Technical Standards in Engineering Education: A Survey Across Professional Sectors

Ms. Amy Kurr, University of Tennessee - Knoxville

Ms. Amy Kurr is a polymer engineer with three years of experience as an electromechanical design engineer for Schneider Electric where she served as a technical product owner for electrical protective devices (e.g., shunt trips, miniature circuit breakers, panel boards, electrical cables). She holds a bachelor's degree in Materials Science and Engineering from Iowa State University and a master's degree in Macromolecular Science and Engineering from Case Western Reserve University. Ms. Kurr completed her Spanish Business Certificate from the University of Wisconsin – Madison. She is currently pursuing a Ph.D. in Energy Science and Engineering from the University of Tennessee's Bredesen Center. In her free time, Ms. Kurr sits on the Standard Technical Panel for Underwriters Laboratories UL-746 (polymer materials) and serves as a professional development facilitator for Tau Beta Pi's – The Engineering Honor Society – Engineering Futures Program and the National Science Foundation-funded CyberAmbassadors Program.

Mr. Jimmy A. Landmesser Jr., UT-Battelle

Mr. Landmesser has 14 years of experience as a fire protection, nuclear and systems engineer at Oak Ridge National Laboratory (ORNL). Upon receiving his degree in fire protection engineering from the University of Maryland in 2009, he joined the Nonreactor Nuclear Division (NNFD) at ORNL as a fire protection system engineer and designer. In this role, he developed his skills as a system engineer overseeing the design, installation and modification of unique FP systems protecting special nuclear materials. To better his understanding of the additional hazards and specialized operations of NNFD, Mr. Landmesser earned a master's degree in nuclear engineering. For the past five years, he has served as a design engineer and project manager for the Laboratory Modernization Division (LMD) supporting new construction and modernization of existing infrastructure. In this role, Mr. Landmesser has honed his technical acumen and improved his management and communication skills while building strong organizational and leadership qualities.

Mr. Landmesser is currently pursuing a PhD in electrical engineering from the University of Tennessee, focusing on modeling soil- moisture impacts to wildland-urban interface.

Technical Standards in Engineering Education: A Survey Across Professional Sectors

Final Submission: May 1, 2023: *American Society of Engineering Education* (ASEE) 2023 Annual Conference and Exposition, Baltimore, MD on June 25-28, 2023

Abstract

The global emphasis on technical standards education in undergraduate engineering curriculums continues to capture the attention of academia, government, and industry. However, many engineering educators engaged in undergraduate engineering instruction lack either the resources to create technical standards educational material for insertion into their courses or access to such pre-developed material which they could customize for their courses. As a result, students' first, primary, and only exposure to technical standards often comes through opportunities external to universities. Examples include internships, volunteer opportunities, conferences, and part- or full-time employment. While industry and government are instrumental in the educational refinement of engineers' technical standards knowledge, the introduction of technical standards content late in undergraduate students' educational journey hinders their performance in complementary technical engineering courses and puts them at a disadvantage when entering the workforce. Furthermore, employers do not have time to bring engineering students' and new hires' technical standards knowledge up to a capable level, but rather, they aim to expand upon students' solid foundation of technical standards knowledge. With the hypothesis that a pre-developed technical standards course would be of benefit to engineering educators, a survey was conducted (1) to gauge the current relationship between technical standards education and the engineering profession and (2) to gather feedback on what characteristics of an undergraduate engineering technical standard training program are most desired across professional sectors in the United States nationwide. The survey was distributed across the engineering field to students, academics, industry employees, and government employees through multiple professional organizations and societies. Two hundred and one individuals participated in the survey. The results show that the engineering field agrees that (1) technical standards should be taught in the undergraduate engineering curriculum, (2) professors teaching undergraduate engineering courses have an acceptable knowledge of technical standards, and (3) four-year academic engineering programs do not put sufficient emphasis on teaching technical standards. Additionally, there is concensus that a technical standards course would be beneficial to students, new hires, and new professional engineers, but also to engineers at more experienced levels. Course content was the primary (81.9%) course feature of interest to survey participants with the most desirable topics including technical standards basics (84.1%), practical applications of standards (70.1%), and how to read standards (69.7%).

Introduction

The incorporation of technical standards into engineering program curriculums has been listed within the ABET (Accreditation Board for Engineering and Technology) criteria for accrediting engineering programs since 2001 when the ABET criteria underwent a reevaluation period [1]. ABET, founded in 1932 by seven professional engineering societies under the name Engineers' Council for Professional Development, completed this reevaluation in response to pressure from engineering educators who felt the pre-2000 criteria were restricting educational customization. Additionally, there was further tension between the poorly meshed engineering graduates' skills and industry needs [2, 3]. The new agreed-upon criteria saw a transition toward specific learning outcomes and away from facility and resource possession. An example of this can be seen in the 2022-2023 ABET accreditation policy 5(d) whereby an engineering department's curriculum is required to include:

> (d) a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work [4].

Today, industry continues to hold a strong vested interest in the accreditation of engineering programs and in technical standards education. Currently (May 2023), 35 member societies (Appendix A) provide input and expertise to set the standards for the ABET accreditation process. Many of these societies (e.g., American Society of Safety Professionals, Institute of Electrical and Electronics Engineers, National Society of Professional Engineers), have a strong connection to the technical standards arena and provide educational technical standards resources of various formats to their members, students, and the general public [5].

Outside of ABET and its member societies, technical standards have similarly grown in use and popularity over the past two decades. With such growth, has come added complexity. People use different phrases (e.g., standards, engineering standards, technical standards, quality standards, medical standards, proprietary standards, codes and standards) to refer to the same topic (i.e., standards) [4,6,7]. However, for others, there is a specific distinction between these words and phrases and what they encompass. Additionally, technical standards on similar test methods can be very similar, very different, or anything in between.

For the entirety of this paper, the phrase "technical standards" will be used as a blanket term in the broadest sense to refer to the entire body of standards that are used to measure or model comparative evaluations. The American Society for Quality's definition of a technical standard adds additional context to the interpretation of the meaning: "documents that provide requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose" [6]. While engineering standards are often technical standards, technical standards are not always engineering standards. The distinction made here affirms that while there are standards in other fields (e.g., medicine) that may or may not be classified as engineering standards, they frequently come into play for engineers (e.g., biomedical engineers) and are technical in nature.

With such complexity in the use and rise of technical standards, society has responded with a large push to educate the public on the world of technical standards. Government and industry funding has increased to create additional and customized standards content for universities nationwide [7]. Standards organizations started and continue to create educational content on the subject at hand. This content can be accessed free of charge or for a small fee via various eLearning programs [8, 9, 10, 11]. Likewise, universities have taken it upon themselves to create technical standards training modules, workshops, and events into their curriculum and courses [12, 13, 14, 15].

This distribution of responsibility for technical standards education is further supported by one pre-survey conducted in anticipation of a two-day workshop hosted by the American Society for Engineering Education in 2018. Results showed that employers – “the primary customer of engineering undergraduates” – affirmed that the Public Safety knowledge, skills, and ability trait (which largely encompass technical standards) that undergraduate engineers should achieve during their academic studies is primarily the responsibility of (1) a combination of academia, industry, and government (41%), (2) academia (12%), (3) industry (24%), and (4) government (24%) [16]. Over half of the 34 participants who participated in the pre-survey agreed that academia has a role in educating students on public safety. The paper published after the workshop notes that “academia will have the responsibility to introduce government-mandated public safety standards into courses and to enforce real-world safety standards at the educational level.” The paper also stresses that industry should assist in providing case studies involving technical standards for educational purposes with the understanding that technical standards will vary greatly across industries.

Technical standards are a critical component in all engineering and extended disciplines. In recent years, the popularity and visibility of technical standards education efforts have grown. However, the new resources and content that accompanied this growth remain siloed between the developers and the academic institutions and between the technical standards organizations and the general public. Few students and educators are aware of the free online content discussed previously. Students that are aware of technical standards resources are reluctant to engage with them for various reasons (e.g., lack of time, decision fatigue, unaware of the value). Many educators (e.g., librarians, professors of practice) are aware of resources but struggle to influence students' intellectual consumption of and engagement with such resources. There is a resounding agreement across the nation that while the production of technical standards content is increasing along with the need to educate students on the topic, the engineering educational curriculum itself is still lagging due to one or more factors. With so many resources it is tough for educators to decipher how much and what technical standards content students require or would most benefit from before graduation. There is no uniform timeline stating when undergraduate students should first be introduced to standards, and there are no uniform learning objectives informing educators of what technical standards content to include in their curriculums. Yet, academic institutions realize they are logically the best-suited entity to provide basic technical standards education for undergraduate engineers. They also recognize that collaborations with outside organizations, companies, and technical societies will allow them to provide more relevant and targeted content. This shift in educational ownership of technical standards content delivery at the undergraduate level can be seen in the increasing integration of modules and case studies into university engineering courses and the reaffirmation and efforts on behalf of standards organizations to provide educators with access to technical standards resources and information [7-13, 17].

A recent effort on behalf of individuals in academia, industry, and government to tackle the issue of technical standards education for undergraduate engineers has resulted in the ongoing creation and development of a national standards training curriculum [18]. The authors are working to consolidate the plethora of publicly available technical standards information into a simplistic customizable curriculum that can be interlaced into existing undergraduate engineering courses or offered independently through in-person and online facilitation sessions. Prior feedback received at the 2022 American Society for Engineering Education Annual Conference and Exposition suggests that such an initiative will aid academics overwhelmed by decisions and/or lacking expertise in technical standards basics.

Up to this point, studies in literature focus primarily on individual groups (e.g., students, industry employees) with small sample sizes [19, 20]. Therefore, to better understand what should be included in the curriculum, the authors developed a survey to poll individuals across the engineering disciplines, across the field of engineering, and in those fields complementary to engineering. The survey questions and response data are provided in full in Appendix C and Appendix D respectively.

Methods

A survey "Technical Standards in Engineering" was distributed to various individuals, organizations, societies, and groups within the engineering field via three primary means of communication: (1) email, (2) discussion platforms, and (3) a QR code handed out on physical paper, like that of a business card. Additional survey respondents were then recruited using the snowball effect in two main fashions. Survey participants were asked to share the survey with others within/in close collaboration with the field of engineering. Individuals were asked to share the contact information of any individuals, organizations, societies, and groups that the researchers should contact. The researchers then used the contact information provided to share the survey via one of the three means of communication mentioned previously.

The survey was open for six months: October 2022 through March 2023. The survey included 27 questions (21 multiple choice, 6 open-ended). Two hundred and one people completed the survey. The survey received IRB approval documented via IRB-23-07511-XM. No compensation was offered in exchange for completing the survey. Survey participants were not required to answer any of the questions. This decision was made to decrease bias in the study as the survey distribution method prevented the authors from knowing who would be completing the survey (e.g., individuals with non-technical backgrounds may not feel comfortable answering specific questions). However, each multiple-choice question received at least 194 responses from the 201 participants. The open-ended questions relating to the survey content received a minimum of 122 responses with the "Next steps" questions (those designed to assist with the snowballing distribution method) receiving a minimum of 53 respondents.

The survey was created using Google Forms and consisted of eight sections: an introduction to the survey (including Graphic 1 shared in Appendix B), career connection to engineering, student education, course specifics, course logistics, course value, everyday use, and next steps. The data for the respective sections is provided in the following figures in Appendix D:

- Career connection to engineering: Figures 1-4
- Student education: Figures 5-8
- Course specifics: Figures 9-11
- Course logistics: Figures 12-15
- Course value: Figures 16-21

While it is not typical to inform participants of the background behind surveys and the research study in question, the researchers elected to share this information due to the nature of the survey and the distribution method. The survey was intended to provide feedback that would be used to update the content in the program curriculum the authors are developing. The authors believed the background content was necessary due to the limitations of conducting a singular identical survey across engineering disciplines and professional sectors. In providing such background context survey participants would ideally be better able to understand the nature of the questions. While it is understood that providing this context may have caused additional bias, the researchers believe there is valuable information that can be gleaned from the data. The shared background content also allowed the authors to utilize the snowballing effect with minimal effort. The two goals stated in the survey were the following: (1) to gauge the current relationship between technical standards education and the engineering profession as a whole and (2) to gather feedback on a solution proposed to tackle multiple challenges surrounding technical standards education at the undergraduate level.

Most survey participants (65.2%) identified themselves as an “engineer by education.” Survey respondents' current/prior job was roughly a quarter each split between student, educator/administrator, individual contributor, and manager/executive. Respondents career level with respect to their current/last position was similarly split into roughly a quarter each for student/intern/co-op, new hire/early career, mid-career, and senior. Respondents were spread out across the following professional sectors: student, education (does not include students), industry, private, government, and other (e.g., non-profit). Education and industry were the largest contributors at 21% and 35% respectively. The graphs in Appendix D provide additional information.

Results

Fifty-five percent of respondents “strongly agree” that technical standards should be taught in the undergraduate engineering curriculum (Appendix D). Additionally, 27% and 31% of respondents “strongly agree” and “agree,” respectively, that four-year academic engineering programs lack sufficient knowledge of technical standards. While most respondents remained neutral (39%) regarding engineering professors' knowledge of technical standards, there was agreement (55% strongly agree/agree) that technical standards education is not emphasized enough in four-year engineering course curriculums. This data indicates a gap. Professors perceived knowledge of technical standards based on the opinion of students and engineering professionals was not interpreted to be lacking. However, the survey results show that there is a lack of emphasis on technical standards in the undergraduate engineering curriculum and a large recommendation for engineers across all sectors (students through engineering professional colleagues) to take a course in technical standards basics, as was proposed in the survey.

Mechanical, electrical, and materials were reported as the engineering disciplines in which a technical standards course would be most desirable for respondents. Engineering disciplines that received the highest amount of write-ins for the Other option include architectural and nuclear. While participants were able to select more than one discipline, each of the four listed above received 80 or more votes (41%).

The single most important feature for respondents with respect to a technical standards course was the content (83.0%). The second desirable feature in such a course was “Heavy industry involvement and influence (content, case studies, videos, articles)” at 55.5%. The following content was reported as being most desirable for inclusion into a technical standards course:

- Technical standards basics (84.1%)
- Practical applications of standards (70.9%)
- How to read standards (69.7%)
- Where engineers use standards (64.7%)
- Standards in the design process (58.7%)

The options listed in the survey for the questions referenced above on course content (Fig. 10) and course features (Fig. 11) were generated by the authors from prior conferences, discussions, and informal surveying of colleagues. The options were then distilled down into main concepts and presented as a few multiple-choice questions. A more thorough description of the options is available in Appendix C. The authors understand that the options listed are likely to be selected with a higher frequency than a write-in option and that survey participants may be less likely to generate additional examples of desirable content on their own when so many have been laid out before them. Similarly, the authors understand that it is unlikely that everyone who took the survey had the same understanding and interpretation of what each of the options meant. The theme of these two questions alone would be of great interest to future studies.

The preferred lesson length was 30-60 minutes with 45 minutes being the favorite (37.7%). With respect to hours of content, the preferred total curriculum length ranged from 4-12 hours with a near tie between 4 and 8 hours worth of content. With respect to course offerings, a half-semester course was preferred nearly 2.5 times as much as a full-semester course. There was a variety of course delivery options selected by participants; the three favorite options were online asynchronous (40.9%), online - any format (37.4%), and in the classroom with multiple training sessions (34.7%). However, regardless of the delivery mode (online vs. in person), participants preferred to have the content spread out over multiple lessons/sessions. There was also interest (30.3%) in hosting onsite company training sessions.

Discussion

The survey results suggest that standards are important in various engineering disciplines and across different professional sectors. The responses indicate that technical standards should be taught in undergraduate engineering curriculums as indicated in the literature. However, respondents report a gap between professors' perceived knowledge of technical standards and students' retention of technical standards upon graduation with their bachelor's degrees from four-year academic engineering programs. The survey results do not provide insight into what causes the discrepancy between professor knowledge and student retention with respect to technical standards. The authors believe additional research into the topic may prove fruitful in determining if it is due to curriculum constraints, resource availability, or other variables.

Overall, participants affirmed that they “strongly agree” with recommending a course on technical standards to early career/new hires as much as to students. However, the responses additionally show that individuals at various educational levels would recommend a technical standards course to their employers and their colleagues. This information reaffirms that the burden of technical standards education in engineering does not lie solely in academia. Success in technical standards education of the next generation of engineers is contingent on support from and communication between industry, academia, and government about the current education needs for engineers.

Curriculum specifics survey results aligned well with the researchers' original hypothesis. The content which is most desired from a technical standards course was reported to be "technical standards basics." Additionally, the desired lesson length was 30-60 minutes long which aligns well with typical university 50-minute- and 75-minute-long classes. The varied course length (4-12 hours) was anticipated due to the variety of individuals who participated in the survey. It also supports the idea that technical standards education should be integrated into other courses which are major-specific to have a stronger impact on students. One common course where this is done is senior design and capstone projects.

As the authors mentioned in the methods section, the inclusion of Graphic 1 in Appendix B and other background information potentially biased the results of the questions. Such bias is likely to be more prevalent regarding the questions about educator preparedness to teach technical standards and educator effectiveness. However, other question areas (e.g., course content, desired lesson length) presumably do not suffer from the same biasing. The large number of participants and diversity across engineering sectors that took the survey is also worth noting. The authors have not found any similar studies done through their literature search with a participant count above 90. The average participant count randed from 20-35.

Limitations and Future Work

The study described above was conducted by individuals with primary ties to industry, rather than a background or degree in engineering education; therefore, unique limitations and biases may exist within the data sets that are less common in studies conducted by typical engineering educators. Major ones are described below.

The survey was designed with the engineering field, particularly that of industry, in mind as studies show that 75% of engineers work in industry or government in 2018 [21]. However, non-engineers, those who have been disengaged from the engineering field for some time, or those who work distantly with engineers, may have taken the survey and found the questions to be misleading or confusing. This may have affected their responses. From the high response rate, it is clear very few participants skipped questions. The Other option was used sparingly by survey participants.

There was no compensation offered in exchange for completing the survey. It is well known that for studies that desire to encompass a population as large as the engineering field in the United States that an extremely large sample size is needed to severely reduce bias in the results. As the authors' main intent behind the survey was to provide feedback for the program curriculum they are developing, this was not of concern. However, future studies that involve monetary compensation are likely to yield a higher response rate and more easily attract an even larger pool of diverse respondents within the engineering community.

The survey's introduction section described the reasoning behind creating the survey, which included sharing current struggles surrounding the education of technical standards. While the consensus from the literature is that technical standards education is lacking, it should be acknowledged that certain programs and universities are far advanced in their technical standards education efforts. Similarly, there are multiple engineers, engineering teams, and individuals who collaborate with engineers that do not interact with technical standards. The authors received communication from various individuals asking/informing them that they found the survey useful to the engineering profession but would not participate in the survey and/or pass it along to their engineering team/colleagues/students as (1) they did not actively engage with technical standards or (2) that they already engaged in technical standards sufficiently so the need for additional education on the topic was not necessary.

The survey distribution method – snowballing effect – is likely to have impacted who received the survey and who chose to participate in the survey. Contacts from a specific discipline or company are more likely to have shared it within their personal networks than to have shared it with random engineers. This distribution method could have affected the responses as the participants may have had similar backgrounds and thought patterns.

For these reasons, the results shared in this paper may not fully represent the opinions of the engineering field at large. However, the large sample size and wide distribution of engineering disciplines, occupational levels, and employment sectors yield insight into technical standards similarities across the nation.

The focus of the curriculum mentioned in this paper and the survey that was conducted in association with it focused on undergraduate students. However, there would be benefits in studying the technical standards education of graduate students as well. Little attention is paid to graduate students' technical standards education and they take few to no structured courses compared to graduate students. Additionally, U.S. engineering graduate students (a minority compared to their foreign national student colleagues) are even more likely to lack technical standards education. In contrast to the U.S.'s approach, many countries introduce their students to technical standards in grade schools and continue that education through high school [17].

As of this time, ABET only accredits bachelor (four-year degree) and master (post-graduate) programs. Therefore, many graduate programs including doctoral programs do not hold graduate students to the technical standards educational exposure and requirements that they do their undergraduate students. Educators who support graduate students (e.g., faculty, staff, engineering librarians) have the added challenges of supporting both undergraduate and graduate students. Two examples include supporting (1) graduate students who did not receive a formal technical standards introduction or education during their undergraduate education but are now expected to perform at a level equivalent to their foreign national educated peers and conduct research in adherence with relevant technical standards and (2) non-traditional graduate students who returned to academia without formal technical standards introduction or education while participating in the workforce. Additional complexity is added when one takes into account that graduate students form a more atypical group than undergraduates. They can vary widely in age, position (e.g., teaching assistant, research assistant), experience, educational background, etc.

This paper encompasses the only results provided by the multiple-choice section of the survey that was conducted. The authors are in the process of analyzing the free response portion of the paper which they believe provides additional insight into the engineering communities' technical standards needs and desires with respect to education at the undergraduate level.

Conclusion

As technical standards form the foundation of engineering practice, undergraduate engineering students must receive a thorough introduction during their academic studies. While this education falls on industry and government informally through co-ops, internships, and senior design projects. There is a known need for academia to formally introduce the basics of technical standards in undergraduate engineering programs. At the moment, this task relies very heavily on engineering librarians who are understaffed, overworked, and underutilized.

The general feeling across the engineering disciples, occupational levels, and employment sectors is that students are lacking sufficient technical standards knowledge, especially the basics. Various efforts led by companies, engineering societies, standards organizations, and academia in the past two decades have helped combat this grave situation; however, such efforts have also brought to light how severe the situation is. Research on technical standards is growing alongside the increased expansion and development of technical standards, but one could wager to say it is still not fast enough. New technologies and law changes are bringing to light new safety issues and public risks that were hard to imagine a decade ago. One example includes the National Fire Protection Association (NFPA) Standards Council's recent approval of the development of NFPA 420: Standard on Fire Protection of Cannabis Growing and Processing Facilities [22]. As technology and artificial intelligence advance and get integrated into the public's everyday lives, the need for a basic understanding of technical standards is necessary. This need is especially prevented in undergraduate engineers; however, survey results show that such information would benefit new hires and engineering professionals as well.

When proposed a pre-designed course on technical standards basics, survey participants preferred a curriculum consisting of multiple 30- to 60-minute lessons with content focused on practical applications. Educators can draw on the insights gleaned from these survey results to target their incorporation of technical standards into current educational materials. Three practical ways to do this as extrapolated from the survey results include (1) keeping lessons on technical standards short, generally, one class period or less, (2) offering the lesson asynchronously online or in the classroom, and (3) focusing on the basics of technical standards with a focus on practical applications.

Acknowledgments

Financial assistance for travel to the ASEE conference was provided by the University of Tennessee – Knoxville Graduate Student Senate.

References

[1] ABET. “Criteria for Accrediting Engineering Programs, 2022 – 2023 | ABET,” 2021. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/

[2] “ABET Engineering Criteria 2000,” Engineering Accreditation Commission. Accreditation Board for Engineering and Technology, Inc. Baltimore, MD. https://user.eng.umd.edu/~zhang/414_97/abet.html

[3] ABET. “History | ABET,” 2021. https://www.abet.org/about-abet/history/#:~:text=Member%20Societies&text=In%201932%2C%20seven%20engineering%20societies (accessed Mar. 01, 2023).

[4] ABET. “Criteria for Accrediting Engineering Programs, 2022 – 2023 | ABET,” 2021. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/

[5] ABET. “Member Societies | ABET,” 2021. https://www.abet.org/member-societies/

[6] American Society for Quality, “What are Quality Standards? List of ISO Quality Management Standards | ASQ,” Asq.org, 2018. https://asq.org/quality-resources/learn-about-standards

[7] “NIST Standards Services Curricula Development Cooperative Agreement Program: Awardees,” National Institute of Standards & Technology, Oct. 04, 2021. https://www.nist.gov/standardsgov/nist-standards-services-curricula-development-cooperative-agreement-program-awardees

[8] “Engineering Student Resources,” The American Society of Mechanical Engineers. 2023. https://www.asme.org/codes-standards/training-and-events/engineering-student-resources

[9] “IEEE Standards University | Innovation · Compatibility · Success,” IEEE Standards University. Institute of Electrical and Electronics Engineers. http://www.standardsuniversity.org

[10] The Source for Standards Education. Intellectual Property Shield. Bensenville, IL. 2013. https://www.ip-shield.com/nist.aspx

[11] “Welcome to: Consumers and Standards: Partnership for a Better World,” International Organization for Standardization. https://www.iso.org/sites/ConsumersStandards/index.html

[12] “Standards Education,” engineering.case.edu. https://engineering.case.edu/training/standard-curriculum/ (accessed Mar. 01, 2023).

[13] D. Solomon, Y.-T. T. Liao, and J. T. Chapin, “Maximizing the Effectiveness of One-time Standards Instruction Sessions with Formative Assessment,” American Society for Engineering Education. Tampa, FL, USA. Jun. 15, 2019. https://peer.asee.org/maximizing-the-effectiveness-of-one-time-standards-instruction-sessions-with-formative-assessment

[14] J. Olshefsky, “Standards Education: Bridging The Gap Between Classroom Learning And Real World Applications,” American Society for Engineering Education. Louisville, KY, USA. Jun. 20, 2010. DOI: 10.18260/1-2—15905. https://peer.asee.org/standards-education-bridging-the-gap-between-classroom-learning-and-real-world-applications

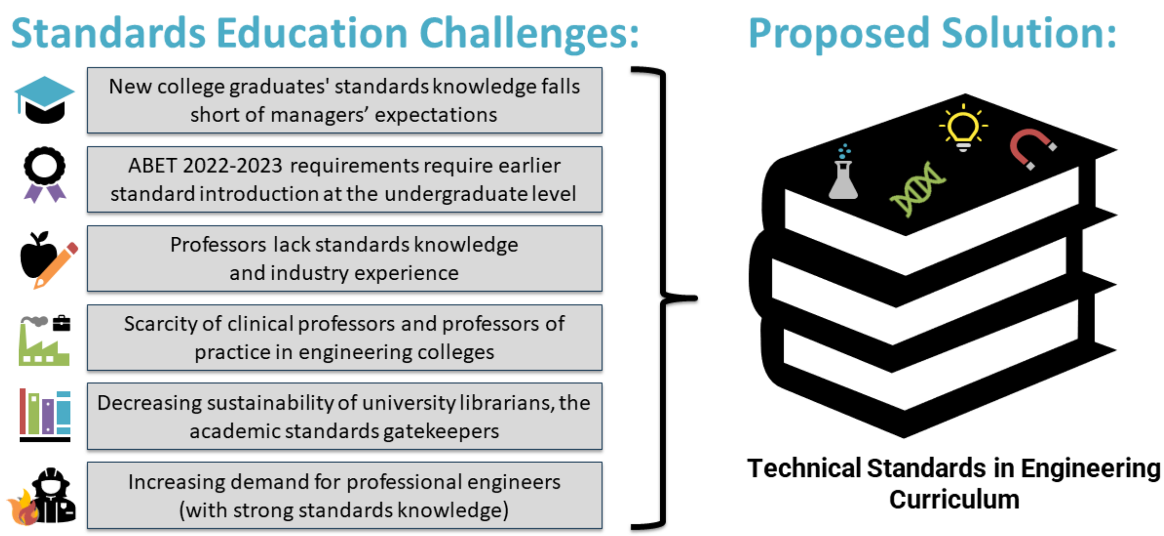
[15] V. Charter, B. L. Hoskins, and S. B. Montgomery, “Understanding the Significance of Integrating Codes and Standards into the Learning Environment,” American Society for Engineering Education. Salt Lake City, UT, USA, Jun. 23, 2018. DOI: 10.18260/1-2—

31181. https://peer.asee.org/understanding-the-significance-of-integrating-codes-and-standards-into-the-learning-environment
[16] "Phase I: Synthesizing and Integrating Industry Perspectives," American Society for Engineering Education. Transforming Undergraduate Education in Engineering. Arlington, VA, USA. May 9-10, 2013. https://monolith.asee.org/TUEE_PhaseI_WorkshopReport.pdf
[17] D. E. Purcell, "The Strategic Value of Standards Education." The Center for Global Standards Analysis. Aug. 2008.
[18] A. Kurr and D. Icove, "Standards In Science and Engineering Education," American Society for Engineering Education. Minneapolis, MN, USA. Aug. 23, 2022. https://peer.asee.org/40907
[19] M. Phillips and S. Huber, "Standards Resources for Engineering and Technology," Issues in Science and Technology Librarianship, Jan. 2017, DOI: 10.5062/F4B27SJ7
[20] B. Harding and P. McPherson, "What Do Employers Want In Terms Of Employee Knowledge Of Technical Standards And The Process Of Standardization?," American Society for Engineering Education. Louisville, KY, USA, Jun. 20, 2010. DOI: 10.18260/1-2—16474 https://peer.asee.org/16474
[21] C. Wilson, "Current Status of the U.S. Engineering and Computing Workforce, 2019" American Society for Engineering Education and Institutional Research + Analytics. 2019. https://ira.asee.org/national-benchmark-reports/workforce2019/
[22] "NFPA - Marijuana grow & extraction facilities," www.nfpa.org. https://www.nfpa.org/Codes-and-Standards/Resources/Standards-in-action/Marijuana-grow-and-extraction-facilities

Appendix A. List of ABET member societies as of February 2023.

American Academy of Environmental Engineers and Scientists.
Association for the Advancement of Medical Instrumentation.
American Ceramic Society.
American Institute of Aeronautics and Astronautics.
American Institute of Chemical Engineers.
American Industrial Hygiene Association.
American Nuclear Society.
American Society of Agricultural and Biological Engineers.
American Society of Civil Engineers.
American Society for Engineering Education.
American Society of Heating Refrigerating and Air-Conditioning Engineers.
American Society of Mechanical Engineers.
American Society of Safety Professionals.
American Welding Society.
Biomedical Engineering Society.
Construction Management Association of America.
CSAB – Computing Sciences Accreditation Board.
Institute of Electrical and Electronics Engineers.
International Facility Management Association.
Institute of Industrial and Systems Engineers.
International Council on Systems Engineering.
International Society of Automation.
National Council of Examiners for Engineering and Surveying.
National Society of Professional Engineers.
National Society of Professional Surveyors.
SAE International - Society of Automotive Engineers.
Society of Fire Protection Engineers.
Society for Mining, Metallurgy, and Exploration.
American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.
Society of Naval Architects and Marine Engineers.
Society of Petroleum Engineers.
The International Society for Optics and Phonetics.
Society of Women Engineers.
The Minerals, Metals, and Material Society.
Women in Engineering ProActive Network.

Appendix B. Graphic shared in the introduction section of the survey.



Graphic 1: Graphic provided in introduction section of the survey.

Appendix C. Copy of Survey Questionnaire.

1. Which classification best describes you as an engineer?
   - Engineer by education
   - Engineer by practice/experience
   - Engineer by license
   - Non-engineer

2. Please check the TITLE which is most representative of your current/last position.
   - Student
   - Educator
   - Administrator
   - Individual contributor
   - Manager
   - Executive

3. Please check the LEVEL which is most representative of your current/last position.
   - Student
   - Intern/Co-op
   - New Hire (0-2 years)
   - Early Career (2-5 years)
   - Mid-Career (6-20 years)
   - Senior (20+ years)

4. Please check the PROFESSIONAL SECTOR which is most representative of your current/last position.
   - Student
   - Education
   - Industry
   - Private
   - Government
   - Other (fill in)

5-8. Rate from strongly agree to strongly disagree:
   - Technical standards should be taught in the undergraduate curriculum.
   - Students graduating from a four-year academic engineering program lack sufficient knowledge of technical standards.
   - Professors teaching engineering courses at four-year academic institutions lack sufficient knowledge of technical standards.
   - Four-year academic engineering programs do not put sufficient emphasis on teaching technical standards.

9. Please check the ENGINEERING DISCIPLINES which are most desirable for you in a standards course.
   - Mechanical Engineering
   - Electrical Engineering

- Computer Engineering
- Civil Engineering
- Aerospace Engineering
- Chemical Engineering
- Materials Engineering
- Biomedical Engineering
- Other (fill in)

10. Please check the CONTENT which is most desirable for you in a standards course.
- Technical standards basics
- History of standards
- Standards creation and development
- Standards technical panels/committees
- Global standards
- Standards in the design process
- Discipline specific standards/organizations
- Importance of standards
- Parts of a standard
- Purchasing standards
- Where engineers use standards
- Standards outside of engineering
- Diversity in standards
- How to read a standard
- Understanding technical writing in standards
- Standards organizations
- Roles different people have surrounding standards
- Standards resources for students
- Practical applications of standards
- Other (fill in)

11. Please check the FEATURES which are most desirable for you in a standards course.
- Content (e.g., technical standards, revision process, certification process)
- Customizability (modular format, add/remove activities)
- Price (Free)
- Accessibility (Canvas Learning Management System)
- Easability (pre-developed outside of your academic institution)
- Target Audience (undergraduate students in engineering)
- Asynchronous (complete at your own pace)
- Heavy industry involvement and influence (content, case studies, videos, articles)
- Universal Design for Learning (UDL) Approach
- Thoroughly evaluated, reviewed, and updated via pilot testing, course surveys, and literature reviews
- Other (fill in)

12. Please check the LESSON LENGTH which is most desirable for you in a standards course.
- 15 minutes

- 30 minutes
- 45 minutes
- 60 minutes
- 75 minutes
- 90 minutes
- Other (fill in)

13. Please check the TOTAL CURRICULUM LENGTH which is most desirable for you in a standards course.
- 4 hours
- 6 hours
- 8 hours
- 12 hours
- 16 hours
- 20 hours
- Half-semester course (1-2 credits)
- Full-semester course (3 credits)
- Other (fill in)

14. Please check the DELIVERY OPTION which is most desirable for you in a standards course.
- Online, recorded lecture, asynchronous
- Online, live lecture, one time training session
- Online, live lecture, multiple training sessions
- In person, live lecture, one time training session
- In person, live lecture, multiple training sessions
- In person, interactive class, one time training session
- In person, interactive class, multiple training sessions
- Other (fill in)

15. Please check the LOCATION which is most desirable for you in a standards course.
- Online: Asynchronous
- Online: Virtual Training (any duration of time)
- Classroom
- On-site Company Training Session
- Conference Technical Talk (20-45 minutes)
- Conference Training Session (1-4 hours)
- Conference Training Session (5-8 hours)
- 1-day Training Session: Weekday (travel required)
- 1-day Training Session: Weekend (travel required)
- 2-day Training Session: Weekday (travel required)
- 2-day Training Session: Weekend (travel required)
- Other (fill in)

16-21. Rate from strongly agree to strongly disagree:
- The proposed course would help address engineering students lack of technical standards knowledge.

- I would recommend this course to my EMPLOYER (e.g., university, company).
- I would recommend this course to my COLLEAGUES.
- I would recommend this course to STUDENTS.
- I would recommend this course to EARLY CAREER/NEW HIRES.
- I would recommend this course to NEW PROFESSIONAL ENGINEERS.

22. What are your biggest challenges with respect to technical standards and technical standards education?

23. Which technical standards or standards organizations are most important to know about for your industry?

24. Why is technical standards education at the undergraduate engineering level most important?

25. What particular aspects of technical standards content do you believe should be included in the curriculum?

26. Is there anything else you would like us to know?

27. Is there a particular group, society, or individual you recommend we request feedback from regarding the course presented above? Please share the respective contact information.

Appendix D. Results from the survey.

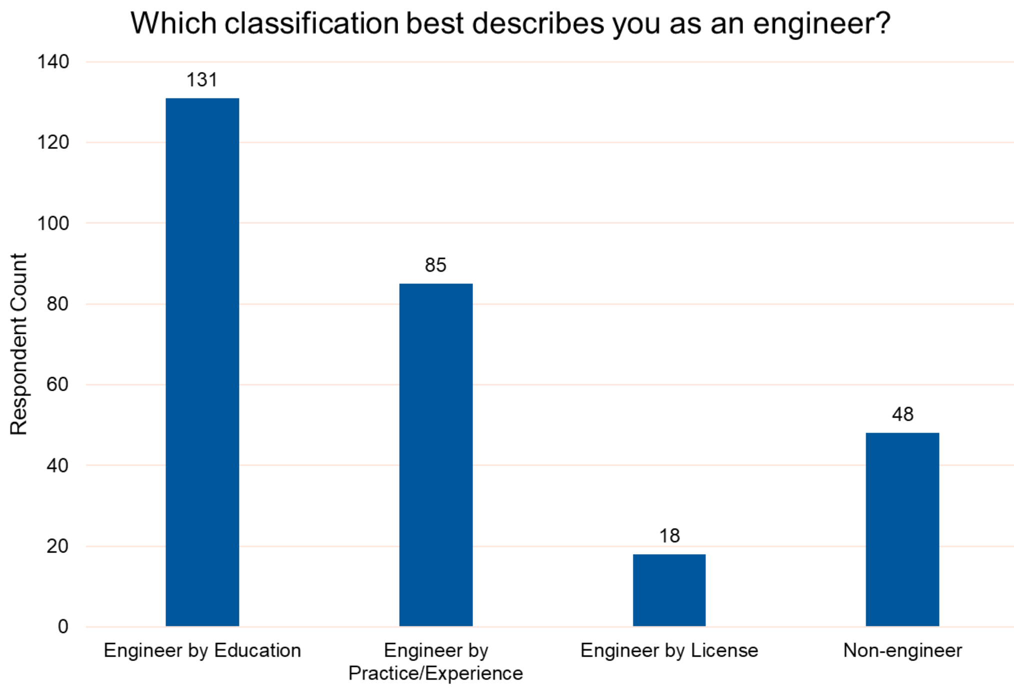


Figure 1: Engineering classifications.

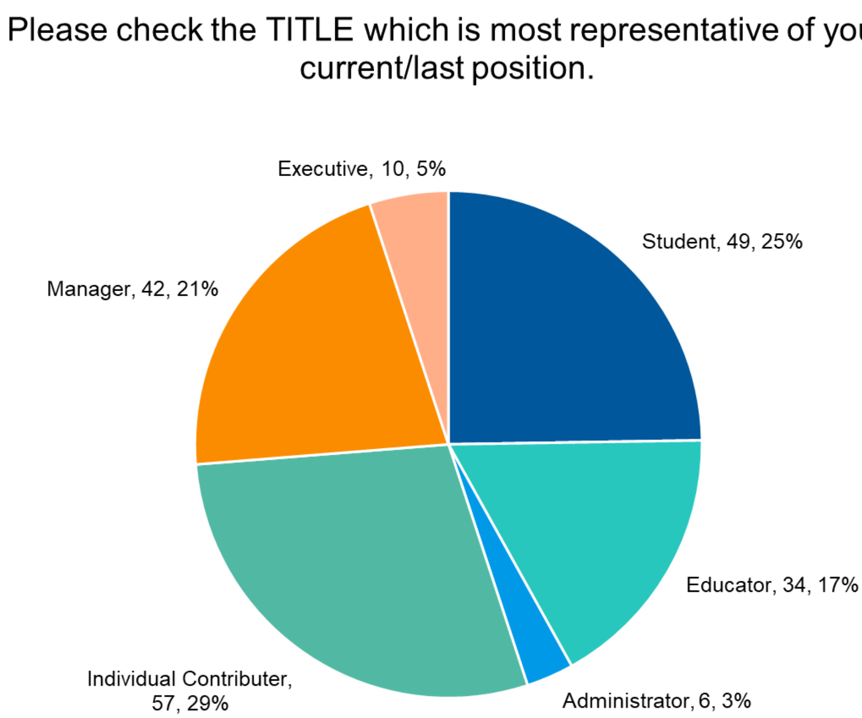


Figure 2: Participant titles.

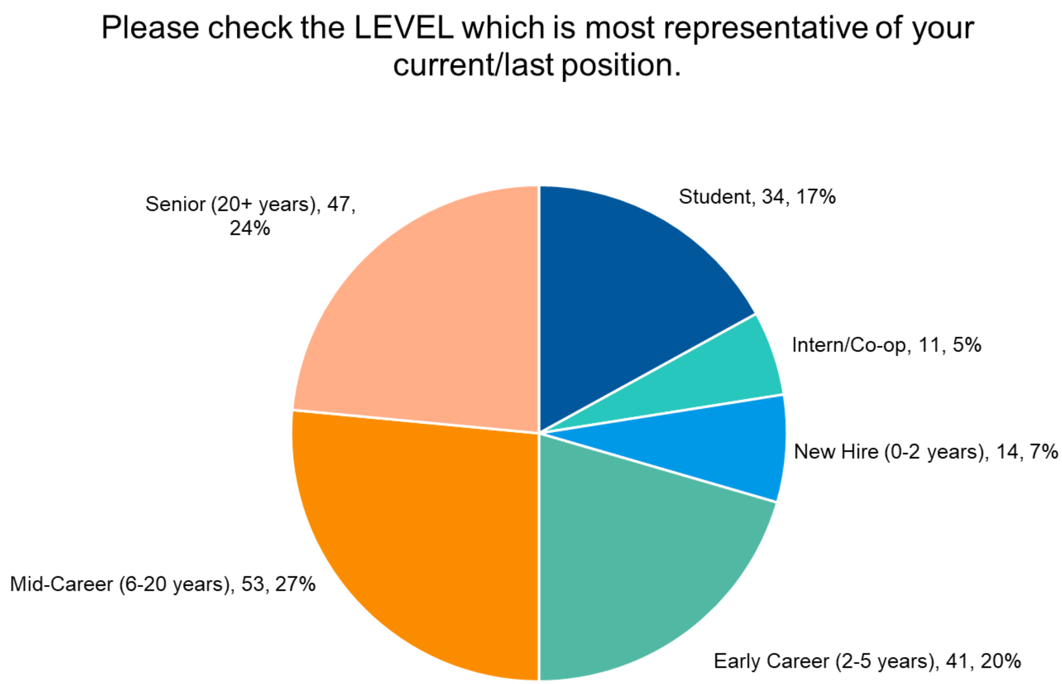


Figure 3: Participant levels.

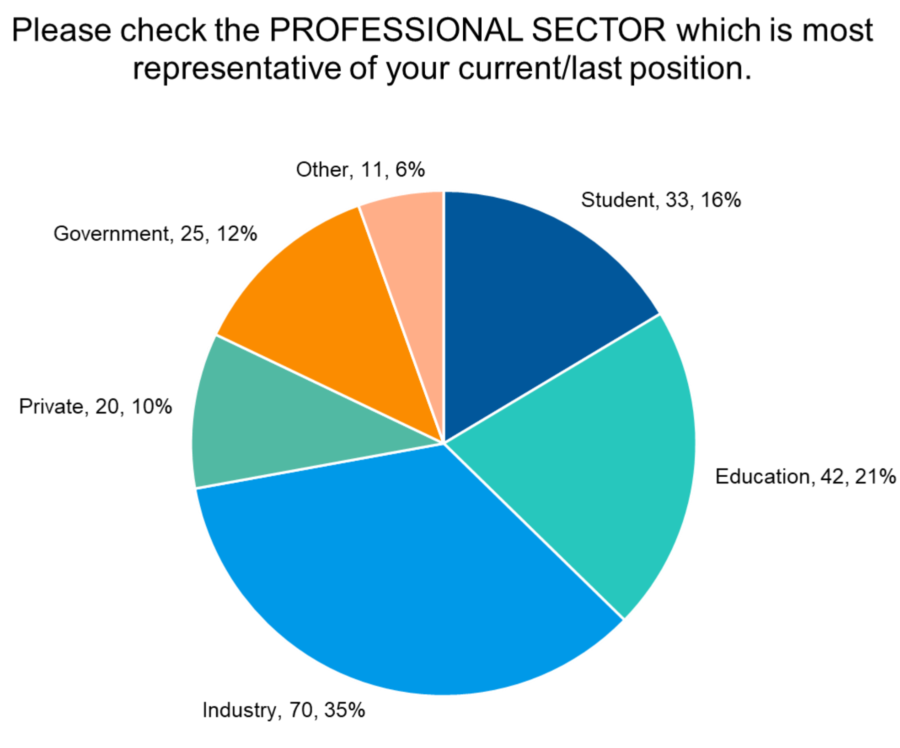


Figure 4: Participant professional sectors.

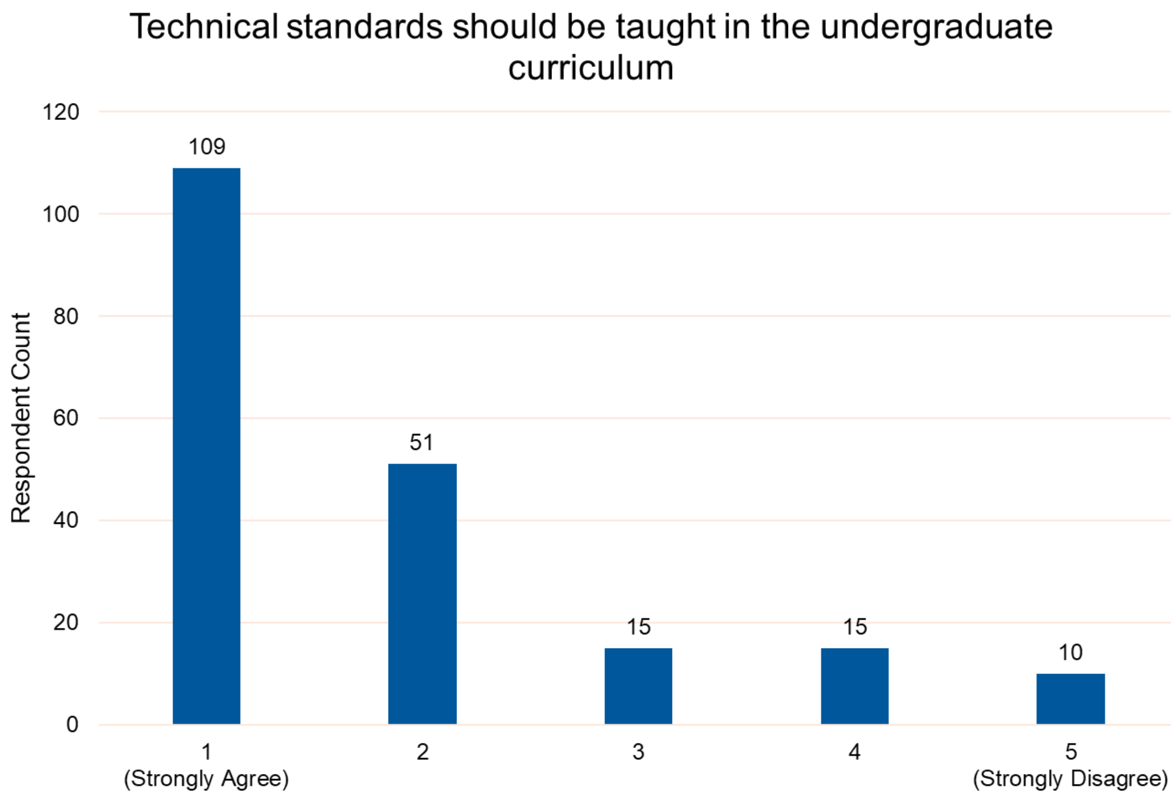


Figure 5: Participant responses to technical standards taught in undergraduate curriculums.

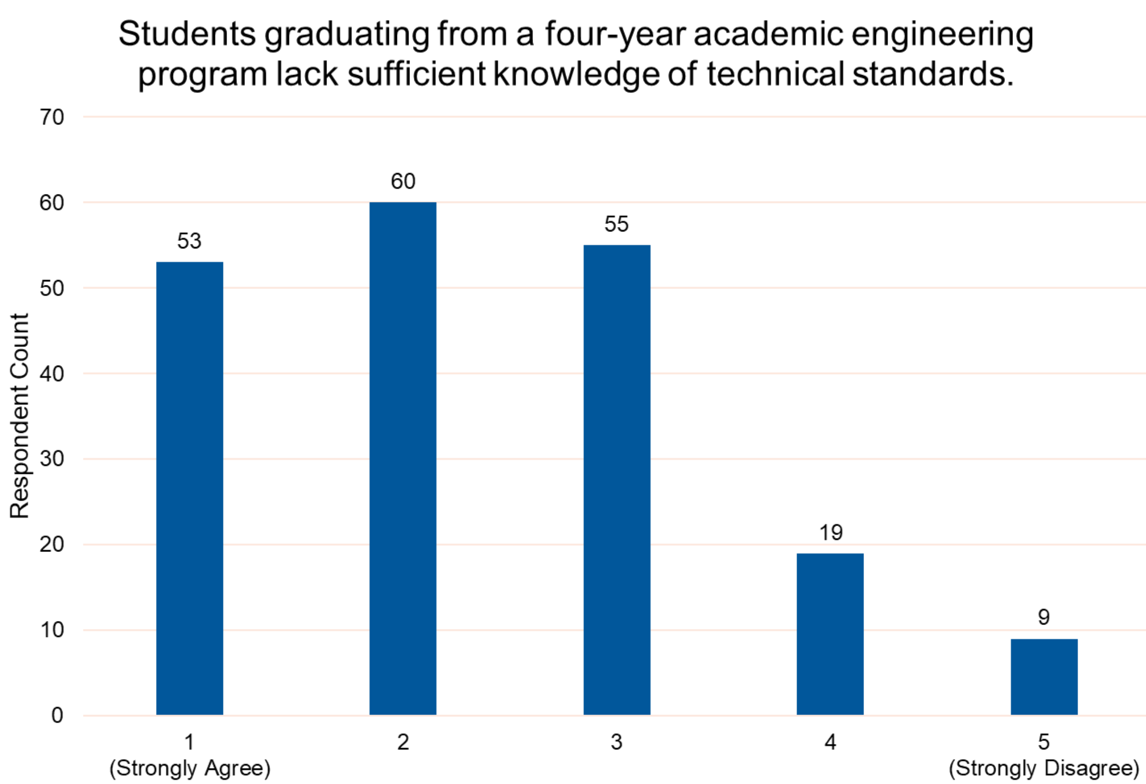


Figure 6: Participant responses to graduating students technical standards knowledge.

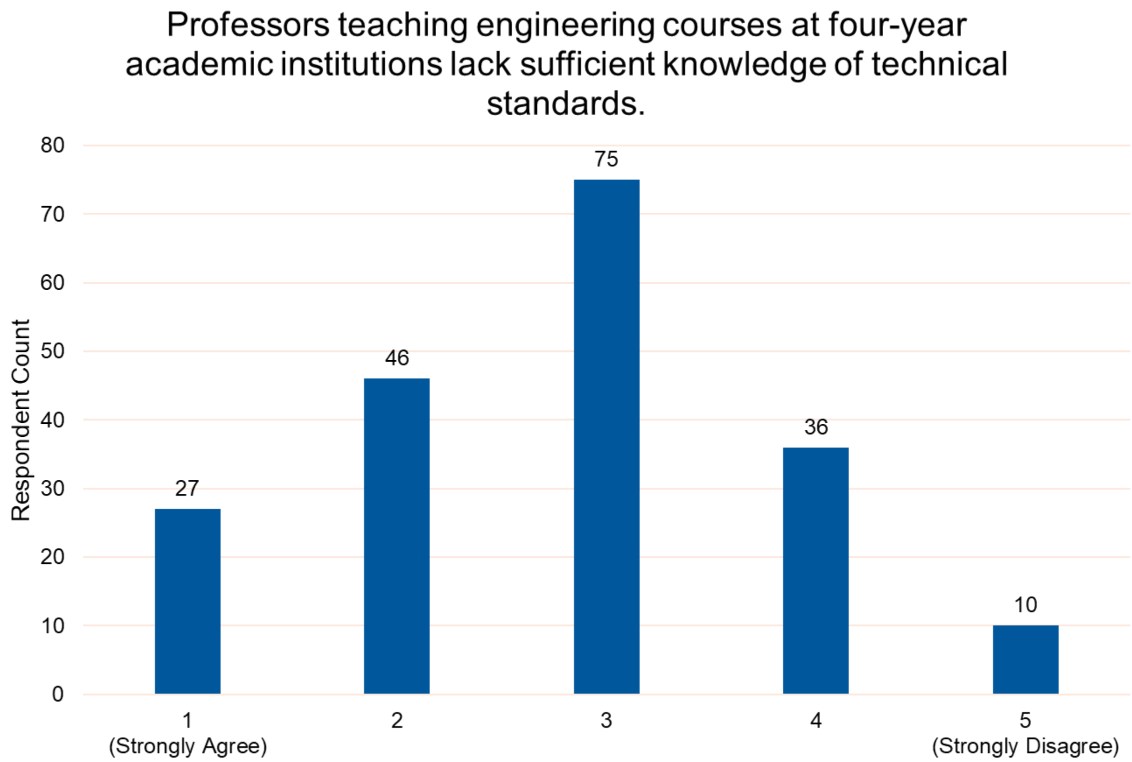


Figure 7: Participant responses to professors' knowledge of technical standards.

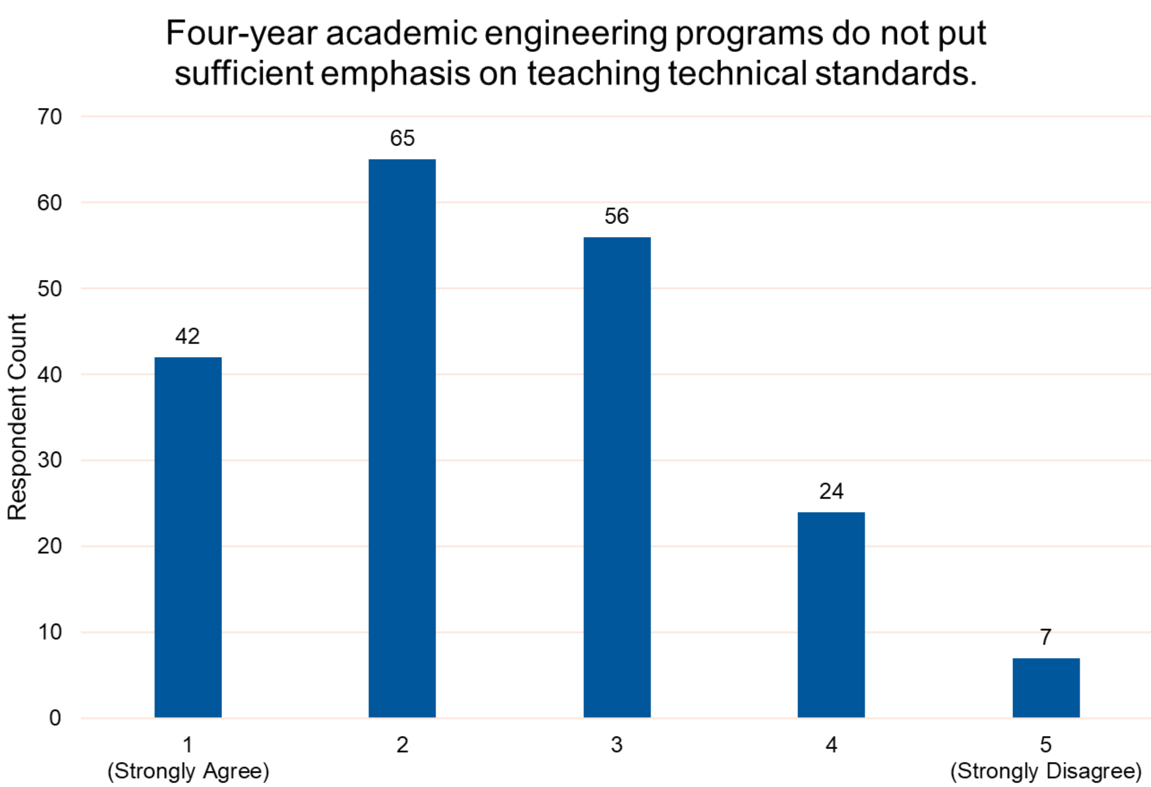


Figure 8: Participant responses to technical standards emphasis in undergraduate curriculums.

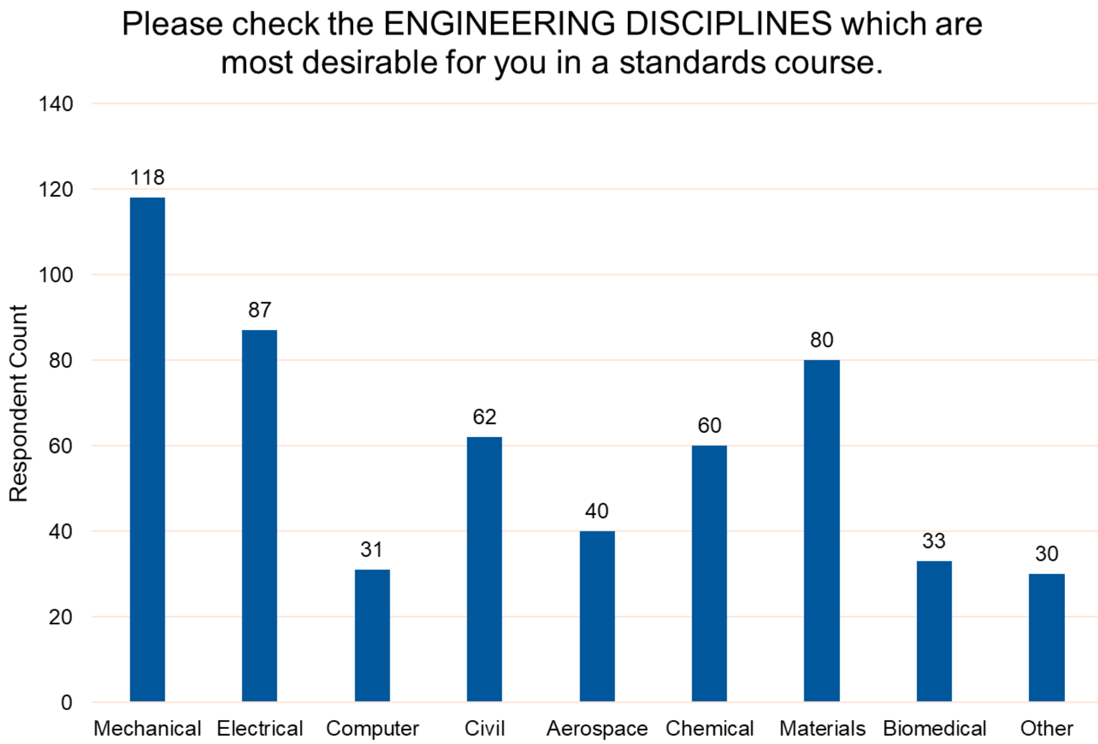


Figure 9: Participants desired engineering disciplines for a technical standards course.

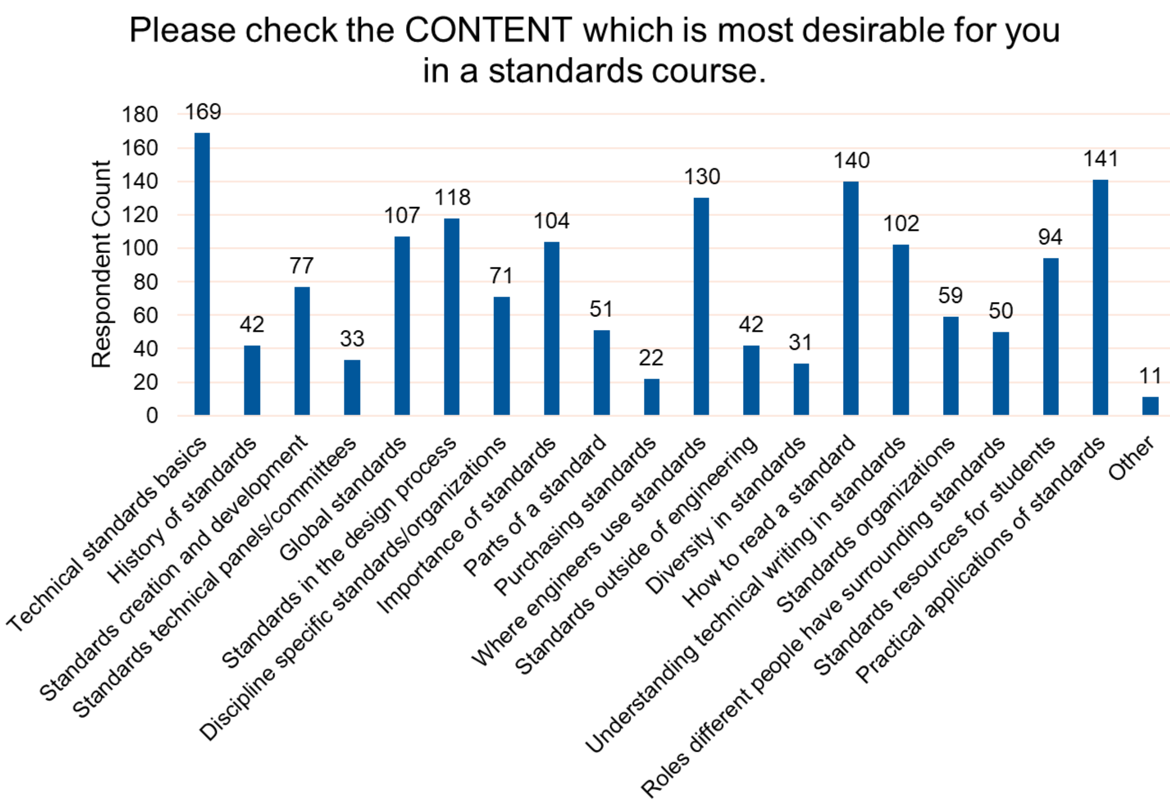


Figure 10: Participants desired content for a technical standards course.

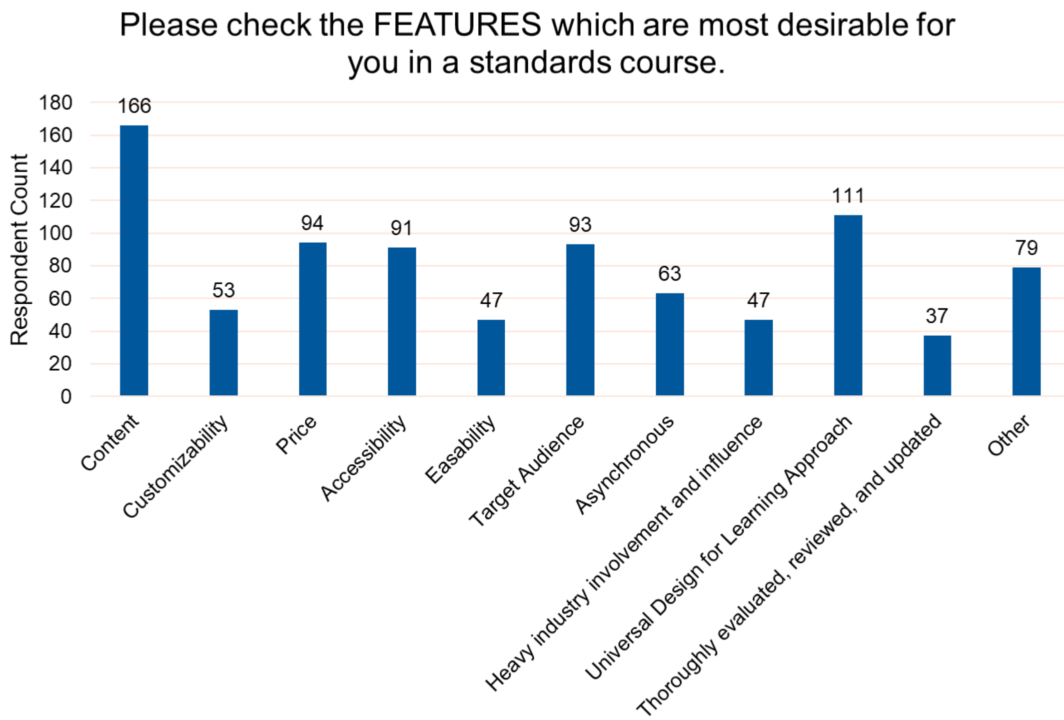


Figure 11: Participants desired features for a standards course.

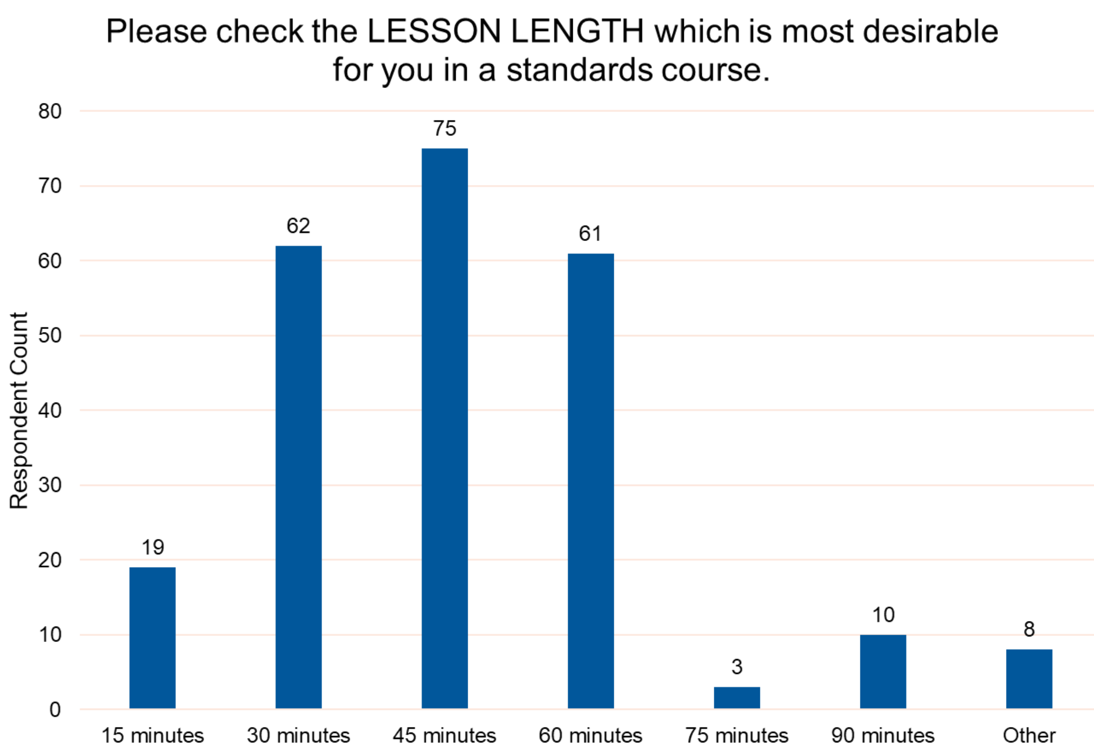


Figure 12: Participants desired lesson length for a standards course.

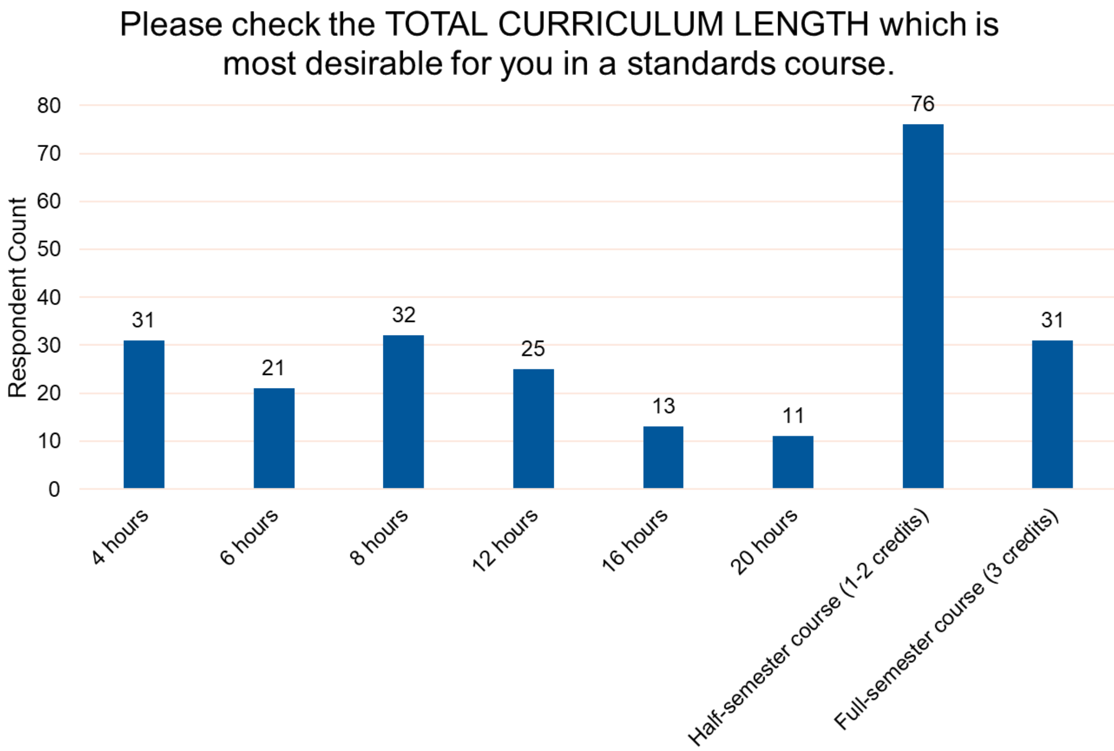


Figure 13: Participants desired total curriculum length for a standards course.

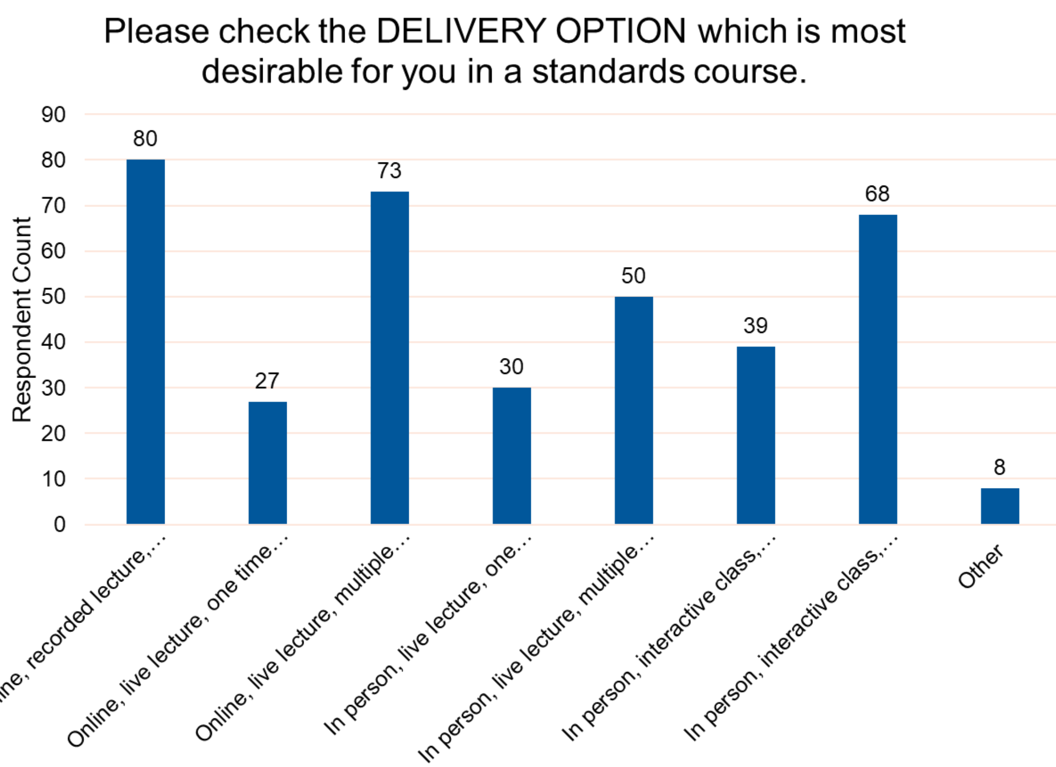


Figure 14: Participants desired delivery option for a standards course.

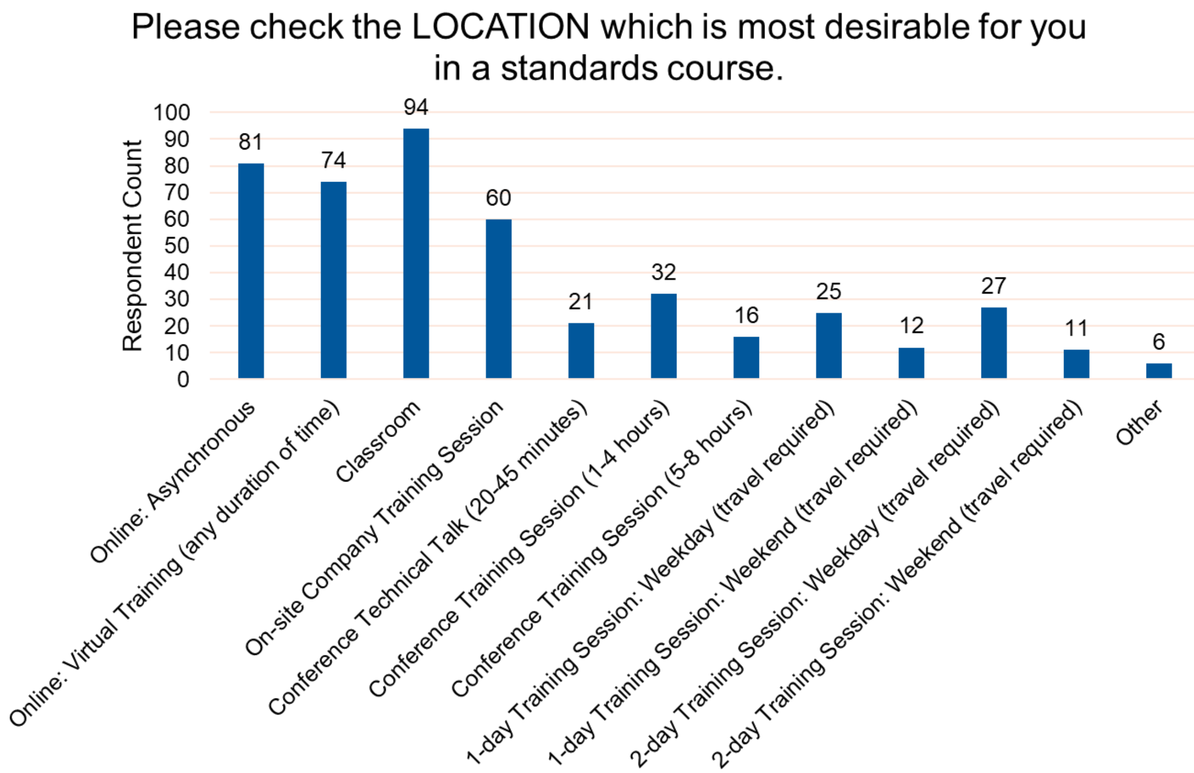


Figure 15: Participants desired location for a standards course.

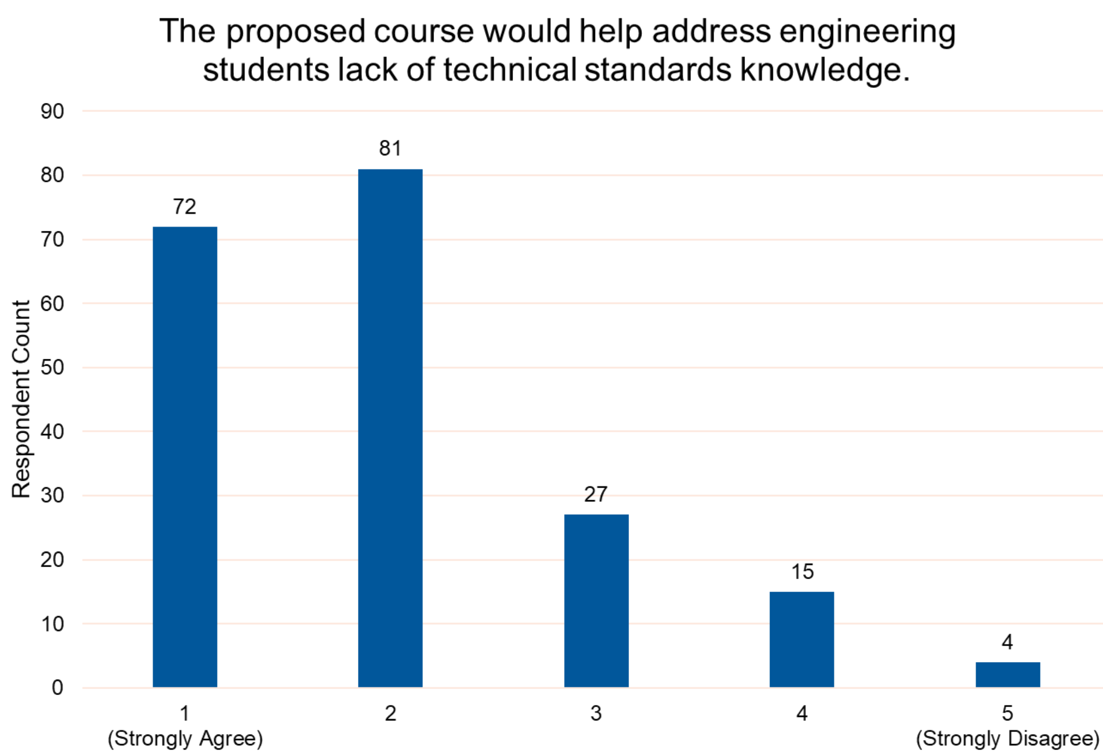


Figure 16: Participants' opinion on the value of a standards course.

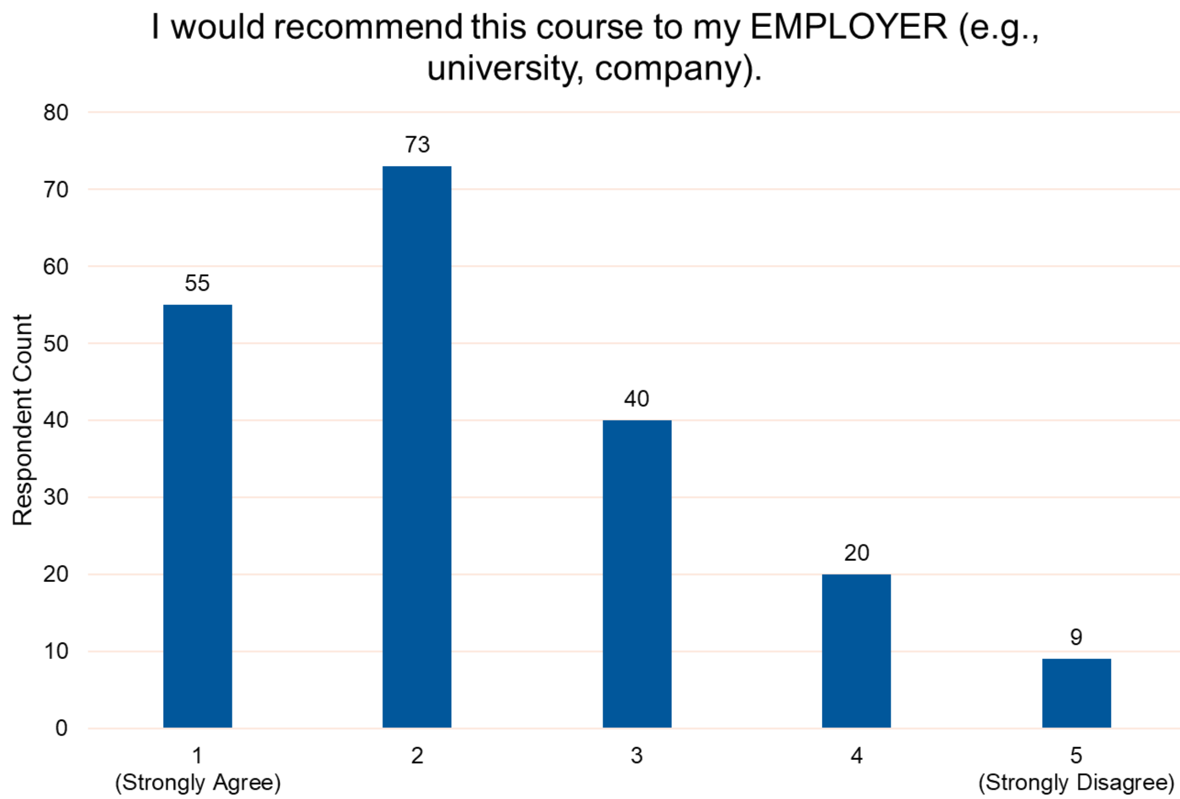


Figure 17: Participants' opinion on the value of a standards course for their employer.

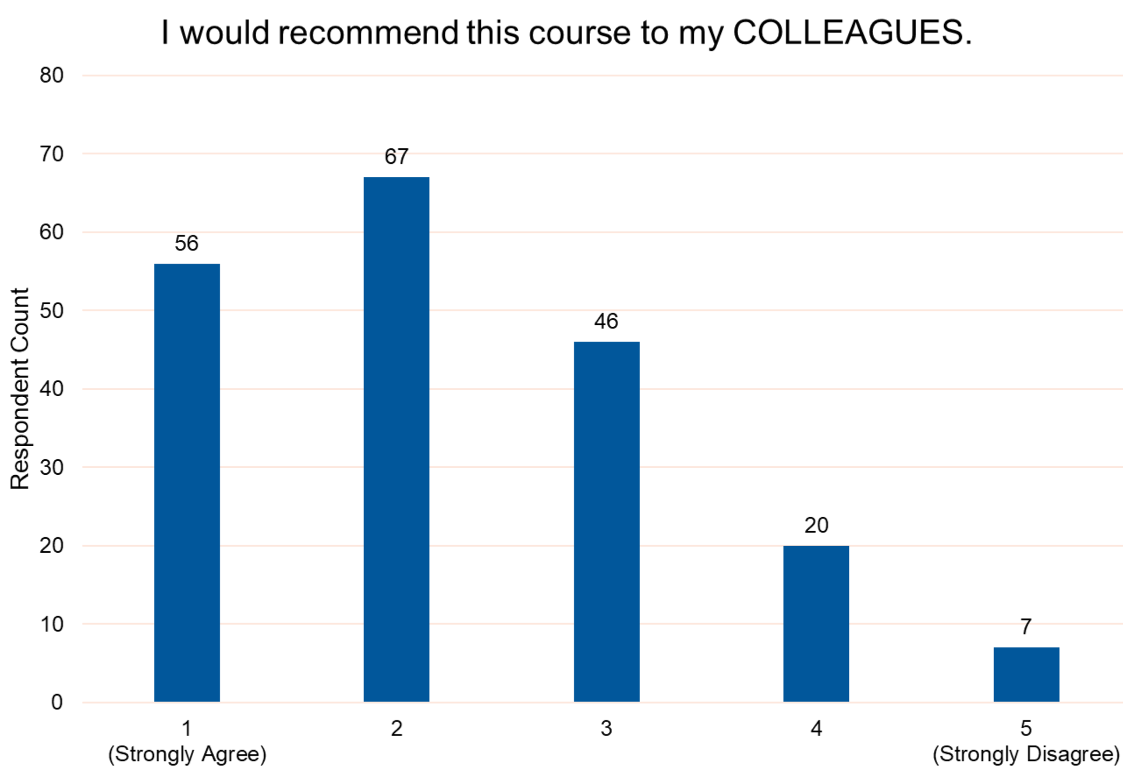


Figure 18: Participants' opinion on the value of a standards course for their colleagues.

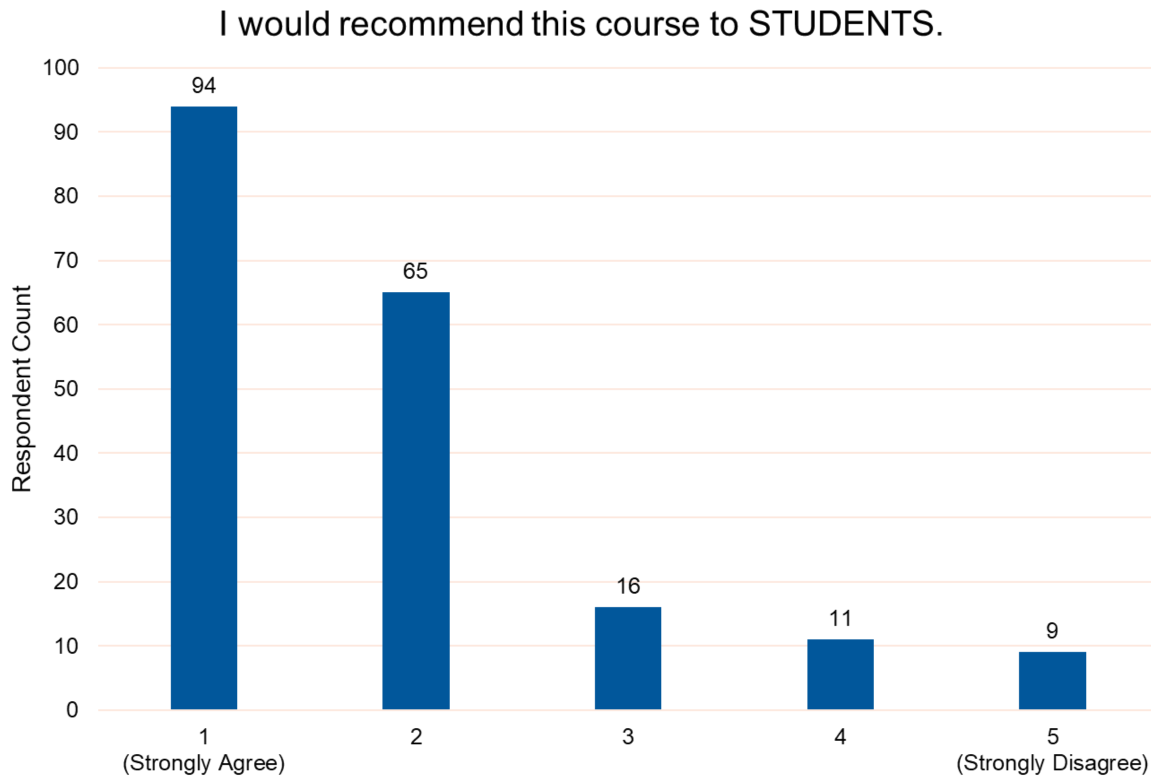


Figure 19: Participants' opinion on the value of a standards course for students.

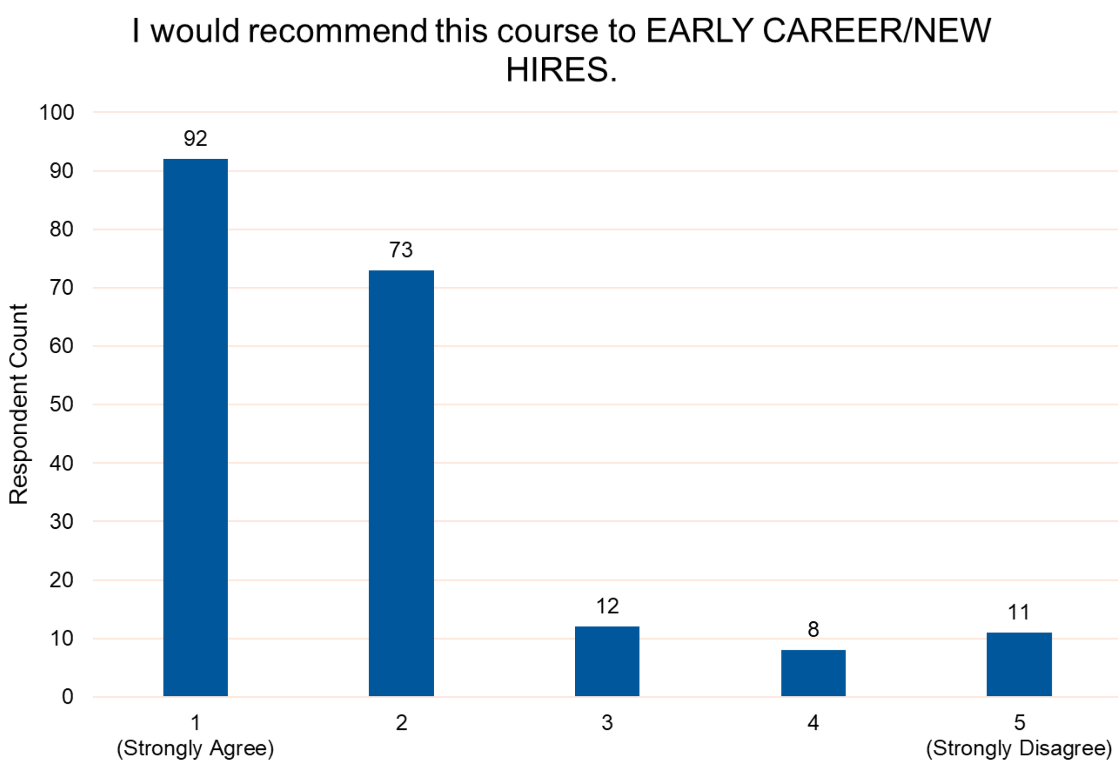


Figure 20: Participants' opinion on the value of a standards course for their colleagues.

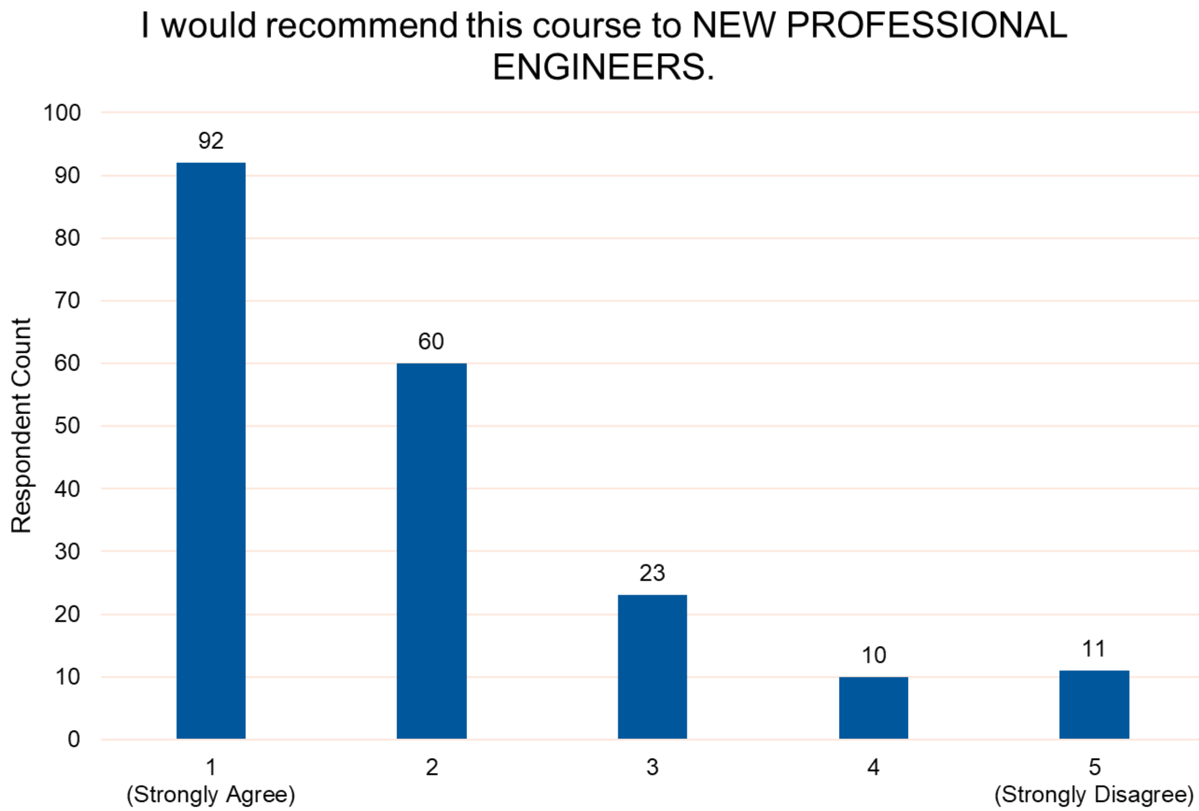


Figure 21: Participants’ opinion on the value of a standards course for new professional engineers.