications.html
	IEC	https://webstore.iec.ch/
	IEEE	https://standards.ieee.org/standard/index.html
	ITU	https://www.itu.int/en/ITU-T/Pages/default.aspx
	NEMA	https://www.nema.org/pages/default.aspx
	ISO	https://www.iso.org/obp/ui/#search (online browsing platform)
	SAE	https://saemobilus.sae.org/
	UL	https://standardscatalog.ul.com/
Government	U.S. Department of Defense	http://quicksearch.dla.mil/qsSearch.aspx (ASSIST data base)
	NIST	https://www.nist.gov/standardsgov/learn-how-find-standards (links to many agencies)

Many university libraries, on their web sites, list the URLs for standards organizations, and their lists (examples are in Table 4) are more extensive than the introductory list provided in the previous table. To find additional sources, google “how to find standards library.” The larger universities with an engineering library tend to have most complete web pages on this topic.

Table 4. Example Library URLs for Standards Sources

University	URL
Georgia Tech	http://libguides.gatech.edu/standards/GT
MIT	https://libguides.mit.edu/standards
Purdue	http://guides.lib.purdue.edu/standards
Stanford	http://library.stanford.edu/guides/standards
University of California-Berkeley	http://guides.lib.berkeley.edu/c.php?g=18477&p=104158
University of Michigan	https://guides.lib.umich.edu/standards
University of Texas - Austin	http://guides.lib.utexas.edu/standards

Standards 101 - How Does One Know If a Standard Found is Any Good?

Faculty and students often expect all information to be online and free and some SDOs provide complementary read access to entire standards. (See https://en.wikipedia.org/wiki/Open_standard.) However, the author’s experience has been that is more the exception than the rule. **Except for standards developed by governments, expect to pay a significant amount for each standard, from \$1 to \$6 per page** (for 20 to 100 pages). When searching for standards, usually only the title and standards number are viewable, though ISO provides a preview of the table of contents, front matter, and references. Thus, the usefulness of a standard is difficult to determine in advance. When delving into a new topic, it is easy to spend \$500 to \$1000 on a set of standards, only a few of which are useful. Access is constrained because SDOs support themselves from the sales of standards as well as dues from organizations who participate in their activities. They aggressively protect their copyrights, for example labeling every downloaded standards page with a recipient’s name, and in some cases, securing documents so they can only be read on a single computer.

Therefore, being able to judge the quality of a standard is important, a topic covered in the requirements engineering literature, especially for software (e.g., Ali, 2006; Saavedra, Ballejos and Ale, 2013; Carlson and Leplante, 2014). As an example, Saavedra, Ballejos and Ale (2013) provide a long list of characteristics -- unambiguous, complete, consistent, internally and externally consistent, correct, traceable, understandable, concise, and so on. ISO/IEC 25000 (International Standards Organization, 2014) provides 6 categories of characteristics, which include many of those just named. However, as most of the standard is not visible prior to purchase, many of those characteristics cannot be examined on line. As an alternative, the author uses the following criteria for initial decisions for ISO standards, where parts of the standard can be previewed.

1. Is there a **table of contents and is the depth appropriate** for the length of the standards?
2. Do the **definitions come from referenced sources**?
3. Are there a **large number of figures and tables**, say one every other page?

Figures and tables usually are indicative of substance, and furthermore, creating them requires some effort to organize the content. Figures and tables are not always listed in the table of contents.

4. Is the document **easy to read**?

Standards have technical content, so some challenges can be expected in reading them. However, if one needs to read the scope multiple times because some of the sentences are not well structured and long, then the standard may not be a good one. See Zhou and Green (2017).

5. Does the standard have a bibliography or reference section with a **substantial number of references**, in particular, that are used to sources to support requirements?

A good standard is based on facts, on evidence, from the engineering and scientific literature. The extent to which that occurs varies widely. For many standards, there are not specific citations of the evidence used to establish requirements, but there are noteworthy exceptions (e.g., NUREG 0700 (O'Hara, Brown, Lewis, and Persensky, 2002), SAE J2944 (Society of Automotive Engineers, 2015)). Over time, research provides new evidence that pertains to a standard, but if there is no information about why specific requirements were established (e.g., citations), and if the authors are no longer available, it is risky to change requirements or to request variances.

Standards have normative references and summary references. A normative reference is indispensable to the application of a standard. For example, for a standard to calculate ship stability (e.g., the center of gravity and metacenter), a normative specification could define the coordinate system to identify the location of structures used in those calculations. Summary references appear in the "References" or "Bibliography" sections, depending on the standard. More references usually indicate a standard for which there is more evidence. When there are no references, it could be because the authors of a standard decided not to include any references they had.

However, given all of this, sometimes the best information about which standards are relevant and which are good comes from someone on the committee that the faculty member or student knows. People can be better sources than Google.

Standards 101 - After Needed Standards Have Been Found, How Does One Get Copies?

For most search tools, when a standard is found, the price is given and there is usually a shopping cart feature to order it. Again, as mentioned earlier, SDOs strongly discourage the sharing of standards and provide constraints to make it difficult.

The few hundred dollars to be spent for standards should not be an impediment to purchasing standards. A conference paper or journal article could be describing research that cost \$50,000 or \$100,000 to complete. However, if there is no connection to application such as via standards, and the research is not basic research, then was funding the research a wise expenditure?

There are, however, several instances where university libraries have subscriptions to standards, and they are available to *only* students, faculty, and staff at that university, sometimes for free. For example, for students, faculty, and staff, via that mechanism, the University of Michigan Art, Architecture, and Engineering Library provides access to the Association for the Advancement of Medical Instrumentation (AAMI), ASTM (through ASTM Compass), IEEE (through IEEE Xplore), National Fire Protection Association (NFPA), and SAE (through SAE Mobilus) standards, as well to as various building codes (through MAD CAD). In addition, U.S. Department of Defense (military) standards are publically available through the ASSIST web site as was noted previously.

However, ISO, with the largest number of standards, is an issue, and other SDOs could be as well. There is, however, a free option. Some organizations, such as ANSI, under its University Outreach Program (https://www.ansi.org/education_trainings/university_outreach), have special provisions for free class use. The ANSI program includes access to both ANSI and ISO standards.

Closing Comments

Thus, given ABET requirements and the importance of getting research into practice, the author suggests that journal article and conference paper author instructions should add a keyword after the abstract, where relevant standards are listed, and require text describing how those standards should be modified based on the research conducted. Admittedly, these requirements should be waived for basic research.

For this to occur, faculty and students will need to know more about why standards are useful, what standards contain, who develops them, where standards can be found, where one can learn more about standards, and so forth. That information appears in this paper (Standards 101). With this information, many of the roadblocks to the proposed submission requirements are removed.

Resistance to this change is expected, in part just because it is a change. However, if organizations are serious about getting research into practice, then they need to implement the proposal offered here or something similar.

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