Maximizing the Effectiveness of One-time Standards Instruction Sessions with Formative Assessment

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Abstract

There are multiple obstacles associated with integrating standards education into the college curriculum, including the limited experience faculty may have with standards, and the difficulty to fit such training into an already-packed engineering course schedule. Facing these challenges, a faculty member, an engineering librarian, and a professional from a leading standard developing organization worked together to create a customizable course module that can be easily fit into existing engineering courses. The module includes an instruction session, a case study relevant to the topic of the course, assignments, and guest speakers (through videos and/or campus visit). The one-time instruction session employs formative assessment activities to identify and correct misconceptions and to build knowledge on standards applications. Formative assessment has been identified as an excellent tool for facilitating understanding and maximizing the effectiveness of a one-shot instruction session. The first iteration of this module has been delivered twice, first in a small class (10 students) and then in a large class (95 students) in two consecutive semesters. The effectiveness of the first session was evaluated by conducting pre- and post-tests and by collecting students' feedback. Based on the results, changes were implemented for the second session. This paper presents the evolution of the project and the challenges encountered.

Introduction

Technical standards are vital for providing quality, safe, and sustainable products and have a great impact on the global market. The critical role that standards play in every aspect of life is reflected in expectations employers have for standards knowledge among college graduates [1]–[3]. Recognizing the important role standards play for society and industries, the United States Standards Strategy (USSS) identified standards education as a high priority for academia, industry, and government and stimulated the development of multiple educational initiatives [4]. The ABET Engineering Accreditation Commission (EAC) has mandated involvement of academic engineering programs in standards education by adding the requirement to use standards for capstone projects to the criteria for accreditation [5].

Standards developing organizations (SDO) are active in producing educational materials varying from videos, to online tutorials, to case studies. For example, ANSI has created online tutorials and case studies. IEEE developed Standards University that includes videos, tutorials, case studies, and other materials. ASTM offers faculty and students resources. NIST offers grants for standards integration into curriculum. ASME offers courses tailored to the needs of industry professionals.

Standards integration in capstone projects requires engineering students to have previous knowledge of standards and standards resources. Despite being identified as the most effective way to introduce standards to engineering students [6]–[9], curricular integration of standards training is still uncommon [10]. The main reasons for this state are: (1) development of new courses and implementation of curricular changes are challenging, (2) highly intensive training associated with engineering curriculum leaves little time for other additional topics and subjects, (3) many engineering faculty have little or no standards experience and/or exposure, and (4) a lack of current, accessible, and easy to adopt training materials [11]. Besides the capstone projects, other initiatives to increase students' standards awareness in universities include integration into class syllabi [11], [12], use of standards in design classes [13], [14], and the development of standardization courses [15]. Other common practices are library one-shot standards instruction sessions [12], [16] or organizing related events [17]. Studies show that library instruction sessions designated solely for standards instruction are more effective than the generic library instruction sessions that merely mention standards among other types of engineering information sources [12], [16].

All identified literature on standards education has as a common element: standards expertise of the faculty member. This expertise allows for a more holistic approach to introducing engineering students to standards. However, graduating well prepared engineers and successfully fulfilling ABET criteria require that standards education be expanded to more engineering courses, including those taught by faculty members with less standards experience. Most existing educational resources developed by SDOs are not easy to implement or adopt by these faculty members due to various reasons including being developed for professionals in the industry, may be SDO specific, or may require access fees. Therefore, the availability of easy to use training materials and/or access to available campus standards expertise helps faculty members integrate standards education into their courses. With this project, we suggest that a more productive collaboration between faculty members and engineering librarians represents a good option for standards education. This approach enables faculty members to successfully integrate standards education with minimal time investment. For librarians, this approach secures access to courses, allows for integration of information literacy elements, and market library resources. The engineering librarians can use their own standards experience if available or use the available open educational resources to introduce students to standards topics. The faculty member could help identify relevant case studies and use class time to create formal learning experiences.

This study offers details on such a collaboration at [our institution]. A faculty member that identified standards education as a crucial component for engineering college curriculum had been working with the Underwriters Laboratories (UL) on developing a training module. To leverage the expertise and resources available at the campus library, the faculty member invited an engineering librarian to join the project. The engineering librarian had both previous standards experience and had been involved with other campus initiatives to increase standards awareness.

The collaboration resulted in the development of a new learning module consisting of a librarian-led one-shot instruction session that is accompanied with pre- and post-test and a homework assignment. To maximize the impact of the one-shot instruction module, the authors investigated learning theories and instructional design models to find the optimal approach for the session. In the end, we decided to adopt formative assessment because of its potential to increase instruction effectiveness and boost students' learning.

Literature Review

Educational theories agree that successful instruction combines instructional delivery and assessment strategies [18]. Assessment provides valuable data on student learning and informs the instructor on instructional delivery efficiency. Assessment is commonly done asynchronously as a measure of learning using tests, quizzes, exams, or homework. When the assessment is done synchronously during instruction, it becomes formative in nature since it provides real-time feedback to both students and instructors that can be used to improve learning and teaching as it happens. Hattie & Timperley [19] suggested that all three components of formative assessment – feed-up, feedback, and feed-forward – need to be utilized to ensure effective students' learning. However, formative assessment is not easily done because it requires mental agility and willingness to provide quality in-class feedback on the part of the instructor [20], as well as commitment to designing, delivering, and improving flexible learning materials [21].

Black & Wiliam [22] found that formative assessment enhances student learning, while Hattie & Timperley [19] found that formative assessment has the potential to improve student motivation, critical thinking, teamwork, and lifelong learning skills. Similarly, the U.S. National Research Council [23] concluded that:

> "ongoing assessments designed to make students' thinking visible to both teachers and students—are essential. They permit the teacher to grasp the students' preconceptions, understand where the students are in the 'developmental corridor' from informal to formal thinking, and design instruction accordingly. In the assessment-centered classroom environment, formative assessments help teachers and students monitor progress."

When planning a formative assessment, Fisher & Frey [24] recommend starting by identifying the desired outcomes of the instruction session, adopting appropriate class activities to create an engaging lesson, and considering what evidence would be acceptable to demonstrate understanding. Class activities that may be considered are pre- and post-tests, various classroom assessment techniques (CATs) with active learning components (e.g., reflection, summaries, questions throughout the lessons, misconceptions checks, short responses, online games), teamwork, peer teaching, etc. CATs represent an excellent way to engage with the audience, and they can be used at any point during a session to provide immediate feedback to students and instructors [25]. The development of information technology spurred the expansion of tools for technology-mediated learning that have the potential to increase student engagement [26], [27]. Student response systems such as clickers or online polls represent efficient tools to engage with the audience, trigger discussions, and help instructors identify points that need review [28], [29]. The use of real-time online polling offers students opportunities for self-assessment and reflection, as well as opportunities to learn from their peers by seeing their responses.

Formative assessment is not new to engineering education nor library instruction. The librarians found formative assessment useful for the one-shot instruction sessions due to time limitations and lack of opportunities for a more comprehensive assessment. Brooks [30] and Swoger [31] have investigated the value of pre-tests to one-shot library instruction sessions and concluded that it gives the instructor useful information about students before the session. Dunaway &

Orblycj [32] found helpful the combination of pre-tests and questions asked during the session, while Broussard [33] concludes that synchronous feedback can be collected using games in the classroom. Formative assessment used in engineering education was found to improve students' conceptual understanding of fundamental concepts [34], increase students' participation and motivation [35], encourage active learning [36], and improves innovative thinking abilities [37], [38].

Instructional Design

Basic standards education in academia should include a comprehensive introduction, demonstration of standards use in the context of a case study, and guidance in identifying and applying relevant standards in engineering design [39].

To cover all these points, the instruction module in this study includes pre- and post-test (see Appendix A), a standards introduction session that incorporates a case study relevant to the topic of the course, assignment, and guest speakers (through videos and/or campus visit). Before the session, students were asked to take the pre-test to help the instructor identify students' previous standards knowledge, misconceptions and misunderstandings, and to uncover specific topics that need to be emphasized in the instruction session. Pre-test questions were created and distributed online using LibWizard, a feedback and assessment tool available in SpringShare. Topics covered during the instruction session include: role and value of standards, standardization system, the voluntary standards development process, types of standards and applications, how to read a standard, and where to find standards as students and as professionals. The instruction session employs formative real-time assessment techniques by using online polling to ask questions after each section in the lecture, see Appendix B. We chose to use PollEverywhere as our polling tool because it is easy to integrate into a deck of slides and students can use any electronic device to respond (cellphones, laptops, or tablets). The results of the online polling were displayed live and were used to check how much students understand about the topic at hand. The live results were discussed in class, and helped reinforce the concepts being presented and eliminate any misunderstandings. After the session, students were asked to answer the same questions as in the pre-test. For the homework assignment (see Appendix C), students were asked to identify relevant standards applicable to a self-selected product and to discuss the impact these standards have on the design, manufacturing, and functionality of the product.

To allow students to learn the perspectives of SDOs, we also generated a series of short (~10-15 minutes) videos featuring standards experts discussing various topics, including the standards development process, definition of requirements, specific examples, and their own experiences where standards have made a significant impact. The advantage of this series of videos is that they can be mixed and matched to suit the needs of specific courses, and their modular nature allows them to be updated easily to remain current for future courses.

Our approach is characterized by its intentional design of a one-shot session that addresses the time constraints in engineering curriculum, its use of formative assessment to maximize student understanding, and its sustainability because it is easy to adopt due to its modular design and irrespective of the course topic.

The module was first offered to a graduate-level course (Fire Dynamics, enrollment 10 students) in fall 2018 as a trial run. Informal feedback collected from students was positive and offered insights on how to further improve the module. After revising, the updated class materials were delivered again during spring 2019 for an undergraduate junior level course (Heat Transfer, enrollment 95 students).

Preliminary Results

The preliminary results we collected demonstrate that applying formative assessment techniques to our module had a positive impact on student learning. More conclusive results, however, depend on overcoming several impediments we encountered during this process.

The first impediment was developing good, straightforward questions for the pre- and post-test, as well as developing questions to ask during the session that would really check for understanding (as opposed to memorization) and create opportunities for in-class discussions to clear up misunderstandings or misconceptions. The results of the pre-test from the trial with 10 graduate students clearly indicated that some questions were not as clear to students. A revised set of questions more closely followed the learning objectives we developed for the instruction session. The analysis of the second set of pre-test results clearly pinpointed three questions that still needed to be changed. These questions will be clarified for the next iteration of the instruction module.

After the trial, we also decided to change the order of the topics in the session, with the benefits of standards to students and all other stakeholders becoming the first topic. We made this change because we considered that if we could successfully convince students of the omnipresence of standards and their benefits to the society as a whole, they would be willing to learn more from the rest of the session. Clearly marking topics as distinct sections also made it easier for us to recognize that we needed more questions to ask during the session. By placing a question after each section, we were able to obtain a more detailed picture of the students' understanding on the topic at hand. Class discussions based on collected answers showed us the importance of having carefully crafted questions because of the critical role they play in creating opportunities for learning for students.

Another challenge was finding case studies that would be relevant to students even when there is no laboratory involved. As the topic of the first course was fire dynamics, we chose to discuss the fire hazard concerning hoverboards and the UL standard (UL 2272:2016, Electrical Systems for Personal E-Mobility Devices) that was developed to ensure the safety of these products. For the heat transfer course, we chose two ASTM standards for measuring thermal diffusivity by flash method, one a test method (E1461-13 Standard Test Method for Thermal Diffusivity by the Flash Method) and the other a process standard (E2585-09(2015) Standard Practice for Thermal Diffusivity by the Flash Method). Class discussions highlighted the importance of these standards to ensureing the quality and consistency of the measurement process, showcased two various types of standards and relationships between them, helped identify the elements of a standard, and practiced how to read standards.

With so much content to cover, we realized that allotted class time was an important element contributing to the success of this course module. The trial run was scheduled for a graduate course with 75-minute class time. The second run was part of an undergraduate course that had 50-minute class time. Having more in-class time available definitely made it easier to go through all the content and allowed for more time for discussions.

The use of polling technology greatly impacted the class time. With a small number of students in class, it took less time to answer questions asked during the first run than it took to answer in the second run of the module when the class had a large number of students. The free version of PollEverywhere we used allows a maximum of 25 answers per poll, and this worked well for the small class. For the large class, however, this maximum represents a strong restriction that needs to be addressed. Additionally, during the second run of the module, we encountered some technical difficulties with the PollEverywhere slides that reduced students' engagement.

Analysis of the effectiveness of our instructional approach was however somewhat limited by the low number of students taking the post-test for both classes. The request to take the pre-test was taken very seriously by students in both classes resulting in almost 100% participation. Despite great class attendance, after announcing that the results of the post-test are to be used for measuring instruction effectiveness and not students' performance, the percentage of participating students dropped to around 20%. For example, for the second class, we had 82 students taking the pre-test but only 20 taking the post-test, see Figure 1. We recognize that data from the post-test is not of statistical significance to our analysis; however, we consider the results promising, as the students taking the post-test demonstrated a better understanding of the materials presented.

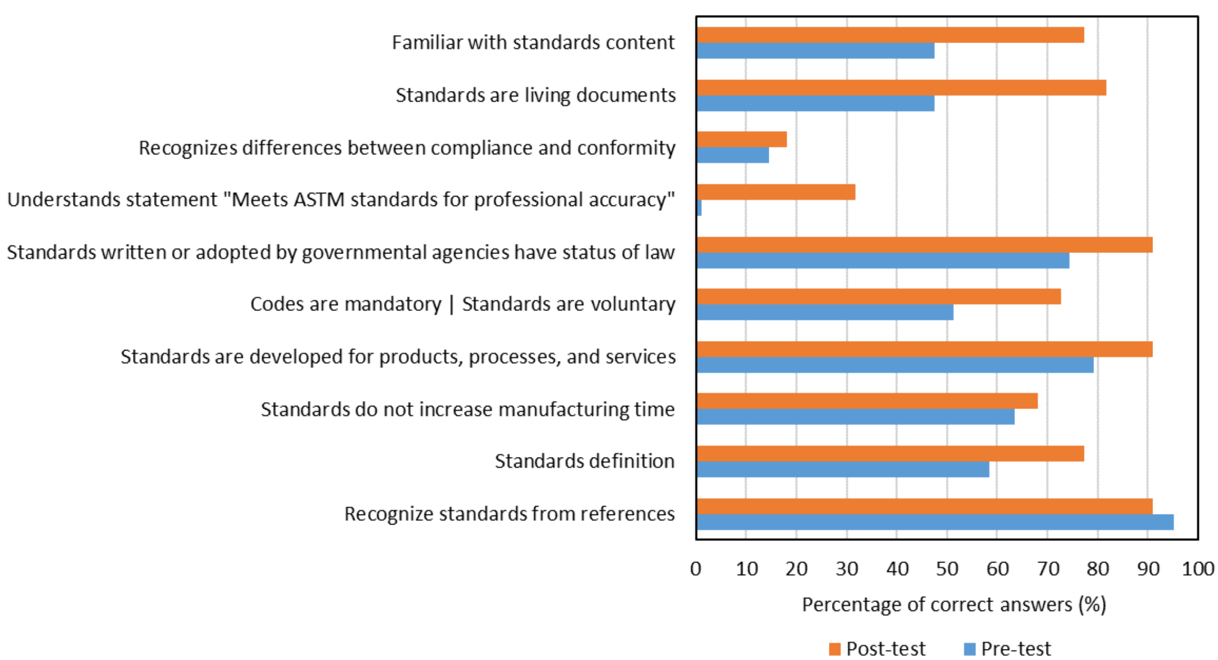

Figure 1. Results of pre- (n=82) and post-test (n=20) for an undergraduate course

When comparing post-test scores with the pre-test scores of the 19 undergraduate students that took both tests, we observed that 58% increased their score, 31.5% received the same score, and 10.5% received lower scores than for the pre-test, see Figure 2.

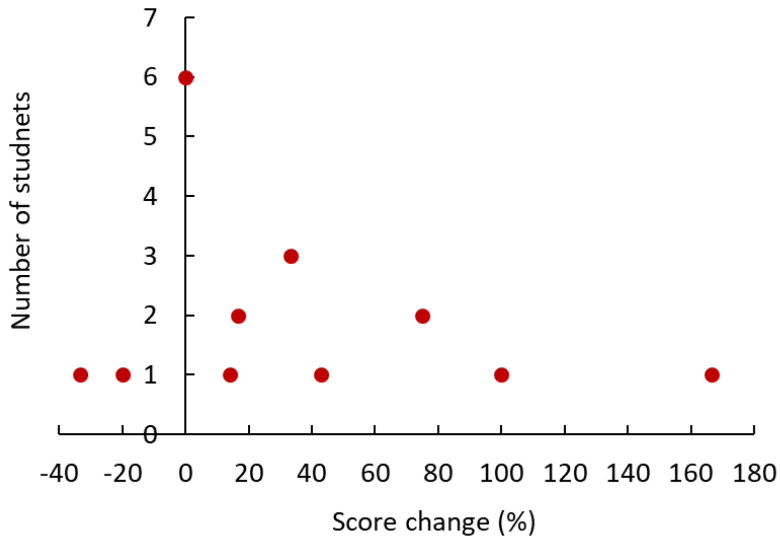

Figure 2. Post-test score change compared to pre-test scores

Conclusions

The need for standards education for engineering students is widely accepted. Creation of multiple opportunities for standards education that are easy to integrate into packed engineering curriculums and that can be adapted by faculty members with various levels of standards expertise is desirable. Carefully designed one-shot instruction sessions that apply instructional design and learning theories could be effective ways to prepare students for using standards in their capstone design projects. Formative assessment has the potential to maximize the effectiveness of instruction efforts.

There are some criteria to consider when designing instruction sessions that apply formative assessment. First is designing assessment activities that reflect the learning objectives for the session. Easily accessible online polling with live results creates learning opportunities for all types of learners. However, careful consideration needs to be given to the limitations of multiple-choice questions as they risk to suggest that there is only one good answer. Time constraints also need to be considered due to the volume of content to be presented and the built-in assessment activities. To help with in-class time management, the online polling tool needs to work seamlessly and accommodate class size. Difficulties in incentivizing students to participate in the post-test impeded on our ability to thoroughly assess the effectiveness of our approach.

The authors will continue to improve upon the test and in-class polling questions based on identified issues. Efforts are being made to integrate this module into other engineering courses at our institution. This will help in developing a collection of case studies related to specialized engineering courses that will be available open access. The authors are investigating opportunities to partially flip the instruction session when class time may be an issue and therefore allow more in-class discussion time.

All the materials developed for this learning module will be published under creative commons license at http://engineering.case.edu/groups/CFDLab/standard_education.

Acknowledgments

The authors would like to acknowledge the support from Underwriters Laboratories.

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Appendix A: Pre-/post-test questions

1. Which document from the list below is a technical standard?
   US3597875A: Toy building set
   ANSI Z21.88-2017/CSA 2.33-2017: Vented Gas Fireplace Heaters
   IBM Research RC25276: Accelerating the Deployment of Security Service Infrastructure with Collective Intelligence and Analytics

2. What are technical standards?
   regulatory documents
   part of business contract
   technical instructions

3. Which of the following is NOT the purpose of standards?
   Safety and Reliability
   Reducing costs
   Help society function
   Increase manufacturing time

4. Which of the following IS true?
   Standards are developed for products, processes, and services
   Standards are developed only for products
   Standards are developed only for products and processes

5. Select ALL true statements from the list below:
   Codes are mandatory
   Codes are voluntary
   Standards are mandatory
   Standards are voluntary

6. Standards written or adopted by governmental agencies have status of law.
   True
   False

7. What does "Meets ASTM standards for professional accuracy" statement on a digital thermometer packaging mean to you? Pick one option.
   Quality
   Accuracy
   Compliance

Too vague
I don't know what ASTM mean
Other

8. Standard compliance requires a product be tested and examined by an independent certification body.
   True
   False

9. Which of the following is NOT true about standardization process?
   Participation is voluntary
   Standards are established by consensus
   Facilitated by Standards Development Organizations
   Standards don't change after publication

10. What standard element gives best information about the applicability of the standard?
    Designation and title
    Scope

Appendix B: Formative assessment questions

1. Standards Benefits Section

Which of the following is NOT true about standards benefits?

Specify requirements for operation, quality, and safety
Reduce product development costs
Increase transaction costs
Create a level playing field for producers
Create common language

2. Standards Development Section

What does voluntary standard mean?

Organizations volunteer to take part in the process
Developed by a recognized body
Established by consensus
Compliance is voluntary
Market driven
All of the above
None of the above

3. Types of Standards Section

What does the basic broadband definition of "data transmission speeds of at least 25 Mbit/s downstream and 3 Mbit/s upstream" represents for a customer?

Testing standard
Product standard
Service standard

4. How to Read a Standard Section

The scope of ASTM A214/A214M—96 includes:

"1.2 The tubing sizes usually furnished to this specification are to 3 in. [76.2 mm] in outside diameter, inclusive. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification."

Which statement from the list below is true?

Point 1.2 conveys consent or liberty to do it
Point 1.2 conveys objectively verifiable criteria to be fulfilled and from which no deviation is permitted

5. Levels of Compliance Section

Which of the following statements are true?

- Compliance is determined based on self-testing
- Compliance is determined by an independent certification body
- Conformity is determined based on self-testing
- Conformity is determined by an independent certification body

Appendix C: Fire Dynamics Course Project

In this project, you are an entrepreneur or a product developer in a manufacturing company. Your company designs and produces a certain product (e.g., coffee machine, computer monitor, cellphone, headphone, Christmas tree, portable heater, blanket, fire fighter uniform). Please work in a team to find Standards that apply to your product.

Presentation

Each group will summarize the project results in a 20-minute presentation on the last day of the class. The presentation should include the following.

1) Description of the product your company produces.
2) A list of standards (at least three) that your product should comply. Among them, one should be fire-related.
3) Presentation and explanation of each Standard on your list.
4) A summary or conclusion slide.

Deliverables

The deliverables include:

1) The presentation slides.
2) All Standards listed on your slides.