From Freshman Engineering Students to Practicing Professionals: Changes in Beliefs about Important Skills over Time

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Abstract

Although there has been a strong focus on adapting curricula to better prepare engineering students for the challenges of the future, few research studies have followed students though their undergraduate experiences and beyond to understand students' preparedness for professional work. This study explored what skills engineering students and graduates believe are important for their careers and how these beliefs change over time. This research is broadly situated in social cognitive career theory and draws from the NSF-funded Academic Pathways Study (APS) data. As part of APS, a group of engineering students were interviewed and surveyed during each of their undergraduate years. Approximately four years after graduation, a subset of APS participants were contacted to examine their perceptions of skills and abilities in math, science, business, communication, teamwork, and the application of math and science. Business skills were perceived as being of lower importance overall and as having the largest spread of data over time. Math and science skills were perceived of as being particularly important in students' first year. Over time, communication skills generally increased in importance while teamwork skills decreased. Understanding how students' perspectives of important skills change as alumni can inform how we prepare engineering students for future success.

Introduction

Over the past decade, a central conversation within the engineering education community has focused on preparing engineers for the technological and global challenges of the future. Such conversations often consider the skills that engineers will need and how we can best help students develop such skills. For example, ABET shifted to skills-based assessment of engineering programs [1]. Additionally, the National Academies proposed a list of the desired attributes of "The Engineer of 2020" followed by suggestions on how to educate the engineer of 2020 [2, 3]. As engineering education researchers have developed assessment tools and techniques to evaluate development of needed skills among students and ways that they are used by professionals [4, 5], few studies have been able to follow the same students though their undergraduate studies and beyond to track the development of skills for professional practice. Therefore, the purpose of our research was to explore what skills engineering students and recent graduates believe are important for their careers and how these beliefs change over time.

To accomplish our goal, we draw on qualitative and quantitative data from both the Academic Pathways Study (APS) and the Engineering Pathways Study (EPS). Using a case study

approach, we use interviews and surveys to follow a total of 13 participants from 2 different undergraduate engineering schools to illuminate beliefs about important skills.

Framework and Situation in Current Literature

Overall our research project is broadly situated in social cognitive career theory (SCCT) [6]. This theory suggests that a variety of factors contribute to career choices. Of particularly importance in the SCCT model is the role of self-efficacy beliefs. In accordance with SCCT, self-efficacy beliefs are an individual's beliefs with regard to their capability to succeed in a particular career [6], in this case engineering. People with positive self-efficacy beliefs regarding engineering are more likely to pursue a career in engineering. However, before we can begin to understand engineering self-efficacy beliefs as they relate to career choice, we must understand what it means to be an engineer what types of things people must believe they are capable of to want to pursue a degree in this field. ABET [1] and *The Engineer of 2020* [7] are two sources of criteria for skills necessary to be successful engineers. However, given the variety in engineering career activities, not all skills may be perceived equally across all contexts and it may not be equally important to participants to be good at all of the skills identified. Therefore, in this work we focus on understanding *what* skills participants, first as students then later as practicing professionals, believe are important. This will lay the foundation for future work to understand how self-efficacy with regard to these skills develops and changes over time.

Studies regarding the preparation of engineering students for professional practice have typically focused on developing competency around skills that educators and employers think are important (e.g., [8-10]). When studies have examined the student perspective on skills needed for success in engineering findings demonstrate that students make a distinction between learning in school and a future real-world of professional practice [11] even seeing school experiences as unrelated to engineering work [12]. Moreover, even though students can list skills, such as communication and teamwork as important, they do not necessarily understand how these skills will be used beyond the classroom and in engineering practice [12, 13]. Other studies have taken a reflective perspective by asking practicing engineers about how they became prepared for engineering work. Findings suggest that some preparation, and particularly with regard to non-technical skills (e.g., interpersonal skills), happens after graduation while on the job [14-16].

Through this analysis, we seek to bridge existing knowledge by following participants through their undergraduate years and on into professional practice. As students, participants were asked about the skills they thought would be important to their future work. Several years after graduation participants were asked to reflect back on their academic preparation and the skills that are important in their current work. We build on a prior analysis by Brunhaver et al. [17] that used interview data in a longitudinal examination of students first as juniors and then again five years later as practicing engineers. Brunhaver et al. found a distinction between the ways in which technical skills and professional skills are developed and used. They also found that participants talked about skills differently over time with working engineers ascribing different

details or meanings to skill categories such as communication and interpersonal skills. In this paper, we seek to extend the timeframe and examine the earlier college years through early professional practice for some of the same participants. Therefore, we draw on a sample that reflects freshman year in college through four years into professional practice. In this paper, we are less concerned about identifying the skills that are important, as a number of researchers have examined this perspective[4, 13, 18-22]. Rather, we are more interested in examining a few core skills to see how they change in students' perceptions of importance over time from freshman year to professional practice. We believe such an approach can help educators think about appropriate ways and times to help students learn critical skills as undergraduates.

Methods

Our data are both qualitative and quantitative. In surveys, participants were asked to select important skills from a list as well as rate the importance of individual skills. In interviews, participants were asked to explain and describe their educational and professional experiences using skills they believed are important. Reflecting these sources, we relied on quantitative data to highlight trends and qualitative data to explain the lived experiences. We used case study methods [23] to follow individual participants' experiences over time.

Data Collection

Data for this analysis were drawn from both the Academic Pathways Study (APS) and the Engineering Pathways Study (EPS). APS and EPS have been described in greater detail in a variety of sources[13, 22, 24-26], so we focus on providing a brief overview then the details needed to offer context for our analysis.

As part of APS, a group of undergraduate engineering students were interviewed once and surveyed twice each year for the first three years of their undergraduate studies. They were also surveyed once in their senior year, and some participants completed senior interviews. Approximately four years after the participants completed their undergraduate studies, EPS followed up with a subset of APS participants. EPS consisted of a detailed questionnaire and interview, with findings informing the development of the Pathways of Engineering Alumni Research Survey (PEARS) instrument for broader administration. From two of the participating institutions, there were a total of 13 people that completed the APS interviews, APS surveys, EPS questionnaire and/or interview, and PEARS. These 13 participants are the focus of our current research because the multitude of data available for each participant provides a unique perspective on how beliefs about important skills develop and change over the eight-year study.

Participants

Participants were initially recruited as freshmen intending to major in engineering from one of two schools in the United States, a suburban private institution (SPri) on the west coast and a technical public institution (TPub) in the Rocky Mountain region. All participants were traditional-aged college freshmen when the study began and all graduated in four years.

Demographic data is provided here in aggregate in order to protect the privacy of our participants. Our thirteen participants included:

- Eight TPub graduates and four SPri graduates
- Six women and seven men
- Four majored in chemical engineering, four majored in petroleum engineering, two majored in mechanical engineering, and one each majored in engineering physics, management science and engineering, and metallurgical and materials engineering.
- During the EPS, 10 were working in engineering jobs, one of those 10 was pursuing an engineering graduate degree in the evenings, one was a full-time graduate student in engineering, one was working in a non-engineering job, and one was a full-time graduate student in a non-engineering field.
- All were US citizens; two were naturalized immigrants.
- Ten reported their ethnicities as White/Caucasian, one as Asian/Asian American, and two as multiple ethnicities.

Data Analysis

Although our data were collected sequentially, we mixed our data during the analysis phase [27] since that makes the most sense for the integrated longitudinal analysis we are working to create. We started with the quantitative survey data collected using the Persistence in Engineering (PIE) survey [22] and tracked participants' responses over time. From PIE we focused on the questions that asked students about the importance of various skills. The prompt asked:

> How important do you think each of the following skills and abilities is to becoming a successful engineer?

Students were then provided with a list of various skills. Answer choices ranged from "not important" to "crucial" or "extremely important" (exact wording depended on survey administration), and were assigned point values where 0 equals "not important"; 1 equals "somewhat important" or "slightly important"; 2 equals "important" or "moderately important";

3 equals "very important"; and 4 equals "crucial" or "extremely important". In some survey administrations the neutral value was omitted while the other options remained the same; these were still scored as shown above.

Participants were asked a similar question about skills in PEARS. Specifically, the question asked:

> In your current employed position (or most recent position if not currently employed), how important is each of the following in your work?

Students were again given a list of skills to rate, this time on a five-point scale from "not important" to "extremely important", and were scored as shown above. We focused on the skills that most aligned with the skills asked about longitudinally across undergraduate years through the PIE surveys.

We turned to the interviews to understand how the students talked about these skills when given the space to use their own words rather than lists on a survey. Specifically, we used the interviews to help us make sense of the trends we observed through the surveys. Interviews conducted as part of APS and EPS asked similar questions. As students most participants had little to no work experience. Therefore, the APS interviews (structured and semi-structured) asked about the skills needed to be successful in engineering, and students expressed their opinions primarily based on classroom experiences, professors' opinions, or internship experiences. Having graduated with engineering degrees, the EPS interviews asked participants what skills are important in the work that they are doing now.

Results and Discussion

We focused on the six skills for which we had the most complete set of survey data across APS and EPS surveys. These six skills included: math ability, science ability, ability to apply math and science, business skills/knowledge, communication skills and teamwork skills. After presenting and discussing the data for individual skills, we examined trends across skills.

Math Ability

Across APS and EPS datasets, the average ratings for math show high perceived importance in the first year of undergraduate schooling, then falling in the sophomore year before leveling out at above average importance, then falling again after graduation (Figure 1). We also looked at individual trends in scores. Consistent with the averages, participants tended to rate math ability as more important in the first year. In subsequent surveys, participants individually tended to alternate between high and moderately high scores. However, in the individual scores from PEARS, we see that the average represents a much broader spread in data with scores ranging from 0 to 4 which are the extreme allowable choices.
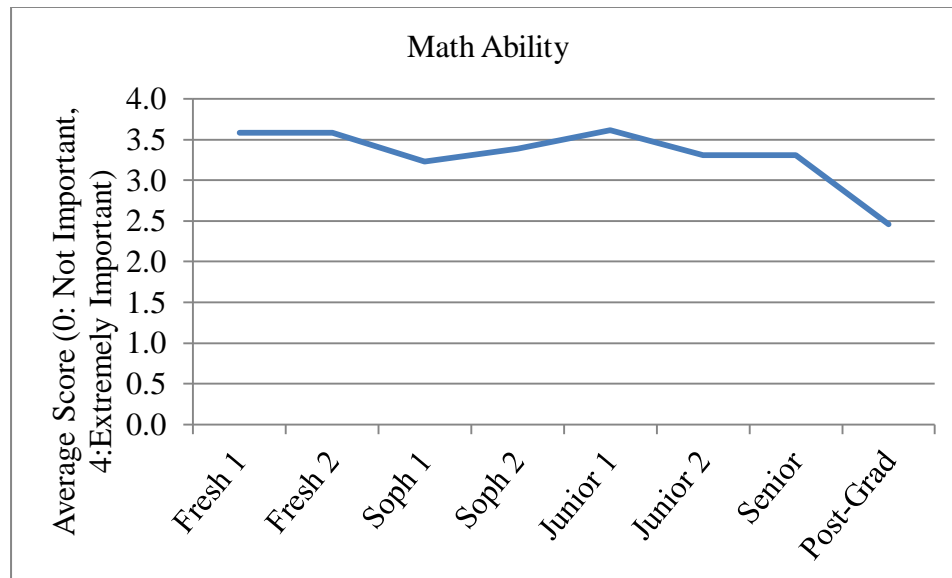
Figure 1. Average Math Ability Importance Scores

To understand these trends, we turn to the interviews for explanations. Freshmen, when asked by the interviewer about what skills were important for engineers, commonly listed math as the very first skill. Typical responses included:

> "Math, diligence, attention span, high attention span, ability to solve a problem in many ways, work in groups" [Lisa, TPub, Freshman]

> "I guess good mathematics and science skills. I guess depending what type of engineer you are - being able to design and build things" [Vince, SPri, Freshman]

These answers changed over time, however. Students shifted first to an emphasis on problem solving using math and science, and finally dropped the math and science part of the skill in favor of skills such as communication, motivation, and teamwork in PEARS.

Josh explained this deemphasizing of math skills in the workplace. While much of his undergraduate coursework had been very mathematically based, he found his math skills to be less important in the workplace. Instead, pre-programmed spreadsheets and software dealt with the majority of the calculations required:

> "When I was going through school we did problem after problem of calculations, and so I thought my engineering role would be a little bit more desk oriented, where ... there'd be a lot more calculations that would be going on, and the way we have it here, is there's already been everything, mathematical templates set up on the Excel computer software, so there's a lot less of hand work than I expected. People have laid the groundwork in the past to help us do our jobs quickly and efficiently with error checks and that type of thing

so, ... It's a little bit less rigorous, less mathematical than I had anticipated." [Josh, TPub, EPS]

Examining the math ability trend as a whole, it is not surprising that students in their first year mention math as being an important skills. Many students report choosing engineering because they are good in math [28] Students also tend to take many math courses in their first year which may confirm the need for math skills. Completion of math courses and moving to engineering courses may contribute to a lesser importance rating on math scores. Although these courses may rely on math, students may not see them as using math skills per se. Similarly, engineering professionals like Josh rely less on pure mathematics and more on standardized methods and software.

Science Ability

The average ratings for science ability across APS surveys suggest science is perceived as highly important in the first and third years of undergraduate schooling, falling slightly during the sophomore year, and reaching a minimum senior year before rising somewhat in the post-graduation data. Looking at changes in individual scores affirms this overall trend with no noticeable differences in response spread. Similar to the math ratings, it is not surprising that students in their first year mention science as an important skill, since students also report choosing engineering because they are good in science [28]. Again similar to math, however, they tend to take fewer science courses after the first year.
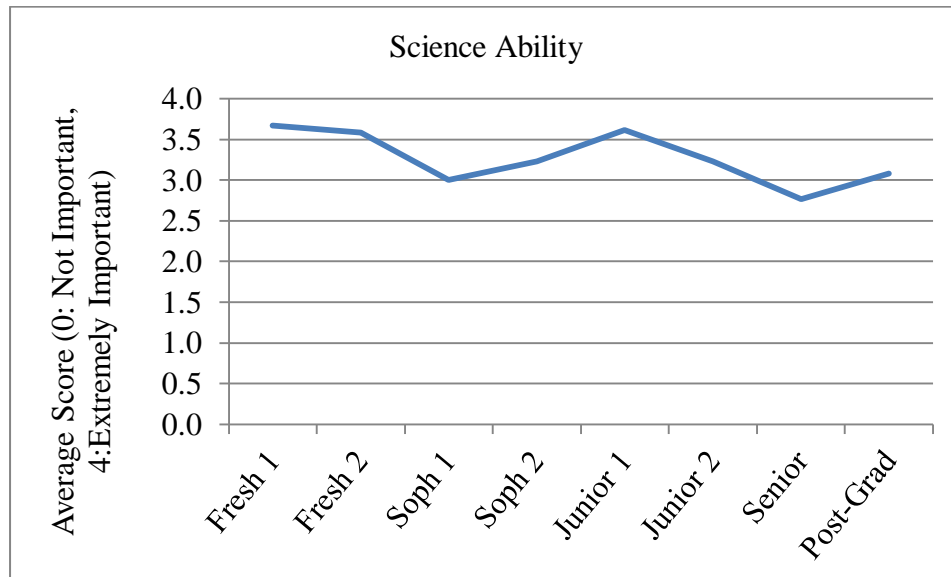

Figure 2. Average Science Ability Importance Scores

Throughout the early interviews math and science are coupled together, nearly as a single "math-and-science" skill. Almost every mention of science ability or skill is tied together as "math-and-science". They do begin to separate towards the end of undergraduate studies, as John described in his interview:

> "Math for me is more concrete. In science I can see where there are different ways to do things a lot. And so sometimes you need to think of all those ways to do something." [John, TPub, Junior]

Upperclassmen also began to differentiate science as deep or theoretical applications.

Turning to data from graduates, we see a continued emphasis on science as theoretical and engineering as applied. Joe described his work as "a science R&D position" in contrast to a "general plant metallurgist position or something more in a production environment" [Joe, TPub, EPS], which would coincide with more traditional engineering. Another participant, Marie, was pursuing a PhD in applied science and conducted high-tech, rigorous scientific research in her daily work. These participants, and others similarly employed in science-heavy fields explain why scientific skills are seen as so important among engineering graduates.

Unlike math ability, the importance of science ability remains stable after graduation. This may be a result of our sample; recall that many of our participants were employed in fields related to chemical engineering which tend to be more interdisciplinary specifically with regard to science.

Ability to Apply Math and Science

Unfortunately, the APS surveys did not ask about the importance of applying math and science to problem-solving in the freshman year when scores for math and science individually were both high. We anticipate that there would have been a high score for applying math and science as well. However, from the data we do have, we see little change over time. Looking at trends in individual scores affirms this overall trend with no particularly surprising individual patterns or spreads in data.
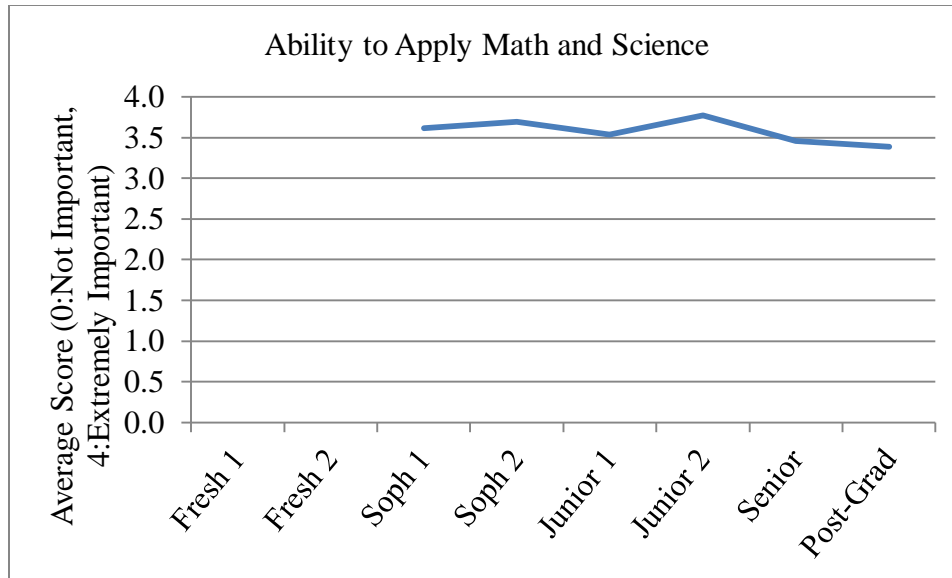
Figure 3. Average Ability to Apply Math and Science Importance Scores

As mentioned previously, undergraduates developed from simply saying math and science were important to discussing applications and problem solving with math and science. Vince's junior response when asked about important skills for engineers was typical:

> "I would say that an engineer needs to be able to think critically, [use] his knowledge of science and mathematics and also the ability to analyze tradeoffs and decide among the tradeoffs." [Vince, SPri, Junior]

Possible slight increases from sophomore to junior year can also be explained by the curricula at TPub and SPri, where students move towards more open problem solving and away from foundational math and science courses as they progress.

Once in the workplace, problem solving through math and science continues to be the defining factor of engineering. Participants describe engineering jobs as:

> "I'd say an engineering job is where you have to use math, science and problem solving to solve problems." [Joe, TPub, EPS]

> "A job that is dominated by complex problem solving" [Max, TPub, EPS]

With these definitions of engineering jobs, and given that 10 of our 13 participants say that they have engineering jobs, it is not surprising that the ability to apply math and science is an important skill.

Business Ability

Compared to the importance of other skills, there is greater spread in the individual scores for business ability for all data collection points and the overall average scores are lower (Figure 4). Notably, for four of the seven surveys at least one respondent reported business ability as being not at all important while others reported business ability as crucial. To illustrate this, we have included Table 1 which includes individual scores over time. The important patterns to notice are the number of times scores bottom-out or top-out across the whole group of participants and the large swings in scores for individual participants.
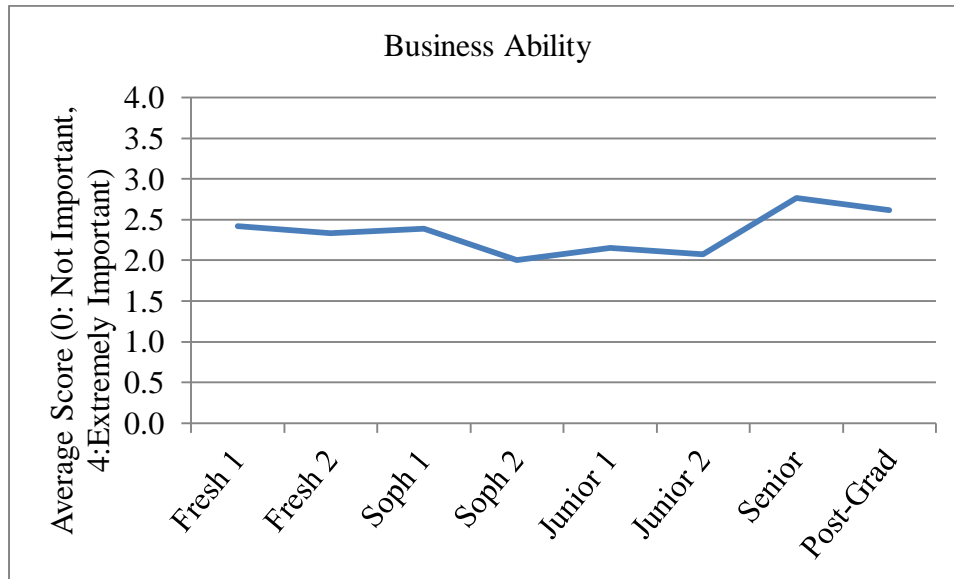

Figure 4. Average Business Ability Importance Scores

Table 1. Individual business ability scores over time.

	Freshman 1	Freshman 2	Sophomore 1	Sophomore 2	Junior 1	Junior 2	Senior	Post-Grad
Dana	3.0	3.0	3.0	1.0	1.0	3.0	3.0	3.0
Graham	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0
Hillary	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
Joe	1.0	2.0	1.0	1.0	1.0	1.0	3.0	2.0
John	no data	no data	4.0	3.0	4.0	4.0	4.0	3.0
Josh	3.0	2.0	3.0	3.0	1.0	1.0	3.0	3.0
Leah	0.0	2.0	1.0	1.0	1.0	1.0	3.0	4.0
Lisa	2.0	1.0	3.0	3.0	1.0	0.0	3.0	0.0
Marie	2.0	1.0	1.0	1.0	1.0	1.0	3.0	0.0
Max	2.0	4.0	1.0	1.0	4.0	4.0	3.0	4.0
Nate	3.0	4.0	3.0	1.0	3.0	1.0	1.0	2.0
Paige	3.0	2.0	3.0	3.0	3.0	3.0	3.0	4.0
Vince	3.0	1.0	1.0	1.0	1.0	1.0	0.0	3.0
Average	2.42	2.33	2.38	2.00	2.15	2.08	2.77	2.62

Considering that it may be that this category is more open to interpretation, i.e., business ability may not mean the same thing to each student, we turn to the interviews for explanations We find that as students, participants may not know what business skills are or what it means to know them. For example, in her senior year Paige talks broadly about business skills, how she will learn them and how she will transfer them:

> "What I want to do is go to the corporate world first, to get experience, I think that's really valuable experience to get from a big company, how they run their business ... And then after that I would like to go into like a non-profit organization and take the ideas, what I've learned from the big company, be able to scale it down and hopefully make whatever systems they're using there more efficient" [Paige, SPri, Senior]

She saw that business ability was important in order to be successful in her engineering pursuits but a detailed understanding of what business ability means is not present in her answer. For Leah, her view of the importance of business skills changed only after she entered the workforce:

> "It's so much more involved than just doing engineering work, I'm doing business with, I'm working alongside a lot of our different departments and it's not just engineering work that I'm doing, it's quite versatile" [Leah, TPub, EPS]

Max also saw the necessity of business skills in managing multiple departments:

> "The geologists don't exactly understand the drilling engineers' needs and limitations, and the drilling guys don't necessarily understand the completion guys, and there's gotta

be somebody in there who knows enough about all of it to, you can't make just one department the most efficient. If one department is at maximum efficiency it is making other departments less efficient. So you have to make all departments somewhat less efficient or less than maximum efficient to make the whole machine maximum efficient." [Max, TPub, EPS].

For Max, ensuring maximum efficiency of the entire production required balancing the performances of the parts. At the other end of the spectrum, two engineering graduates reported that business skills were not important. Both of these participants were full-time students, and therefore responded that their current position did not involve business skills.

Max is able to talk in the most concrete way about what he means by "business skills". Note that both Max's and Leah's answers differ from Paige's conception. Max and Leah are talking about the interdisciplinary work needed to be successful at work whereas Paige is talking about making the systems that run a business more efficient. Both conceptions of business skills make sense. It is the variety in conceptions that helps us understand how scores on this item could vary by person and by time; responses could easily depend on how participants are defining business skills at a given time. Changing definitions relative to engineering work are consistent with findings from a similar sample that suggest that over undergraduate years, students become better able to articulate what it means to be successful as an engineer (including the skills that are needed) [29] and that students may reconceptualize success to match the skills that they believe they have [30].

Communication Skills

On average, and relative to other skills, communication skills are perceived as having the lowest importance in the first year of undergraduate schooling, rising to between "very" and "extremely" high importance over the remaining undergraduate years and into post-graduation years.   Note this item specified "written communication" for freshman, but that qualifier was later dropped. All of the undergraduate surveys had a separate item for public speaking, which was not included in PEARS.

Looking at trends in individual scores, we see more variation in ratings during the first year covering the spectrum from 0 to 4. However, in the PEARS survey, all respondents rated communication skills as "very important" or "extremely important". Moreover, these ratings stay the same or increase from senior year PIE results.
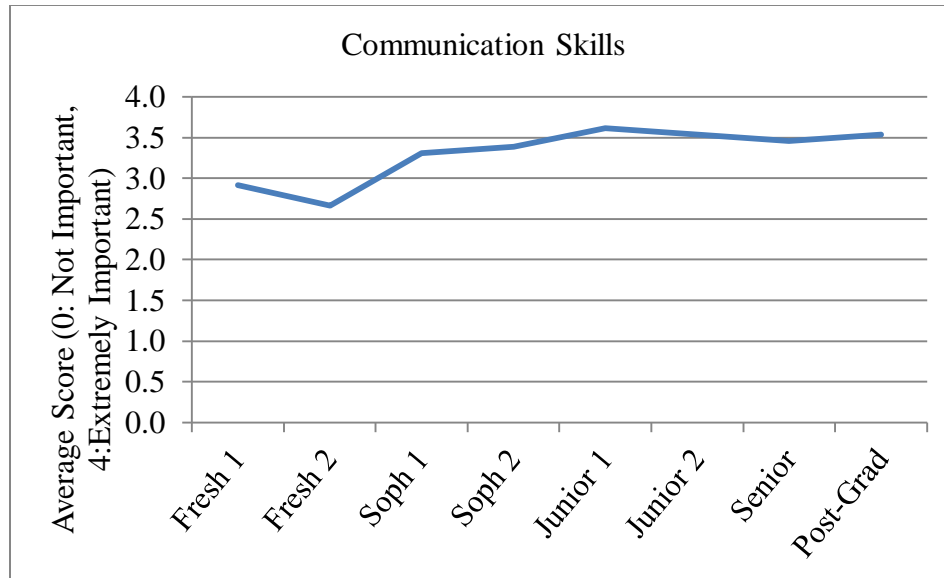
Figure 5. Average Communication Skills Importance Scores

Hand in hand with the heavy math and science load in the first year, freshman may not see how communication fits with being an engineer. With the strong ABET push for communication skills and after completing some introductory engineering courses, however, sophomores seem to know that they need to at least list these skills.

Graham, as a sophomore, added communication skills at the end of his list of important skills for engineers:

> "You also need to have good communication skills, writing skills and speaking skills, that sort of thing" [Graham, TPub, Sophomore]

Josh elaborated, as he had learned that different groups needed to work together:

> "Communication is really important to people you're working with, to the geologists around because geologists know different things about the reservoir than you know, they do different things with it." [Josh, TPub, Sophomore]

As Graham and Josh demonstrate, as they learned more about their discipline, their perceptions of the importance of communication skills are increased from what they had originally thought as freshmen.

Unsurprisingly, practicing engineers also emphasized the importance of communication. When asked in a pre-questionnaire before their EPS interviews to list the five most important skills for engineers, communication was the most popular selected choice. Leah explained why engineers need communication skills:

"I think one of the things that's really lacking with the people I've been exposed to is, as smart as they are, is the ability to communicate which just seems so key when you're in such a big organization with people with so many different focuses and backgrounds. So I think that perfecting those skills is a good idea for everybody." [Leah, TPub, EPS]

Leah's sentiments were echoed by other engineering graduates that also emphasized the need to have effective communication skills across differing backgrounds.

Teamwork Skills

Unfortunately, the APS surveys did not ask about the importance of teamwork skills in the first year of undergraduate schooling. However, from the data we have we can see a slight peak in the junior year followed by a surprising decline in PEARS data. Looking at the details by participant, the PEARS data (post-graduation) also show an increase in spread, with three of the 13 participants reported teamwork to be not at all important while three report teamwork to be extremely important.
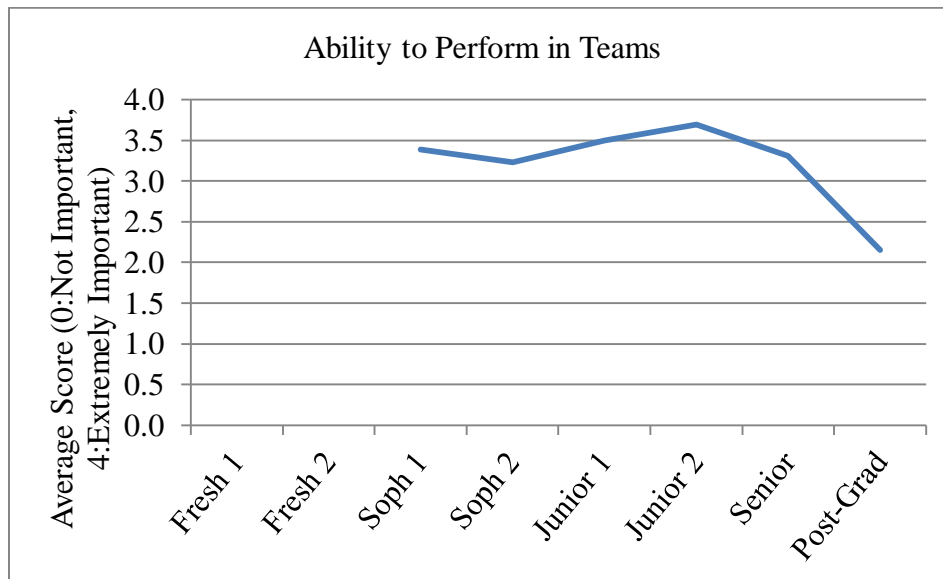

Figure 6. Average Ability to Perform in Teams Importance Scores

While freshmen survey data on teamwork were not available, teamwork was addressed in the freshman year interviews. The engineering curriculum at TPub included freshman team projects, which were both frustrating and helpful for our participants. Hillary described her experiences learning to work with a group:

"I think that I don't always have a lot of patience for other people and I think that'd be really important to have because you're working with other people, you can't do it alone, and like I said before I'm very organized and linear and obsessive and I want it done

now, when I say I want it done! And, I have trouble working in teams sometimes because I want it done right and I know sometimes the only way to get it done right is to do it yourself sometimes, and so that I think would be frustrating in part about working in an engineering team is that I can't always have control over everything." [Hillary, TPub, Freshman]

Hillary has realized that teamwork is necessary, but that relinquishing control is challenging. Other interviews expressed similar sentiments about the scope of engineering work requiring teams as well as general appreciation for teamwork in engineering:

"I think it's important to be able to work in teams. … Usually problems are bigger [than] just one person [can] solve." [Paige, SPri, Sophomore]

By sophomore year, Paige had already learned that the scope of problems in engineering required teamwork in order to adequately address them.

The precipitous drop in the importance of teamwork among graduates was surprising. Paige, one of the three participants that report teamwork as "not important" in her work, told the interviewer:

"One of the skills you need for this job is program management, just knowing how to plan out, how to get a team going" [Paige, SPri, EPS]

This seems to contradict her survey response. Similarly, Nate said teamwork was not important but reported working with various teams on a daily basis.

Josh gave a typical example of why teamwork skills were important in his office:

"For teamwork, definitely everything out here that we do is a big team- there's so many people that are involved, and just one part of one project, that it's really important to understand and get the right people involved early in a project, communicate the end in mind of a project and make sure you have everyone involved that needs to be. So the team, crafting your team is very important for the success of a project" [Josh, TPub, EPS]

As we consider the drop in importance of teamwork, we believe that, like business skills/knowledge, this teamwork is another category with a broad set of possible interpretations. Some participants like Josh will think about teamwork as generally people working together to get things done. Others might not call this teamwork because it is structured differently from teamwork in school in several key ways: much more interdisciplinary, not everyone has same level of responsibility, not everyone has same timeline, etc. Moreover, for others like Paige management and leadership are more important than on-the-ground teamwork.

Trends Across Skills

Summarizing the data, we find that all six of the skills we examined were perceived to be important on average. Business skills were perceived as being of lower importance overall and as having the largest spread over time. Math, science, and the application of these skills to solving problems, were perceived of as a being particularly important in the first year of undergraduate schooling. Communication skills generally increased in importance while teamwork skills decreased over time.

Looking across the six skills, we find that building on existing literature by incorporating the freshman year data into our analysis adds an important perspective.

Conclusions and Implications

While other studies have examined trends across undergraduate years or trends from seniors to recent graduates e.g., [17, 31, 32], we combined both in this study to look across all four undergraduate years and into professional practice. In doing so, we found trends that vary by skill and across time. Based on our findings, we believe there are some important implications for research and practice.

The results of this mixed-methods work remind researchers and educators alike of the complexity of the many skills engineering demands. The categories of skills neatly listed in ABET and NAE documents belie the ambiguity of individual categories. For instance, our findings suggest that student conceptions of business, teamwork, and communication skills vary widely. One potential explanation for the apparent contradiction in survey and interview responses about teamwork skills is that students like Paige might conceive of teamwork and leadership skills as being distinct, to some extent. While being an effective team member and leading a team are related, it seems reasonable to see them as different skill sets. As researchers, we might need to refine empirical approaches for understanding what specific skills these categories comprise, not only as conceived by students but also by other key stakeholders, like professional engineers and faculty.

We also saw suggestions that students are conceptualizing these skills and assigning them importance not just in the abstract and individually but in context and in concert. "Business skills," when referred to as such, were deemed unimportant by alumni in academic settings, yet many skills that might fit in this category are critical to contemporary academic success, including managing organizations (e.g., a research group, a team of TAs), working across disciplinary boundaries, and seeking efficient work processes. (Note that these are the business skills Paige, Leah, and Max discussed in their interviews.) The interviews also illustrate how skills are interrelated in practice, as in Josh's and Leah's quotes about communication's critical role in effective teamwork across disciplines and roles. Josh also discussed math skills in the context of working as part of an organization and in relation to specific computational tools and processes.

With the broad scope and small sample size of the present study, our findings only provide a glimpse of the complexity described above. Focused follow-up studies could provide an "exploded view" of each of the categories of skills described above, as well as how they are related to each other and to different aspects of context (e.g., academia vs. industry, R&D vs. designer role). We also note the value of a mixed-methods approach, such as the one we used here, for such follow-on work. In our analysis, triangulation of findings across data sources and types provided additional insights; had we relied solely on the survey responses, we might not have recognized the varying definitions of business, teamwork and communication skills at play. Finally, recalling that our study is broadly situated in SCCT and with future intentions towards advancing understanding of engineering self-efficacy beliefs, we note the value of explicating what skills are important before we examine participant's capability beliefs with regard to these skills. We must resolve some ambiguities in meanings of specific skills in academic and professional contexts to give a richer meaning to understanding exactly what it is participants believe they are capable of doing/being.

As educators, we need not wait for the future work described above to be completed to better facilitate development of these interrelated skills. We can create opportunities for students to reflect on these skills and articulate how they are developing them in both curricular and co-curricular settings (e.g., coops, internships, clubs). This can provide for more integrated educational experiences, prepare students for lifelong learning, and inform efforts to teach and assess key skills. In doing so, educators might consider how context and even labeling of skills (as discussed above with "business skills") might unintentionally limit student appreciation and understanding of them.

Acknowledgments

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