WIP: Think-Aloud Interviews for Assessment of Engineering Students' Opportunities to Practice Professional Skills

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Abstract

As the need for interdisciplinary collaboration increases, industry needs engineers who are not only affluent in technical engineering skills but also efficient in skills such as communication, problem-solving, engineering ethics, and business management. As a result, engineering programs are tasked with providing students with sufficient opportunities to develop non-technical professional skills to better prepare them for the workforce. Previous research has focused on exploring how and where students tend to develop profession skills and assessments have been established to measure the level of professional skills. However, without a means to measure whether students are getting sufficient opportunities for development, it is hard for educators and engineering programs to determine whether or where scaffoldings are needed. We developed an instrument to assess undergraduate engineering students' opportunities for professional skill development. To increase content validity, we conducted 20 think-aloud interviews with students from a large Midwestern university. The aim of this WIP is two-fold. We present the preliminary results of the think-aloud interview to determine what changes need to be made to existing items and what emerging themes appear regarding to participants' professional skill development opportunities. After thematic analysis of the interview transcripts, we revised 10 items by simplifying the grammar or altering certain words that tend to confuse participants or carry negative connotations. We found that, compared to students who have only been involved in class projects, those with co-curricular experiences tend to report more opportunities in skills related to business management principles and problem-solving skills. Co-curricular activities were also the most referenced in building communication skills. Our next step will be piloting the instrument across multiple institutions and conducting validation analysis.

Introduction

Increased levels of interdisciplinary collaborations and globalization have altered the skills needed for today's engineering workforce. Non-technical professional skills—once relegated to "soft skills"—have become equally important as technical fluency. These evolving workforce needs have been widely recognized and reflected in educational standards by ABET (the accreditation board for engineering) and reports by organizations such as the National Academy of Engineering and the American Society for Engineering Education [1]–[3]. These organizations advocate for engineering programs to incorporate the development of skills such as

teamwork, leadership, business management, and engineering ethics into the engineering curricula [1]–[3]. In addition, research has shown that opportunities for students to practice professional skills significantly contribute to them being prepared for actual professional practice upon graduation [4], [5].

While engineering programs have worked to incorporate non-technical professional skills into the already-packed curriculum, the development of these skills has also been shown to occur in other settings. Co-curricular activities such as professional societies, student organizations, and research opportunities offer students tremendous opportunities to develop professional skills [6], [7]. For example, a study including over 5,000 undergraduate engineering students across multiple institutions revealed that co-curricular activities are significant predictors of leadership skills [8]. Carter and colleagues conducted a study of a similar scale and confirmed that research experience is a significant predictor for engineering students' communication skills [9].

When the COVID-19 pandemic forced higher education institutions to shift to remote instruction, students began to lose opportunities for co-curricular opportunities for skill development that were once taken for granted. For example, student clubs and professional organization meetings were canceled or moved online [10]. Additionally, remote working may create more challenges for activities such as internships and research opportunities.

Our work focuses on measuring engineering undergraduates' opportunities to develop and practice non-technical professional skills. This work-in-progress paper documents one aspect of developing the Professional Skills Opportunity (PSO) survey. Here we present preliminary results from cognitive think-aloud interviews of the PSO. We answer the following research questions:

1. What changes should be made to the existing PSO items?
2. What are the emerging themes about undergraduate engineering students' opportunities to develop professional skills?

Background

Professional Skills

Professional skills development has been the emphasis of accreditation agencies such as ABET for over two decades. Compared to technical competencies, professional skills are non-technical and reflect an individual's ability to function as a professional [11]. The recent emphasis on professional skills has profoundly influenced the structure and curriculum of many engineering programs [12]. By incorporating professional skill development into learning outcomes of engineering programs, students gain early exposure to real-life, professional settings and acquire hands-on experiences [13]. Students are also trained to view and understand the discipline of engineering as a social enterprise and consider themselves and their designs under a broader social context [14], [15]. Thus, facilitating professional skill development not only helps students to become well-rounded engineers in the workforce but also cultivates a deeper sense of social awareness and professional responsibility.

Professional skill development is much more complex than that of technical knowledge. Unlike technical knowledge, which is usually taught in classes, professional skills are not bound by classrooms and may require a longer time to develop [12]. Instead, professional skills develop in multiple settings and can be acquired outside of the boundary of academia, such as internships, research projects, community service, and professional organizations [6], [9]. Research has shown that participation in these co-curricular and extracurricular activities contributes to the development of professional skills [6], [16], [17]. One explanation for this positive correlation is that students, especially racially and gender-minoritized students, have more opportunities to form meaningful relationships with others while engaging in co-curricular activities. Thus, students have more resources and chances to practice and develop the required skills [6]. In a way, these relationships and networks can function as a form of social capital and aid in students' professional development journeys.

Ways of Being

Most assessments of professional skills tend to focus on students' knowledge and abilities in the form of self-rating scales [18], development of reasoning [19], third-party evaluation [20], or behavior-based scales [21]. While assessments based on these types of scales provide measurements of the level of skills, no scale using these approaches encompasses the assessment of all professional skills of concern in our study. Likewise, using a self-rating scale will frequently lead to elevated means [22] and may be of questionable validity and practical use. We instead turn to a professional preparedness-based scale to assess students' professional skills.

Holloway and colleagues [7] developed a scale of graduate students' opportunities for professional skill preparedness by applying Dall'Alba's ontological approach of "ways of being" framework [4]. According to Dall'Alba and Sandberg [5], the process of being and becoming a professional means acquiring both knowledge and skills through a process of practicing and the opportunities that students have to do so. Thus, Holloway et al. focused on assessing students' opportunities to practice professional skills [7]. In their study [7], they found that overall student scores on their scale were normally distributed, and they found strong evidence of structural aspects of validity and significant relationship to other theoretically related variables. We employ a similar approach to assess undergraduate students' opportunities to practice professional skills in our study.

Method

Initial development and expert review: Our team developed definitions for the six professional skills in our instrument, including teamwork, communication, problem-solving, business and management principles, ethics and professional responsibilities, and leadership. We followed the process for instrument construction established by Netemeyer and colleagues, which can be roughly summarized as a four-step procedure: generating construct definitions, generating and judging instrument items, designing and conducting studies on the instrument, and finalizing such instrument [23]. Next, we turned to the existing literature on assessments and operational definitions for these professional skills, prioritizing research in engineering or other STEM fields in this process. After synthesizing the construct definitions for the professional skills from literature and modifying them according to the undergraduate engineering education context, we

generated items for each skill. All questions have the stem of "In your undergraduate engineering experiences, how often did you." As a result, the instrument required respondents to rate the frequency with which they engaged in the activity described to practice professional skills. We then followed the procedures of Holloway et al. and went through a round of expert review and think-aloud interviews [24]. During the expert review process, we shared the draft instrument with over 20 reviewers to gather their feedback. The reviewers come from diverse backgrounds in their research areas, including engineering education, teamwork, engineering ethics, and assessment. We asked the reviewers to evaluate the accuracy and comprehensiveness of our construct definitions as well as the alignment between the question items with the definitions. After incorporating the feedback from expert reviews, we revised the items and definitions to improve the construct validity and alignment of the instrument.

Think-aloud interview: To conduct the semi-structured think-aloud interviews, we recruited 20 participants from a large midwestern university. The participants were primarily undergraduates and were evenly split between male- and female-identifying students (as shown Table 1 and 2 for more demographic information). Among female students, four identified as international students. For male participants, six identified as international students. We audio-recorded and later transcribed the interviews. During the interviews (no longer than one hour), we gave participants the expert-reviewed instrument and asked them to read each question aloud [25]. After reading each question, we asked them to select a response and explain why they decided on their answer. We did not answer questions about the instrument content and instead prompted participants to talk about any questions, confusions, assumptions, and hypotheses they had while taking the survey. We analyzed interview transcriptions using thematic analysis [26] with two major aims in mind: identifying necessary changes of the instrument and discovering preliminary emerging themes about engineering undergraduate students' opportunities to practice and develop professional skills.

Table 1

Female-identifying student demographics

Year	**Race & Ethnicity**	**Major**
Sophomore	Asian, Indian	Mechanical Engr
Sophomore	Asian, Chinese	Mechanical Engr Technology
Junior	Black	Civil Engineering
Senior	White	Biomedical Engr
Senior	White, Hispanic	Mechanical Engr
Senior	Asian, Bengali	Biomedical Engr
Senior	American, Latino	Geological Engr
Senior	Caucasian, Latina	Environmental Engr

Table 2

Male-identifying student demographics

Year	**Race & Ethnicity**	**Major**
First-year	White	First-year Engr
First-year	Asian, Chinese	First-year Engr
First-year	White, Middle Eastern	First-year Engr
Sophomore	Asian, Indian	Mechanical Engr
Sophomore	Middle Eastern	Mechanical Engr
Senior	White, North American	Mechanical Engr
Senior	White, North American	Electrical & Computer Engr
Senior	White, Latino	Mechanical Engr / Industrial Engr

Senior	Latino	Mining & Metallurgical Engr	*Senior*	White, Latino	Mechatronics Engr
Senior	Latino	Civil Engr	*Other*	White, Brazilian	Engr Education

Note. All the participant demographic information presented in the tables is as the students identified in the survey. No student reported as non-binary.

Preliminary Results

Necessary changes to the instrument

Our preliminary results suggested the need to shorten, simplify, and alter some items' sentences, grammar, and word choices. For instance, most participants whose native language is not English reported difficulties understanding words such as "tailor" and "budget" when used in the items as verbs. These students tend to be thrown off by such words with multiple uses. Additionally, students whose native language is not English also tended to repeat longer and more grammatically complex question items multiple times before comprehending. As a result, we shortened and simplified several items to eliminate potential bias towards English proficiency. Another common issue we identified was the severity of some of the words in items. For example, both native and non-native English speakers reported that they relate the action of "persuading others" as too strong and having a negative connotation. Participants reflected that their past experiences seldom required them to persuade either their teammates, instructors, or superiors because they were not trying to "force people" and would simply try to "say their thoughts on it" or "try for consensus." Words such as "consequence" are another example that made students automatically establish connections with negative feelings and sense of doing something wrong, which led to low ratings. Since our team intended these question items to be neutral and not to carry overtly strong emotional notions, we adjusted these words according to the participants' perceptions. Overall, we modified ten items as a result of analyzing the think-aloud transcripts. Out of these modifications, we revised six items due to word choices. We revised the remaining four items to simplify their grammatical structures to decrease the cognitive load on respondents and eliminate bias that may result from different levels of English proficiency.

Emerging Themes Based on Think-Aloud

Among the think-aloud participants, we found that their opportunities to practice certain skills vary depending on their previous experiences and the types of co-curricular or extracurricular activities they have been involved in. For example, students who had previous experiences with activities other than class projects tend to report more opportunities to practice business and management principles. This difference was the most apparent when participants were asked whether they had to anticipate future stakeholders' needs within the project. Since most class projects only span one semester and have a clearly defined scope and problem boundary, participants who lack out-of-class experiences are less likely to engage in this step. In contrast, students who had previous involvement in internships or community service projects and have worked with real, rather than imaginary, stakeholders tend to report that anticipation of future needs is a step they must consider when working on a project. Additionally, professional skills

related to managing the financial aspect of a project or considering the impact of their financial decisions also exhibit this disparity. Again, since most classroom projects do not emphasize engineering economics, students who have only participated in these projects generally report little to no opportunity to practice these skills.

Additionally, co-curricular activities were referenced frequently when participants answered questions about their opportunities to practice communication skills. For example, participants who had previous experiences in community services and internships tend to report higher frequency when it comes to adjusting the content and style of their communications due to a more diverse audience (e.g., management personnel, conference attendees, content experts). In other words, they tend to get more practice in terms of shifting the focus, the level of technicality, and the level of details of their engineering design when communicating, or even learn a different way of writing in the case of students who participated in research and academic writing during co-curricular activities.

Conclusion, Limitation & Future Work

Based on the results of the think-aloud interviews, we revised some items that were confusing, complex, or contained negative connotations to participants. We also made some preliminary discoveries regarding students' opportunities to practice professional skills. Like previous research, many of our participants confirmed the role of co-curricular activities in students' professional skill development. The limitation of this work includes a relatively small sample size in the think-aloud interview process, with 20 participants. Even though the researchers tried to recruit a diverse group of students based on their demographic information, the small sample size may still affect the generalizability of the findings in this paper. As a result, our next step will be to pilot the instrument and perform validation analysis to our instrument design. Further validation analysis including factor analysis may yield more insights on how the instrument design can be improved based on a larger sample size. Ultimately, we hope to provide educators with an assessment measuring students' opportunities for professional skill development and help improve engineering programs to prepare their students for the workforce better.

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