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Hardening Freshman Engineering Student Soft Skills

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***Abstract* - This paper, based on pre/post test scores of engineering student responses to ABET soft skill knowledge, explores the possibilities for freshman engineering students to engage meaningfully in six of the 11 outcomes for engineering graduates. With a focus on multi-disciplinary teamwork, professional ethical responsibility, effective communication, engineering solution impacts, life-long learning, and contemporary issues, the researchers surveyed >50 engineering students at a large western university to establish a baseline of their ABET soft skill understanding. Even after attention to soft skills, as explored in the literature review, findings show that even senior engineering students do not know about ABET accreditation, soft skills related to communication, or ways to apply those soft skills through conflict resolution. Currently as stand-alone course sessions embedded within engineering classes, exposure to ABET's soft skills as well as conflict resolution techniques, can dramatically improve student understanding and collaborative interactions. The researchers propose utilizing these techniques and creating a freshman class or embedding the work in another course early in the engineering students' program as explicit instruction is needed. For this study, techniques used in a stand-alone course session are explored. Implications for improved engineering student success are large and easily transferred to other programs as well as offering female engineering students a means to leverage socio-cultural capital.**

Index Terms – ABET, Computer Science Education, Computer Science, Conflict Resolution, Engineering Education, Partnerships, STEM, Soft Skills

INTRODUCTION

At the heart of all product creation and problem solving is human partnership. Inherent in the ability of people to listen, act and react, imagine, test, and create something, are the countless interactions between both technical and non-technical audiences. Just the idea that knowledge is created slowly over time with 'various layers of thickness' allows the creator to engage and disengage with the project at hand. Having spent time in an engineering lab where creations happen both slowly and quickly depending on inspiration (and perspiration), researchers often explicitly understand the value of conversations and talking through problems to solve their own problems. As educators, it would be convenient to 'bottle' the wisdom of product creation and pass it along to students. However, students need explicit instruction on what engineering researchers and practitioners implicitly understand and use daily. This explicit instruction of communication and partnership is captured in the Accreditation Board of Engineering and Technology's (ABET) nontechnical, or soft, skills.

PROBLEM, PURPOSE, AND RESEARCH QUESTION

The problem is that senior engineering students, who are about to embark on engineering careers, do not explicitly know about ABET soft skills such as proper communication and partnership conflict management. Often, when engineering students engage in group projects, their focus and assessment are on the final product instead of both the product and the process of product creation. To gain understanding of the collegiate students' knowledge, the purpose of this study was to elucidate engineering students' knowledge base regarding soft skills from the ABET Computing Accreditation Commission (CAC) and Engineering Accreditation Commission (EAC) criteria [1]-[2]. The authors of this paper sought to answer the following two research questions:

1. *"What do university engineering students – at all levels - know about ABET and soft skills?" and*
2. *"Is there a difference between freshman / sophomore and junior / senior level engineering studen'ts understanding of soft-skills?"*

LITERATURE REVIEW

Soft skills such as teamwork, communication, and management are vitally important to engineering success and students need these nontechnical skills [3]-[10]. Williams [11] outlines the development of ABET's Engineering Criteria 2000 and focuses on technical communication which is essential for students' success. Burrows and Harkness [12] show the importance of conflict management and means to achieve it, while other researchers have investigated the gap between university engineering classes and the attention to soft skills and found that students lack the nontechnical skills in specific areas such as communication [6],[13].

To combat the lack of soft skills issue, universities have adopted different approaches. Some universities have implemented required courses, or parts of courses, for engineering students as part of their degree [14]-[15]. Other universities have encouraged student co-curricular involvement to enhance soft skills and show data to back up the claim [16], as well as implementation of leadership and service [17], and cooperative learning in outside courses and design processes, such as a chemistry course or competition, to do the same [3],[18]. Researchers have also explored the challenges to providing courses with soft skills, even in online courses, and pointed to students' perception, maturity, and context of application [19]. Additionally, there are nonintrusive methods to assess soft skills in group settings [20]. However, no researchers claim that soft skills are not important, and some experts believe that soft skills are twice as important as content knowledge alone [21].

Mahasneh and Thabet state that "it is difficult to teach or measure soft skills, [but] they are proving increasingly valuable" [22]. Finally, there is a large body of research that showcases females in engineering valuing the engineering social skills and implications, and emphasis on soft skills could encourage more female engineering student applications [23]-[26].With changes being made to university engineering programs, and the understanding of soft skill importance, the authors of this article wondered if they too would find a gap between university classes and ABET soft skill identification and understanding.

METHODS

As a baseline study, the authors of this paper only collected quantitative data. The first wave of data collection occurred in a junior/senior level computer science elective course. Eighteen students (of the 33 enrolled in the course) completed the pre/post survey on ABET soft skills via a six-question paper questionnaire. Between the pre and post-test assessments, the first author conducted an intervention of soft skill explanations with a hands-on example. Two questions related to what ABET is and what ABET does, one question related to soft skills, and three questions related to successful partnerships, types of conflict, and ways to approach conflict (Table 1). The activity was a game in which student teams worked together to get paper balls into target areas for points. The second author collected the paper questionnaires and team activity totals for data analysis.

TABLE I
SIX QUESTIONS RELATED TO ABET, SOFT-SKILLS, PARTNERSHIPS AND CONFLICT.

#	Questions	Potential Full Credit Response (Abridged)
1	What is ABET?	Accreditation board for engineering (and technology)
2	What does ABET do?	Accredits engineering/computer science programs based on how the meet established criteria (students, faculty, administration, curriculum, facilities, etc.)
3	What are "soft-skils" as described by ABET?	At least 5 items related to criterion 3 [student outcomes] from abet eac criteria (abet-eac, 2015), abet cac criteria (abet-cac, 2015)
4	What are essential components of successful partnerships?	Common objectives, mutual benefit, communication, effective conflict resolution, etc.
5	What are three (3) main types of conflict?	Resource, objective/goals, identity
6	What are the four (4) main ways to approach a conflict?	Antagonism, resonance, invention, action

The second wave of data collection occurred at the end of an academic year via online anonymous survey. It was accessible to all undergraduate computer science students (approximately 150 students) and a link was sent to them via email. Thirty-seven students completed the survey and the data was collected via Google docs. The second author collected the open-ended responses on the same six questions as described previously.

THE STUDY, PARTICIPANTS, AND LIMITATIONS

The large, western university where this study took place has a 23% non-white population and a female population of 16% across all engineering disciplines. All of the participants were undergraduates in the on-campus university engineering program and volunteered to take the survey.

There were 55 unique participants (18 in-class and 37 online surveys) spanning four years of traditional class standings. These 55 participants included seven freshman (12.7%), nine sophomores (16.4%), 19 juniors (34.5%) and 20 seniors (36.4%). Of the 55 participants, 18 were exposed to the Soft Skill Applications intervention and completed a post-assessment. The breakdown of this subset of participants is skewed towards upper-level undergraduate students (e.g. juniors and seniors) as this experience occurred within a cybersecurity elective course with a number of pre-requisites. These 18 participants included one sophomore (5.6%), three juniors (16.7%) and 14 seniors (77.8%).

There are several limitations in this study. First, the pre/post occurred immediately prior to and immediately following the intervention class. Long term soft skill retention has not yet been assessed for those completing the activity. Secondly, the authors were biased with the knowledge that engineering students often do not know about ABET soft skills and thus could have influenced the findings without intent.

ANALYSIS & FINDINGS

To answer the first question "What do university engineering students – at all levels - know about ABET and soft skills" the authors used pre and post survey results (Tables II & III respectively) for the 18 students who participated in the in-class intervention within a semester-long cybersecurity course. Using per-student identifying information, a paired, two-tailed, t-Test was performed for each question – again the null-hypothesis (rejected when p is small) is that both the pre and post survey result come from the same underlying population. Table IV shows the average and standard deviation for each of the six (6) questions pre/post as well as the computed probability that the two groups came from the same underlying population. The null-hypothesis is rejected for each of the six (6) questions related to ABET, soft-skills, partnerships, and conflict – thus a one-lecture course is capable of impacting student knowledge and awareness.

TABLE II
PRE-RESPONSE RESULTS FOR 18 IN-CLASS PARTICIPANTS, BROKEN DOWN BY GRADE LEVEL

Grade Level	Q1	Q2	Q3	Q4	Q5	Q6
Sophomore	0%	0%	0%	0%	0%	0%
Junior	33%	0%	0%	40%	22%	8%
Senior	14%	14%	11%	19%	2%	2%
Overall Average	17%	11%	9%	21%	6%	3%

TABLE III
POST-RESPONSE RESULTS FOR 18 IN-CLASS PARTICIPANTS, BROKEN DOWN BY GRADE LEVEL

Grade Level	Q1	Q2	Q3	Q4	Q5	Q6
Sophomore	100%	60%	60%	100%	100%	100%
Junior	93%	87%	67%	87%	100%	100%
Senior	96%	80%	79%	86%	67%	57%
Overall Average	96%	80%	76%	87%	74%	67%

TABLE IV
PRE AND POST AVERAGES AND STANDARD DEVIATIONS FOR EACH QUESTION, ALONG WITH THE PAIR T-TEST PROBABILITY

Question	Pre	Post	P-Value
Q1	16.67% ± 31.62%	95.56% ± 10.97%	$p < 1x10^{-7}$
Q2	11.11% ± 25.87%	80.% ± 25.67%	$p < 1x10^{-6}$
Q3	8.89% ± 18.44%	75.56% ± 27.06%	$p < 1x10^{-7}$
Q4	21.11% ± 25.18%	86.67% ± 25.67%	$p < 1x10^{-5}$
Q5	5.56% ± 17.15%	74.07% ± 43.62%	$p < 1x10^{-5}$
Q6	2.78% ± 8.08%	66.67% ± 46.18%	$p < 1x10^{-4}$

In order to answer question two, "*Is there a difference between freshman / sophomore and junior / senior level engineering student's understanding of soft-skills?*" we compared the pre-test responses of all 55 unique participants. The two groups of responses from the early-undergraduate students (n=16), consisting of freshman (7) and sophomores (9) and upper-level undergraduate students (n=39), consisting of juniors (19) and seniors (20), both had right-tailed chi-squared distributions. Given a two unique population sizes (n=16, n=39) and chi-squared distributions of survey results, the likelihood that both results came from the same underlying population can be evaluated though the use of an F-test. As with the t-Test, a low value would reject the null-hypothesis that both samples came from the same underlying distribution, while a high value would accept the null-hypothesis.

When comparing the early undergraduate student responses versus the upper-level undergraduate students, the F-test found that the two groups likely came from the same underlying population (p>0.85). Thus, when it comes to student knowledge and awareness of ABET, soft-skills, partnerships and conflict, there is little difference between early undergraduates and upper-level undergraduates. Table V shows a summary of the average per-question scores of both groups, as well as the overall F-test probability that the two groups belong to the same underlying population.

TABLE V
AVERAGE SCORES PER QUESTION, SPLIT BY EARLY UNDERGRADUATE AND UPPER-LEVEL UNDERGRADUATES

Question	Early Undergraduates (Freshman & Sophomores) [n=16]	Upper-level Undergraduates (Juniors & Seniors) [n=39]
Q1	15.00%	23.59%
Q2	11.25%	22.56%
Q3	5.00%	11.28%
Q4	28.75%	33.85%
Q5	12.50%	14.53%
Q6	15.63%	12.82%
-	F-Test	(p>0.85)

Conclusions and Implications

Like other researchers, the authors of this paper found that engineering students at all levels do not know about ABET or the soft skills that are required by the standards. Conflict identification and management was almost absent in pretest findings, and when questioned, the engineering students quickly admitted that they did not know how to handle problems in groups other than to try and compromise, but it did not always work.

The large, western university where this baseline study was conducted will investigate the models presented in the literature review (e.g., interventions, courses, cooperative learning, competitions, etc.) for implementation into the engineering programs. The authors of this paper encourage other universities to do the same. Clearly, this study, which supports the soft skill literature, shows that recognition of the problem is not enough. Administration and faculty must focus on explicit soft skill implementation – in and out of the classroom - and then assess those soft skills in the teamwork, communication, and management categories. The authors of this article encourage conflict management scenarios – real and imagined – as a part of engineering projects, where students could voice the problem, what is known, and possible ways to solve it. Encouragingly, the first author noted no difference in female and male participation in the in-class soft skill intervention.

In anecdotal conversations after the class, the students told the first author that the in-class intervention soft skill information would have been better served earlier in their engineering coursework, and that they did not see a reason for it so late in the graduation requirements. The first author was discouraged that the student group did not make a connection with future engineering positions and projects as a means to utilize the information from the in-class intervention. However, both authors of this paper are encouraged that students are interested and engaged in soft skills when given the chance, and with explicit instruction and guidance, engineering students can understand and apply soft skills in their schooling and future positions.

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