Board 46: "Good communication skills are super, super important": Developing students' professional communication skills for career-ready engineers

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Abstract

With a national shortage of skilled technicians and engineers in the microelectronics industry, developing talent to fill roles in the workforce is critical for the U.S. national security and economy. Given this, a public-private-academic ecosystem was formed with the goal of further developing the U.S. microelectronics workforce. This Work in Progress Paper describes one of seven findings of a workforce needs assessment study completed by this group. Communication was a key finding of this assessment and was a link between the technical and professional skills identified. This finding guided the research questions for this paper: (1) What value do hiring professionals and supervisors in microelectronics engineering place on communication when hiring entry-level microelectronics technicians and engineers? (2) How do microelectronics industry professionals describe desired communication skills? Looking specifically at communication, the following sub theme was identified. Within microelectronics, effective communication among individuals and within interdisciplinary teams is necessary as it allows technical information to be quickly "distilled" and understood by management and other non-technical stakeholders. However, participants shared that individuals often lack sufficient oral and written communication skills that allow them to quickly and succinctly articulate the "so what" to non-technical stakeholders. This paper includes detailed examples of how microelectronics professionals describe and value communication skills and identifies ways that focusing on communication as a professional skill improves student development, the associated student outcomes, and career readiness.

Tags: communication, engineering, microelectronics, workforce development

1 Introduction

With a national shortage of skilled technicians and engineers in the microelectronics industry, developing talent to fill roles in the workforce is critical for the U.S. economy and to secure national defense. The CHIPS Act of 2022, a 54-billion-dollar appropriation for U.S. semiconductor production, is just one example of recent U.S. investment in the microelectronics workforce and supply chain [1]. Given this, a public-private-academic ecosystem was recently formed to generate partnerships between the U.S. government, industry, and academia, with the goal of further developing the U.S. microelectronics workforce. This workforce development program focuses on motivating and preparing students for entry into the microelectronics workforce with the necessary professional and technical skills. A workforce needs assessment was conducted to assess the needs of the microelectronics workforce.

The purpose of this Work in Progress (WIP) Paper is to describe one finding from a larger microelectronics workforce needs assessment study that illustrates the importance of communication as a professional skill. This larger project sought to gain an understanding of the hiring needs of the microelectronics workforce and was guided by the following overarching research question: What is needed for entry-level microelectronics positions as identified by microelectronics professionals? The researchers then re-focused to ask the following more specific research questions: (1) What value do hiring professionals and supervisors in microelectronics engineering place on communication when hiring entry-level microelectronics technicians and engineers? (2) How do microelectronics industry professionals describe desired communication skills?

2 Literature Review

Communication, among other professional skills, is an increasingly high-demand skill in the engineer's toolbelt. However, professionals in many industries, including engineering education, continue to refer to professional skills as "soft skills" [2]. Shuman and colleagues explain how the term "soft skills" is used "often in a naïve or occasionally derogatory fashion" [3, pp. 41]. In this work, non-technical professional skills (i.e., communication, leadership, teamwork) will be referred to as professional skills. The following paragraphs introduce professional skills in engineering education and examine the role of communication development.

As background context, we first examine research regarding the larger context of professional skills in engineering. When discussing the evolution of professional skills in engineering, Shuman and colleagues [3] note that since the beginning of the 20th century, "practically every decade has witnessed a major study of engineering education that collectively has shifted the focus from course content to the development of students as emerging professionals" [3, pp. 42]. Engineering Education accreditation standards (i.e., via ABET) have changed over time in response to changes in the engineering industry's needs [3]. Specifically in the 1990s, changes like the increased use of information technology, corporate downsizing, outsourcing work abroad, and globalization of the industry have altered the knowledge required of engineers [3]. Rapid technological innovation currently requires engineers to develop solid professional skills like communication and lifelong learning in order to adapt to the needs of their industry. However, graduates hired in computer engineering and electronics frequently lack the ability desired by employers to concisely communicate their designs and technical results [4]. For example, Campi and colleagues researched communication skills in a project-based Microelectronics course designed to simulate an industrial environment [4]. This study was driven by the need for professionals in the microelectronics engineering industry to be able to report individual, specialized work to team members and supervisors. The authors emphasize that communication "becomes even more important when the graduate has to face, in the course of his/her professional development, external organizations such as corporate partners, customers, or service providers" [4, pp. 16] To address the gap between the communication skills of graduate-level engineers and industry needs, Riemer [5] unpacked different elements of communication with engineering-related examples and suggestions for future research. Beyond simply developing oral and written communication skills, the author elaborates on other professional communication skills such as listening, visual communication, emotional intelligence, interdisciplinary communication, and intercultural communication [5].

Engineering educators have the opportunity to positively impact the value of an engineering degree through a focus on professional skills. Communication has been introduced in engineering education in a variety of ways due to workforce demands. However, the development of engineers' communication skills has been inhibited by "students' attitudes to communication, insufficient course content, deficient or inappropriate teaching methods, and lack of opportunity for engineering students to practice communication skills" [5, pp. 91]. Understanding these roadblocks along with past success stories can help inform future development of communication skills in engineering students. Although many university engineering programs provide communication related courses, Campi and colleagues emphasize that it is imperative to provide students with the opportunity to practice applying communication skills to realistic technical work [4], [5]. Applying these skills can help students practice the ability to know what details are essential to audience understanding and what can be withheld [4]. Additionally, communication is an important competency for learning experiences (i.e., project-based learning, internships) [6]. Students need to be able to practice communication skills and apply them to different contexts and within different types of situations (i.e., internal vs. external stakeholders). This is especially important considering that there is an apparent misalignment between students' communication skills and industry expectations [6]. The alignment gaps in communication skills are affected by individual engineering departments and discipline-specific industry needs [7]. Engineering education has to be able to reflect the demands of the workforce to prepare entry-level engineers to succeed in a rapidly-changing global economy. Understanding the value professionals place on communication and other professional skills is necessary when developing the next generation of microelectronics engineers.

3 Theoretical Framework

The theoretical framework used for the larger microelectronics workforce needs assessment study included two models that illustrate a variety of competencies that are necessary for developing students with professional skills that make them a career-ready engineer: ABET Process and Awareness Skills and Engineering Habits of Mind (EHoM) [8]. The following previews the theoretical framework used for this Work in Progress Paper to further illustrate the importance of communication as a professional skill.

Shuman and colleagues [3] looked at professional skills as outlined in ABET Criterion 3 in 2005, and separated them into two different types, process and awareness skills. Process skills were defined as skills that could be taught via a process and easily assessed [3]. Awareness skills are skills that students should be aware of and considered when solving a problem. The requirements for communication, 'an ability to communicate effectively,' [3, pp. 41] was classified as a process skill because communication can be taught systematically and integrated within an engineering education curriculum. Since 2005, ABET Criterion 3 requirements have changed from being called professional skill to student outcomes and its requirement for communication has expanded to include the multiple people and groups that an engineer engages with in the workplace. The new requirement is, 'an ability to communicate effectively with a range of audiences' [9, pp. 14]. Additionally, the National Association of Colleges and Employers (NACE) positions all forms of verbal and non-verbal communication as the bridge that connects workers to both technical and non-technical members of their organization, including internal and external organizational stakeholders [10]. Good communication is further described as the ability to ask appropriate questions and employ active listening [10].

4 Methods

As previously stated, this study is the result of a workforce needs assessment that was conducted as part of a larger workforce development project from 2021 to 2022. The goal of the larger project was to assess the needs of the microelectronics defense industrial base (DIB) workforce to better understand the knowledge, skills, and abilities that employers require when hiring students as interns and professionals in the field of microelectronics.

Participants for this study were either workforce development project internship partners or were selected based on their experience hiring professionals into the field of microelectronics engineering. The six participants in this study were selected due to their work experience within the DIB sector. This factor limited who was chosen to participate in this study and the number of participants interviewed for this study. All of the participants had experience working in the DIB sector in areas that work with microelectronics engineering and they were involved in the hiring of entry-level employees and interns. Each participant represented a different area of the microelectronics engineering development process and was able to inform the larger study regarding different technical and professional skill needs. Table 1 documents the pseudonyms and the areas in which the participants had experience. Participants were from a variety of sectors within the DIB, including government agencies, a government contractor, private industry (i.e., aerospace and engineering technology solutions), and government laboratories for research and development.

Table I
Study Participant Demographics

Participant	Name	Job Sector
1	Dale	Government Agency
2	Melissa	Government Agency
3	Marcel	Government Contractor
4	David	Government Research Laboratory
5	John	Private Industry - Aerospace
6	Dominic	Private Industry – Engineering Technology Solutions

A total of five semi-structured, qualitative interviews were conducted using an open-ended interview protocol. One of the five interviews involved two participants. These interviews served as the main data collection method [11]. Each of the interviews lasted about one hour, and was conducted over ZOOM, in person, or via telephone. Interviews were audio recorded and subsequently transcribed verbatim.

To analyze data, the initial two interviews were reviewed by a member of the research team. Memos documenting the topics discussed throughout the interviews served as the baseline for creating initial themes. The memoing process uncovered participants' perspectives about professional skills and how those skills are intertwined with technical skills. After all interviews were conducted, the team used thematic analysis to read through and analyze all of the interview transcripts [12]. The team then coded the transcripts and identified the technical and professional skills needed to be career-ready interns and employees in microelectronics engineering. In this round of coding, the codes selected were not limited to those identified in the theoretical framework that served as a lens for the larger study. In this way, gaps in alignment between the data and the four original theoretical frameworks were identified. Once this review was complete, the team came together to compare codes and discuss possible resulting themes. The team came to consensus on a list of the final themes that capture the skills reflected in the codes. These themes were then further defined to ensure the team explored the same concepts. With the themes identified and defined, an Excel spreadsheet was utilized to organize coded sections of the transcripts. Multiple themes were assigned to data when more than one could be identified within a specific transcript section.

5 Results

Results from the larger study included themes for seven professional skills. The seven professional skills included: applied learning experiences, communication, leadership, lifelong learning, resiliency, system-thinking, and teamwork. These themes were discussed as critical skills by all of the participants. Of these seven themes identified by the larger study, this paper will only focus on the one essential theme of communication because, in our analysis for the larger study, communication best demonstrated a dependent relationship between professional and technical skills.

Communication was identified by government and industry participants as a professional skill that is critical for individuals to possess as they enter the microelectronics workforce. Effective communication among individuals and within interdisciplinary teams is necessary as it allows technical information to be quickly "distilled" and understood by management and other non-technical stakeholders. However, participants shared that individuals often lack communication as an awareness skill. For example, individuals need more sufficient oral and written communication skills that allow them to quickly and succinctly articulate the "so what" to non-technical stakeholders.

5.1 Communication: The Gateway to Understanding and Knowledge

Participants in this study were asked (1) What value do HR professionals and supervisors in microelectronics engineering place on communication when hiring entry-level microelectronics technicians and engineers? When answering this question, all of the participants emphasized the need for students to be able to articulate their problem-solving processes both orally and verbally. Examples are provided herein.

Participants also described how important clear and effective communication is when working with interdisciplinary and non-technical team members. John stated the following when discussing his role as a software engineer, "...if you are capable of being a good communicator, you are head and shoulders above the competition." He went on to say that, "the ability to speak, to distill technical information…well, I wouldn't say necessarily to a non-technical person, but to somebody with a different technical background, is really important." John further explained that an individual may need to talk to someone in a different technical area "about why their request to do something isn't a good idea, even though it seems like a good idea to them." John discussed the importance of knowing how to adjust communication strategies for a specific audience or context, and being adept at distilling information both up and down, across various levels of management, or in parallel with other team members. In this way, John describes communication as both a process and awareness skill.

Dale also talked about the importance of communication from entry-level employees up to the highest stakeholder. In his words, "I think everybody pretty much needed to work on the communication part. You know, how clearly and concisely they can deliver." Dale discussed the importance of practicing how to deliver information (i.e., process skill), taking into account other people's tone and wording (i.e., awareness skill) in the conversation. For microelectronics engineers, Dale stated that knowing how to effectively use communication skills is critical for success.

Participants were also asked (2) How do microelectronics industry professionals describe desired communication skills? Multiple participants mentioned the value of being able to communicate the "big picture" to different audiences. Melissa discussed communication as an essential skill that can be further developed by students through networking at professional conferences. Melissa stated the following in her own words:

> Good communication skills are super, super important. We have to be able to take very complex [technical] problems, whether it's microelectronics or packaging, and we have to be able to communicate to our leadership why it matters. Our leadership doesn't always care what the engineering is or what the physics is. They care [about] what does it mean to my system? Is my system going to work or not work? Is it going to cost me a lot of money to fix it? And so, having good communication skills to be able to translate a hard problem into the "so what." Being able to talk in a big group and present and answer questions on the spot...those are really, really key skills to have, and they're not always easy skills to get. But that would be a big focus. If we can get students to go to more conferences, and start talking to folks when they're undergraduates or graduates at conferences, that's a big help.

Melissa summarized communication as being able to talk effectively to multiple audiences about complex technical problems, and knowing how to get to the "so what" of a problem or issue. David also discussed the importance of communication and being able to articulate information. He was also the only participant to acknowledge that students are getting this type of training within their education, but he also pointed out that it is still an area that most graduates need to work on. In his words, David stated:

> You know, being able to translate what you've done into, you know, something that someone else can take and digest and then being able to, you know, interact verbally. That's, that's, probably the biggest thing I see…I don't know, some recent grads, they they're so used to communicating, uh, you know, nonverbally through text or email and they have difficulty engaging verbally sometimes … Which is weird because I know they get plenty of practice with it at school. I mean, I know that's like a big thing.

In this way, participants in this study viewed communication as a process and an awareness skill. Specifically, engineers must be able to speak about technical issues (i.e., process skill) to a variety of audiences across workplaces and cultures (i.e., awareness skill).

6 Discussion

Microelectronics engineering industry professionals have established that communication is a critical professional skill and that it is inseparable from technical skills in making an individual an effective intern or professional employee. Participants in this study placed high value on engineers being able to distill and communicate the "so what" when communicating with non-technical stakeholders. Examining Riemer's range of communication skills [5] was helpful when gauging the value and description of communication as indicated by professionals in the microelectronics industry. Specifically, the emphasis on communication by those who hire and supervise microelectronics engineers means that workforce development efforts should also reflect the importance of learning and practicing communication skills throughout students' educational journey. Looking at communication as a process skill, for which students should be given a foundational process through their education, requires it to be incorporated holistically into the engineering curriculum [3]. Several important points are discussed below.

For students to be able to learn the process of communicating in multiple, real-world engineering contexts, communication needs to be intentionally and explicitly emphasized as an awareness skill that is fully assessed within engineering curriculum. Many engineering students in Bachelor's degree programs have perhaps one class where communication is a central focus. Providing communication experiences that follow real-world employment contexts is important. Riemer notes that integration of communication elements across engineering curriculum would not only reinforce these skills but help increase the value students place on their own communication development [5]. While this might require a reworking of existing engineering curriculum to focus on both oral and written communication within technical classes it is a worthwhile endeavor that is necessary to develop career-ready engineering students. Including both communication and engineering faculty in course design, development, facilitation, and subsequent student assessment, would leverage the diverse faculty base within universities of higher education while modeling the interdisciplinary interactions that are encouraged for faculty and students alike.

Additionally, because communication skills are something that evolve over time and become better with practice, giving students the opportunity to improve and progress in their communication abilities over the course of their educational journey will ensure that more students have a strong communication competency level and can also apply their knowledge in real-world contexts. However, as discussed by Donnell and colleagues, simulating a wide variety of real-world, professional contexts in a university setting is anything but straightforward [7]. Therefore, the communication skills needed to succeed in the microelectronics industry require multiple touch points of teaching and practice, including development through experiences with co-curricular and extra-curricular activities, including conferences and internships. This means that students also need to receive support and encouragement in seeking out internships and other extra-curricular enrichment activities that place a strong focus on mentoring and allow for further practice of communication skills. Student engagement in these opportunities is critical for creating robust ways for students to gain additional communication competence.

Finally, communication opportunities both inside and outside of the classroom should connect with the necessary technical skills. Students should be developed to effectively communicate with both content experts and non-technical organizational stakeholders. For example, while they graduate with shared engineering backgrounds, microelectronics engineering professionals end up specializing in independent areas of work [4]. Participants in this study touched on this as an important distinction when discussing the need for entry-level engineers to be proficient in communicating the "big picture" importance of their work to a variety of audiences. How the students communicate with their teammates, colleagues, stakeholders and members of the public are all opportunities to further develop communication as a process skill. Effective communication "up and down" ensures that all levels of stakeholders are able to understand and contribute to engineering-related processes, in turn assisting engineers at being effective at their jobs and maximizing benefits to society.

7 Implications, Limitations, and Future Work

Understanding the needs within the microelectronics engineering industry is critical for the process of developing a career-ready workforce. This study obtained input from a variety of industry stakeholders, as part of a workforce development program, to understand what technical and professional skills students must develop to enable them to work effectively in microelectronics engineering roles. As a result, this study provides empirical evidence that communication is a professional skill that is highly desired by employers within the engineering field. Yet gaps still persist between the industry-desired skill and development of students' communication competence needed for internships and entry-level engineering positions. The current gap in students' communication skills comes from a misalignment between industry needs, academic development, and extra-curricular experiences.

To effectively develop career-ready students in microelectronics engineering, the engineering discipline as a whole must reimagine how students develop communication competency through their education. This research recommends best practices, including the reimaging of course curricula to intentionally scaffold the learning and practicing of communication as a professional skill into coursework and other co-curricular and extra-curricular experiences. Communication skills must be holistically learned and practiced as part of student preparation, and not solely as a one-time course requirement to be completed because it is part of the student's plan of study. Specifically, students engaged in learning oral and written communication skills must do so within engineering contexts (i.e., problems, challenges, and research opportunities). By engaging communication within engineering contexts, students will learn about their own communication strengths and weaknesses using contexts that are salient to their engineering learning and further develop the necessary communication skills before entering the workforce.

Given this, undergraduate engineering educators, including professors, mentors, and advisors, must place a strong emphasis on the development of effective oral and written communication pedagogy across engineering courses. This will enable students to learn and practice effective communication skills by understanding and applying communication theory to contexts that are relevant to real-world engineering experiences. Communication should enhance what is learned in engineering courses, not replace engineering content. However, we argue that a solid theoretical foundation is needed to teach students *effective* communication skills.

Industry partners also have a role to play in developing students' communication skills by providing students with internships, extra-curricular, and mentoring opportunities that focus on developing communication as a professional skill. This engagement will help students understand what is expected of them from future employers in a real-world, non-academic, professional engineering setting. By intentionally providing students with experiences that allow them to apply the communication skills that they have developed through their education, industry partners will help students further develop and improve their communication skills within real-world contexts.

Participants in this study articulated that developing engineers is an issue across multiple sectors when hiring interns and professionals. Preparing workers to meet the challenges within a quickly evolving engineering industry requires an alignment between industry and engineering educators in developing students with the necessary professional and technical skills. This study provided important suggestions for developing students who are career-ready through communication competence.

Several limitations should be acknowledged. First, this paper is presented as a Work in Progress that focused on one professional skill—communication. However, the results of this study are part of findings from a larger study that identified multiple professional and technical skills necessary for the full development of students as interns and entry-level professionals in microelectronics engineering. All professional and technical skills must be considered fully and simultaneously in order to develop a career-ready microelectronics engineering student. Second, the population sampled was from a very select set of hard-to-access microelectronics engineering professionals within the U.S. defense industrial base. This served as only one data touchpoint for this microelectronics engineering workforce development program.

Future work might consider including a larger sample size across multiple engineering disciplines and would also include the input of microelectronics engineering students themselves. Future Engineering Education research should also consider studying how communication development of engineering students is currently being done in universities. This work should explore the types of communication courses that engineering students are exposed to (e.g., technical communication, presentational speaking) both within and outside of engineering disciplines and whether coordination of those courses include engineering themes or contexts. Future work should examine how effective communication skills may complement engineering curriculum more fully.

8 Conclusion

This paper focused on the importance of communication as a professional skill in student development for microelectronics engineering workforce development. Definitions found in existing scholarship were used to frame this skill within an engineering education context. The findings from this study provided detailed examples of how microelectronics professionals describe and value communication skills and highlighted areas that they recommended for microelectronics engineering student development. Further, the insights provided by the DIB employers who participated in this study were important as they framed student development of communication skills as being critical to the overarching workforce development program. Implications for changes in the engineering curriculum and related collaboration between higher education and industry partners are suggested. Finally, this study indicates that the specialized role that workforce development efforts serve as a connection between academia and industry can help create a united effort in increasing career-ready microelectronics engineers.

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