Board 89: What Engineering Students Think About How They Learn Professional Skills

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What Engineering Students Think About How They Learn Professional Skills

To promote better engineering education within the United States, in 2004, the National Academy of Engineering launched *The Engineer of 2020* project [1]. This project ushered in a new era of engineering education by emphasizing not only technical skill development, but also the development of critical social skills needed for engineers to be successful in an increasingly diverse workplace [1]. For the United States to maintain its innovation edge and ensure it can attract high technology jobs, educators must make sure engineering graduates are both highly technical and have the professional skills needed to compete in a modern global economy and global workforce.

Other universities across the country have also recognized the importance of developing and assessing the professional skills modern graduates' need to be successful. For example, Beard, Schwieger, and Surendran, from Southeast Missouri State University, discuss the use of exit exams, exit interviews, class projects, portfolios, and surveys to develop and assess not only students' technical skills, but also their professional skills [2]. Hall and Bryant discuss the University of Houston's use of senior project courses to develop and assess students' professional behaviors and capabilities [3]. Additionally, Briedis suggests several classroom strategies, such as discussing with students professional support systems typically available in professional settings (e.g., professional societies and continuing education), inviting industry professionals to the classroom to discuss current trends affecting their organizations and industries, and introducing practical engineering problems in which students need to consider the impact of their decisions on the local and global environment, as ways faculty members can integrate professional development into the classroom [4]. Thus, the integration of professional development into science and engineering programs is not a new concept.

According to the review done by Shuman, Besterfield-Sacre, and McGourty, there is encouraging evidence to suggest that the Accrediting Board for Engineering and Technology (ABET) professional skills can be taught effectively [5]. Specifically, these authors highlight the importance of incorporating real-world experiences into the engineering curriculum as the most effective way to integrate both professional and technical skill development into a comprehensive educational experience [5]. Though informative, students' attitudes regarding these methods are essential to understand as theory suggests attitudes are immediate precursors to actual behaviors (i.e., theory of planned behavior) [6]. To date, students' attitudes towards learning professional skills is understudied.

Although other engineering programs around the world have worked to implement curricula designed to help students develop these professional skills, the effectiveness of these programs depends on the quality of the program and the desire of the students to learn these skills [7]. Furthermore, traditional engineering education largely focuses on science, technology, and mathematics as its core content [8], but an emphasis on technical skills combined with a lack of in-class time spent on professional development inadvertently sends the message that professional skills, such as communication and leadership, are not essential components of the engineering profession [7]. Despite this lack of attention paid to professional development in

education, professional skills have become even more valuable than ever before as engineers are expected to work in diverse and interdisciplinary teams [9].

This paper presents a case study describing the assessment of a program launched specifically to foster professional skill development in engineering students. The results from this study can be used as a guideline for other universities looking to enhance the development of professional skills in their own students.

Background

To address the need for an effective program that teaches engineering students critical professional skills, Colorado State University introduced the Professional Learning Institute (PLI) to function adjunct to its College of Engineering [10]. The call to action originated from an incident in the College regarding inappropriate student behavior. The university required the College implement a program to improve students' cultural awareness and related skills. The College broadened this requirement to include the professional skills identified within the ABET criteria, and to respond to requests from the various department industry advisory boards, including the Department of Electrical and Computer Engineering's (ECE) Industrial Advisory Board (IAB). In the decade prior to the development of the PLI, the ECE IAB had driven several initiatives designed to teach and build capacities for professional skills. However, previous recommendations had been largely delivered in silos, mostly via a senior design capstone experience.

As part of the college-wide effort to address the inappropriate student behavior, a former ECE IAB member and Fortune 500 executive joined the College team taking action. She began by conducting interviews with individuals from a broad range of organizations about the changing role of the engineer. Based on the input received from the interviews and messages being delivered from well-regarded publications, such as *The Engineering of 2020* [1], the PLI was launched as a college-wide program in 2007. The five topic areas or pillars upon which the PLI focused align with ABET's non-technical outcomes: ethics, cultural adaptability, innovation, leadership, and civic & public engagement.

The College of Engineering describes the PLI as a program designed to assist in the development of engineering students' professional skills by providing students with a broad array of workshops, presentations, and experiential opportunities. These events introduce students to professional development through required extracurricular activities. PLI sessions are mostly taught by industry leaders, with some involvement from faculty and staff who specialize in the five focus areas. Over a typical 4-year undergraduate plan of study, students are required to attend 11 sessions distributed across the five focus areas. Additionally, students who wish to broaden their knowledge further can earn a certificate in one of the key focus areas by attending extra sessions.

Although the College of Engineering recognized that professional skills are often lacking from the traditional engineering curriculum, students were already at their maximum number of credit hours taking technical content courses. Since attempts to implement additional credit hours to provide professional skill training were discouraged, the PLI was developed as a practical

solution for providing extra instruction without requiring additional credit hours. Thus, the purpose of the PLI was promoted as: (1) provide students with extracurricular actives that teach them skills to enhance their professional careers, (2) satisfy the ABET requirements associated with professional skill development, and (3) provide certification for expertise in key areas.

Content of the PLI

The content of the PLI consists of workshops, presentations, and activities in each of the five focus areas. The topics covered within each focus area often vary between semesters in order to provide a wide range of learning in each topic area. An initial list of topics within each area was developed after consulting with industry partners, College of Business faculty, and key staff, such as the Student Advocacy Offices and the Office for Equal Opportunity. The content is reviewed semi-annually with the PLI advisory board, which consists of representatives from industry, faculty, students, engineering societies, and the Division of Student Affairs staff. Based on feedback received from the advisory board, changes may be made to the tracks and topics within each track. Additionally, there is flexibility built within the PLI that allows for the addition or subtraction of tracks or topics, as appropriate.

The ethics curriculum is taught by the Conflict Resolution team on campus, and by engineers working in both the public and private sectors. Ethics is also incorporated into many of the workshops within the other four tracks and some of the technical curriculum. The ethics content consists of sessions such as A*cademic integrity*, which covers ethical issues that students may encounter in the university environment; *Ethics in engineering*, which focuses on specific ethical issues that engineers face; and *Ethics in engineering case studies*, which presents case studies of ethical dilemmas faced by engineers and involves practice and discussions on how to work through those dilemmas.

Cultural adaptability is defined as the ability to work effectively within diverse teams. The goal of this topic area is to make students aware of the global economy and global workforce, provide insight into cultural differences and norms, and to provide them with skills to effectively understand and respect cultural diversity. Although these workshops are taught primarily by the Student Advocacy Offices, Human Resources personnel from several industry partners have assisted with the content development of this track. Top industry professionals also lead sessions to further elaborate on the challenges and skills needed to work with and manage global teams. Some of the content for this track includes *Today's business environment*, which provides information about the global economy and workforce; *Communicating effectively in the global marketplace*, which teaches students how to communicate effectively with cross cultural colleagues; G*ender and the workforce*, which covers how learned gender differences play out in the workplace and challenges biased assumptions about gender; and C*reating teams that work for you and others*, which provides an understanding of the United States' system of privilege and learn how to enhance team inclusiveness.

Innovation focused on developing students' creativity and innovation skills. The content consists of *Introduction to innovation*, which highlights innovation topics from industry experts; *Secrets of innovation*, which includes a panel of top industry innovators; *Innovation in public works*,

which discusses the many innovations created daily in public work areas; *Entrepreneurship*, which encourages students to identify problems, develop creative ways of solving those problems, and shares ides of how to become an entrepreneur; and *Ethics of innovation*, a session in which faculty industry innovators discuss ethical dilemmas associated with technological innovation.

The leadership track aims to improve students' leadership skills by offering workshops in four general categories of leadership: effective teams, personal leadership, communications, and organizational leadership. Specific leadership topics covered vary each semester, but the two courses that are recommended for all students are *Project management*, which provides basic project management information that students can use both in school and in the workplace, and *Leadership panel with industry leaders*, which includes several panelists who discuss their own leadership development and provide advice on how students can develop and demonstrate their leadership skills.

Civic & public engagement is focused on the positive impact students can have in their communities by volunteering for an activity in which they can use their technical skills to improve the community. To encourage participation in volunteer activities, a competition on who can log the most volunteer hours is hosted between student engineering societies. The winning student organization then receives PLI credit for this focus area. The recommended curriculum for all students involves *Introduction to service learning* where students are introduced to the idea of civic and public engagement and participate in a 1-3 hour service-learning project.

Initial Feedback on the PLI

The college has used different methods to evaluate the PLI. In 2010, an Engineering Information Foundation grant allowed the college to develop tools to assess learning outcomes of the program. These initial results indicated that regardless of level of exposure to the PLI, there were no statistically significant differences between students. Consequently, to get more detailed and rich information, focus groups were conducted with students who had participated in the program. Recurring themes from these focus groups were related to content, delivery mechanisms, and lack of interactivity in the sessions. With these findings, the PLI was revised to include more hands-on activities and learning exercises that take the form of interactive games and case studies emulating real-world scenarios. In addition to altering the PLI activities, a new online assessment was implemented to continuously improve the quality of the workshops and the program overall.

To receive student feedback easily and quickly for each session, the Operations Team (the team managing the PLI program and who reports to the Associate Dean for Academic and Student Affairs) developed a brief questionnaire consisting of four questions:

1. *How would you rate the speaker?* (on a scale of 1 to 5, with 5 being the highest rating)
2. *How relevant was the topic?* (on a scale of 1 to 5, with 5 being the highest rating)
3. *What did you learn during this workshop?*
4. *What suggestions/comments do you have about the topic or the speaker?*

Students were required to complete these surveys within a day after completing the PLI session, and if they did not, they did not get PLI-credit for attending the session. The ratings and comments are compiled, provided to the speaker, and used by the Operations Team to improve the sessions. The speakers used this information to improve their presentations, often with the assistance of the Operations Team. At the end of each semester, student focus groups were held again to provide feedback about the present state of the PLI. Some examples of previous student comments and resulting Operations Team responses include:

- *More communication about PLI sessions.* The team posts information about upcoming PLI sessions in the main hallway in the Engineering Building and sends emails to students about each week's sessions.
- *Host recent graduates to talk about their transition to the workforce*. Panels of recent graduates are held each spring semester.
- *Send reminders about PLI sessions for which students signed up.* The team uses an automated tool sending students a reminder email two days before a registered session.
- *More emphasis on communication skills*. A communication skills development session is included as part of the leadership certification and an effective listening workshop is offered in the spring.

Although the College of Engineering had already been pursuing their own feedback on the PLI, the College was offered and took an opportunity to participate in a research study (part of a larger study within ECE) that would assess engineering students' attitudes towards learning ABET skills, to which we turn to next.

Recent Feedback on the PLI

The current study was part of a larger project aimed at investigating student attitudes towards professional development. College of Engineering students were surveyed in the fall of 2016 about their overall attitudes towards learning ABET professional skills: communication, ethics, cultural adaptability, leadership, teamwork, innovation, and civic & public engagement. Students were asked whether they thought the PLI, which was in its 10th year, was an effective, valuable, and engaging program. An open-ended comment box was also included in this online survey, which allowed students to express their thoughts about how they were learning ABET criteria. For this current study, we focused on examining their comments to understand what they think about how they were learning the ABET professional skills, specifically, via the PLI, since this was the learning mechanism provided by the College.

Of the 2,628 engineering students enrolled in the college, 534 completed the survey, resulting in a typical online survey response rate of 20% [11]. The sample was 30% female, 76% White, 5% Hispanic, 2% Black, 2% Asian, 2% Multi-racial, 7% International, and the remaining were classified as unknown. With respect to grade level, 45% of respondents were seniors, 19% were juniors, 20% were sophomores, and 16% were freshmen. Demographic analyses showed the sample was proportionately representative of the College of Engineering student body.

Of the 534 students who completed the survey, 319 filled out the opened-ended comment box. Of the 319 students who provided comments, 32% were female, 82% identify as White, 3.5% as

Hispanic, 2% as Asian, 3% as multi-racial, 3.5% as International, and the remaining 6% were classified as unknown. With respect to grade level, 51% were seniors, 19% were juniors, 16% were sophomores, and the remaining 14% were freshmen.

Content Analysis Results

A content analysis was conducted on the 311 usable open-ended comments (upon further review, 8 of the initial 319 responses did not contain useable content). The analysis was conducted by classifying comments into four categories based on their content: scheduling, structure, logistics, and effectiveness of the PLI program. If a comment's content covered multiple categories (i.e. logistics and effectiveness), it was assigned to all the appropriate categories.

Results from the content analysis showed that students expressed value for developing the skills outlined by ABET. For example, some of the student comments included, "The principle motivation behind the PLIs is excellent," and "I have been able to use everything I have learned toward finding a job and being able to communicate effectively with potential employers." One student described PLI sessions as "interesting and engaging" and another student would "recommend PLI sessions to incoming freshmen" to help them "develop real world skills for problems they will experience during and after college."

However, negative comments specifically aimed at how they were learning ABET skills via the PLI program overwhelmingly outnumbered the positive comments. Specifically, out of the 311 comments, only 27 of them contained at least one positive comment (i.e., a little under 9%). All 27 of these positive comments were directed towards the effectiveness of the PLI. No positive comments were recorded regarding the scheduling, structure, or logistics.

Some of the negative comments were provided by non-traditional students who indicated the PLI was a waste of time. This appeared to be due to a lack of acknowledgement or credit for their relevant work experiences. Specifically, students reported the PLI as "a huge waste of time when you have so much homework (and maybe a job) to do" and the requirement "comes across insulting." Some students reported that the lack of a "test-out" capability was insulting for individuals entering the program with years of experience applying a particular skill set (e.g., military leadership). Thus, it appeared the College of Engineering assumed all students entering engineering had no professional skills.

Beyond the already heavy course load engineering students typically have, combined with the lack of a "test-out" capability, both non-traditional and traditional students cited problems in all four categories (i.e., scheduling, structure, logistics, effectiveness). For example, a common scheduling complaint was that the PLIs "often don't fit in with my class schedule." This comment is particularly relevant because students who showed up just after the session started or had to leave a few minutes before it ended were not given credit for the session. Additionally, students commented that the sessions were "too long for the subject matter" and were delivered at "inconvenient times." Some students advocated for "shorter or more sessions" to be provided to help ease the issues surrounding scheduling conflicts.

Turning to the structural concerns, students expressed the opinion that the "PLIs are not very workshop-like or interactive," and "I don't think those skills can be learned in a class." They suggested that offering more interactive workshops would be "much more effective and create motivation to attend."

Logistically, some students experienced problems with the post-PLI surveys. One student commented, "the surveys that we are supposed to take after each session are very difficult to find," which meant they could not always complete the required questionnaire in time to receive credit. Suggestions to improve PLI logistics included "a PLI newsletter" and more "emails about the sessions" to help students "remember to sign up for them."

Lastly, negative comments about the effectiveness of the PLI were, in general, the harshest. Many students described the PLIs as "a waste of time" and believe "the PLIs fail in every way to accomplish their purpose" of providing engineers with professional skills. Others stated that the PLIs "feel too forced" and make students "go through the motions" without learning anything. In sum, the consensus among students was that the PLI is not an effective way to teach and/or reinforce ABET professional skills.

For a long time, people had expressed their frustrations with how the PLI was implemented and being run, but they had no idea how to replace the program. For example, along with the issues reported in the student comments, advising staff reported the number one complaint they heard from their students was about getting their PLI credit. Although it was clear from the comments that most students did not believe the PLI was effectively implemented and managed, students did report seeing the value in learning professional skills. When it came to general suggestions on how to improve the teaching of ABET skills at the university, the most common suggestion was that "if professional skill development is so important, it should be incorporated into the engineering core curriculum." Coincidently, around the time of this survey, the ECE department had been developing ways to integrate professional skill development into their major curriculum as part of a National Science Foundation (NSF) grant focused on revolutionizing engineering education.

Thanks to the survey results providing clear evidence that students were not happy with the way they were currently learning professional skills, compounded with previous years of reported frustrations, the PLI was recently removed as a graduation requirement and rebranded as a career development resource. Additionally, the findings from this study supported what the ECE department's NSF grant was working to accomplish – implement professional skill development within the curriculum. Though a post-PLI assessment has not yet taken place, plans to evaluate the effectiveness of integrating learning professional skills within the ECE curriculum in the next year are underway.

Integration into the Curriculum

With the PLI graduation requirement removed, all engineering departments became responsible for providing professional skill development to their students as opposed to the college owning that responsibility. One way to offer professional skill development is to embed specific training directly into the curriculum of each engineering major. An advantage with this approach is that

the development efforts can be tailored to the particulars of that major. A disadvantage, however, is that the burden of professional skill development then falls on every department and redundancies and inefficiencies are likely to occur. The goal of embedding ABET criteria training into the curriculum is to focus on the integration of professional and technical skills, as opposed to treating professional skill development as an "extra" requirement that comes secondary to technical skill development. Of course, there may be other ways to offer professional skill development that have yet to be explored.

One particular approach used by the ECE department may offer a potential avenue for how ABET criteria training can be embedded into the engineering curriculum to achieve integration. ECE initiated several curricular innovations to improve students' professional skills as part of their NSF sponsored project focused on improving engineering curriculum. A major emphasis of the project was to create an integrated approach to delivering second- and third-year course content with relevancy to application in the ECE curriculum. The curriculum changes were implemented by creating coordinated efforts between the three main courses taught each of the two third-year semesters. As part of this integration, students from all the classes periodically meet throughout the semester to work on an integration assignment that requires knowledge from across all three classes. These assignments have become one of the vehicles for improving students' communication skills. For example, students are required to develop oral presentations on the integrated assignment and discuss the integration of knowledge required for completing the assignment. These presentations are captured using video technology and then submitted through the online course learning management system. Additionally, students are required to review the submission of three peers and provide anonymous feedback. To scaffold this effort, exemplary presentations with faculty feedback were developed by graduate students. These videos were then made available to the students to assist their learning [12]. Ethics has also been incorporated into the integrated ECE curriculum. Similar to the communications assignment described above, an ethics case study is presented to the students as part of the periodic integration assignments [13]. This case study is tied to the content for the larger integration portion of the course. Students are required to read about the case study and answer several questions before the combined class meeting in which a discussion of the case study is facilitated by the faculty. Lastly, an effort to increase students' teamwork skills using a voluntary virtual internship project is currently being piloted at the first-year level. First-year students are recruited to participate in a design project for the first half of the semester, which is followed by a faculty-led design effort over the second half of the semester. In sum, the activities described above represent important steps towards integrating professional skills throughout the curriculum.

Conclusion

In this case study, we focused on understanding engineering students' perceptions of how they were learning ABET criteria at Colorado State University. The original goal of the PLI was to ensure engineering students graduate with the ABET professional skills needed for success in the workforce. To achieve this goal, the College of Engineering provided students with professional

skill development content delivered separately from and outside of the standard engineering core curriculum.

Our study results suggest that having a rigorous survey or feedback mechanism developed using the scientific principles of effective survey development, such as what we provided for this study, can give informative and valuable feedback about students' needs, challenges, and concerns with how they learn professional skills. The typical short satisfaction survey, such as the one used for the PLI sessions, was not enough to understand comprehensively what students were thinking regarding how they were learning professional skills. Our results showed that students value the ABET outcomes and think professional skills are essential for career development but felt the PLI implementation was not an effective way to teach and encourage those skills.

As industry and student needs evolve over time, programs similar to the PLI must remain adaptable and receptive to feedback to ensure the content reflects those changes. Based on the results from our current study, engineering students believe they should be learning ABET professional skills via integration into the core curriculum. As ABET professional skill development is integrated into the core engineering curriculum, it will be essential for engineering colleges to evaluate and continuously monitor the success of this approach. It is our hope that other universities will continue to find new ways to integrate ABET professional skill development into engineering core curriculum and that they will consider our findings when developing those methods.

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