

AC 2010-602: “MORE THAN JUST ENGINEERS”- HOW ENGINEERS DEFINE AND VALUE COMMUNICATION SKILLS ON THE JOB.

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“More Than Just Engineers”: How Practicing Engineers Define and Value Communication Skills On the Job

Abstract

While most professional and academic sources have expressed a need for engineers who possess strong communication skills, what these skills are actually defined as on-the-job remains somewhat vague in the literature. In this mixed-method study of practicing engineers from industry and governmental engineering workplaces, we heard and observed some answers to help define what communication skills engineers are actually practicing in their jobs. Through qualitative data collected over the past two years in six workplace case studies (including over 50 hours of observation and more than 50 interviews), interviews of engineers and their managers (N=91), and surveys of engineers and engineering managers (N=162), three main themes emerged to provide insights into what engineers mean when they say they value “effective communication” in other engineers.

The first theme was what numerous engineers in our study described as “the big picture,” or the ability to effectively speak, write, and interact with audiences who were outside of their specific discipline, work group, or focus. Our second theme centers on an engineer’s willingness and self-motivation to initiate communication with others and to seek out resource information through informal interactions. Finally, the third theme involves the ability of engineers to listen carefully to others in order to do their best work and achieve results that are valued by their stakeholders (clients, managers, co-workers).

Understanding these three themes can inform more authentic and engaging ways of teaching engineering students. Teaching improvements are needed, as one interviewee put it, because “Good engineers typically are more than just engineers....I need someone who I can drop in [who] can communicate effectively today.”

Introduction to the Problem

“Someone can be technically brilliant, but if that person can’t communicate or work with others, what use is their skill?” As engineering educators, we have all heard this question and posed it frequently to our students as well. However, in this mixed-method study of practicing engineers, we heard it resoundingly echoed back from industry and governmental engineering workplaces. While the answer to the question is obvious, what it means to be an engineer who can “communicate” is not as easy to define.

Increasingly in recent decades, the engineering field has recognized its need for engineers who have strong communication skills¹. In fact, ABET curriculum requirements ensure that institutions teach those skills to their graduates². While several studies of engineering undergraduate curriculum^{3,4} have shown that communication skills are being taught primarily through technical reports and presentations, other studies have indicated^{5,6} that these may not be the most, and certainly not the only, required skills needed in engineering workplaces. For many communication instructors who have little, if any, direct experience with engineering workplaces outside of academia, it can be challenging to know how to tailor courses to develop a more interpersonal communication skill set in students. Indeed, as Trevelyan pointed out in his study

of communication practices of engineers in Australia, “assessment of communication in engineering education is misaligned with practice requirements”⁵. To better align educational assessment of communication practices in the first place, educators need to know more about how this skill set is defined and practiced in engineering workplaces. This paper intends to help shed light on that question through reporting on the ways that practicing engineers valued, defined, and practiced “communication skills”.

Study Description and Methods

This study is part of a larger project sponsored by the National Science Foundation which examines the alignment of engineering practice and engineering preparation, in part, to determine how well- or under- prepared engineering graduates are to succeed in the profession. This three-year study’s final aim is to suggest ways that engineering educators might better design curriculum and pathways to engage, retain, and eventually produce successful engineers.

The survey questions and interview protocols used in our study were crafted based on competencies identified in the National Academies reports *The Engineer of 2020*¹ and *Rising Above the Gathering Storm*⁷. The American Society of Civil Engineers’ Body of Knowledge⁸ was also consulted. Hatfield and Shaffer’s work on epistemology assisted in developing the survey and interview questions as well since part of our aim was to identify the ways that practicing engineers developed their epistemic frame⁹.

The first of three methods used to collect our qualitative data involved interviews and observations with practicing engineers within six different organizations across a spectrum of engineering employers. Specifically, we aimed to work with employers from government and industry, from small to large-multinational conglomerates in size, and across a broad range of work sectors. For more information about the six organizations we worked with during our study, see Table 1.

Table 1: Study Sites Overview. *In choosing sites, we focused on getting a range of employers representative of different workplace sizes, sectors, and business factors.*

Name	Size	Sector	Description
Porter & Young Technologies	Large, multinational	Technology, public	Study took place at two different campuses.
Northwestern Construction Engineering	Mid-sized national	Construction, private consulting	Study took place at one campus.
Ayer Electronics	Small, national	Technology, private consulting & manufacturing	All aspects of the company were at one site, from the CEO to manufacturing.
Engpro International	Large, multinational	Construction technology, public	Study took place at one campus.
Geminid Environmental	Mid-sized, regional	Environmental, state government enforcement	Engineers often worked individually or in small teams with distinct, unconnected goals.
Rowley Tech Innovations	Small, national	Aerospace technology, public	This organization is currently attempting to broaden its scope from government contracts to consumer product work.

From this portion of the study, we conducted a total of 53 semi-structured interviews and observed individual and group work in the organizations for over 50 hours. Observations included “shadowing” a participant during a typical task, observing at group meetings, and also recording some talk-aloud tasks during which the participant described what he or she was doing as a task was completed.

Our second method of data collection asked freshmen engineering students in an introductory communication course at a large midwestern public university to interview practicing engineers. Participants were practicing engineers, managers, or individuals with engineering backgrounds. In all, 91 student interviews were conducted. The interviews used a protocol consisting of 15 open-ended questions which asked participants about their background, their reasons for becoming an engineer, and their career goals.

Our final method was an electronic survey (N=264) sent to alumni of the college of engineering of a large midwestern public university. This survey was 37 questions in length, including questions on personal background and current professional work. The bulk of the survey consisted of likert-scale and open-ended questions on individual’s skills, values, and professional practice. Respondents who identified themselves as now working in fields other than

engineering were not used, so this research is based only on the responses of engineers and engineering managers (n=162).

All data collected are managed and coded using the coding software package, EnVivo. Data are coded using 40 different analytic categories and analysis within them is ongoing. Of the codes used, this paper will report on findings from the categories of “values”; “essential skills”; “job description”; “attributes of an effective engineer”; and “attributes of an ineffective engineer”. Within these general categories were additional levels of specific coding including: “skills – communication”; “skills - teamwork ”; “job description -working w/clients”; and “job description – collaboration”. With these queries, we were able to do even more specific coding for descriptions of how communication was defined, practiced, and valued by the engineers.

Findings

Above all other skills required to be an “effective engineer,” communication was ranked as “essential” by over 60% of our survey respondents. An additional 28% ranked it just below essential on a likert-scale question. Looking at the second most highly rated skills helps put this ranking in context: 55% of respondents ranked problem solving as the top essential skill. Beyond this ranking data, to help us understand how engineers defined effective communication, we used discourse analysis to interpret and group the engineer’s responses from the interview questions, open-ended survey questions, and observational comments. Several large themes of effective communication emerged from this grouping, along with some associated sub-themes that will be discussed.

Theme #1: “Big Picture” Awareness

A consistent theme mentioned by the engineers was the importance of developing broader awareness of the context in which they, their teams, and their work functioned. Indeed, this theme aligns well with several of the Proposed Desired Attributes of a Global Engineer (2009) and shows promise that, if curriculum were developed to assist undergraduates in thinking more broadly about the context of their work as it functions in their organizations and society, they will be better prepared for their future work roles¹⁰.

This theme also supports, in a way, the claim that Sheppard, et al made about the “central activity of engineering work” being that of “problem solving”⁵ (p.430). In the cases described by the respondents who touched on this theme, the social, political, and business awareness (aka “big picture,” as so many respondents defined it), that certain engineers had developed gave them the necessary edge to effectively solve problems faced in their jobs. This also was supported by numerous comments regarding “critical thinking” ability as another descriptor of effective communication as one such quote illustrates, “A good engineer questions and checks results to ensure their accuracy and their applicability to the given situation. They can put technical results into the larger business context”. As this response illustrates, not only did engineers see importance in being able to think critically about technical results, but also in the ability to see the business and rhetorical aspects of the problem that the results were operating within. Another engineer described the gap he perceived in his practical use of these skills and his educational focus on them:

You know, back in school, the only thing I focused on was the technical aspects. The nitty-gritty mathematical and physical details. But in here, on any given day, I probably don't spend more than say two to three hours looking at technical stuff. A lot of my time is spent interacting with people in marketing, sales, field support, and other engineers in different disciplines. I'm an electrical engineer, but I have to work with other engineers here to understand the big picture. ...a lot of writing, documentation, and presentations [are necessary] when you have to put ideas across

For this engineer, and numerous other interview respondents and case study participants, being able to communicate with others outside of his engineering discipline was absolutely essential to doing his job well. In addition, a strong understanding of the rhetorical and business situation was underscored by other participants in several instances such as this response illustrates:

An effective engineer asks direct questions and gets direct answers, fast. He doesn't waste time writing long narratives in reports or creating detailed hourly simulations when a quick estimation will do. He delivers reports that are short, easy to read, and answers the questions the client asked. He relies on experience and intuition to direct his recommendations – the calculations are secondary.

Further evidence of business awareness being tied to success as an engineer was also shown by numerous responses similar to the following:

The way you treat a customer is important. The way you write email to them, the way you ask questions, or even the way you answer questions. A lot of this can make or break business relationships. This can be more important than having a slight mistake in a calculation. Being a jerk to a client will lose you your job while a mistake in a calculation happens to everybody.

An engineer at Geminid, our governmental agency site, described how he goes about gaining the “big picture” to inform his communications with various audiences in the governmental realm:

I try to be aware of who the audience is. For instance, if it's a legislator, I will go to the website, I will determine whether that legislator is a Democrat or a Republican, what part of the State that legislator is from, male or female, age, any number of other things. The content of my answer is going to be the same. The delivery and the order of the delivery is going to be different. I try to be aware of who the audience is and how the message is going to be best delivered and best understood.

Linked to this aspect of being able to effectively communicate outside one's technical field was keen awareness of how to best communicate risk to an audience. Being able to “explain risk well” to others who may be unfamiliar with the technology or situation was seen as an essential skill by many respondents as also seen in this interview response:

Engineers should be able to communicate risks. They shouldn't wait until the 11th hour and suddenly say, ‘I think we have a problem’ and start raising alarm bells and worry.

They should be able to clearly, succinctly, summarize issues at hand at all phases of the process...they need to be able to present technical information in an interesting and compelling way.

The need for this skill was often seen in relation to pressures of working in international environments where attention to audience and language use was even more critical. One engineer described this well, saying:

As I do a fair amount of collaboration with the developers and testers in China, I have to be able to describe highly technical problems and issues so that they all understand...I also interface with product management so I have to be able to describe technical and nontechnical details to people who may not have the same background as me... Programmers get paid to write code, but it's being good at all the interpersonal stuff that allows a Software Engineer to keep his or her job.

While the study participants gave several different instances of the importance of being able to assess and communicate to a variety of audiences, one thing was made very clear through this study's findings: to be a successful engineer means to be able to analyze any audience to anticipate what they want and what they need in their particular context. While the engineers often described this ability as being able to see or understand "the big picture," what they were often describing was an awareness of audience as that audience functioned within a larger, complexly situated field.

Theme #2: "Willingness to engage"

Our second theme seen in the data involved engineer's willingness to proactively seek out discussion, clarification, or even debate with others as a means of obtaining the strongest information to operate effectively. As one engineer described a colleague who he felt was particularly ineffective as an engineer, "Lack of ability, I can forgive, but someone who is unwilling to communicate? That is terrible." Overall, being merely "willing" to communicate was identified specifically as a trait of an effective engineer in over 10% of our open-ended, survey responses, and it was also supported by numerous interview responses. One such example came from an engineer with Rowley Tech as she described her struggles of getting her design engineers to be more efficient and effective in their jobs:

What I discovered with the engineers I work with is that they have this tremendous fear of communication...of going and physically talking to someone about a question that they might have. They are great at sending little emails back and forth to each other, but those don't really get to what they [clients] are asking so I have to force them to meet in person and force them to talk more often...they are afraid to call customers.

The obvious challenge this theme presents to the curriculum is, how does one teach "willingness" or self-motivation? In fact, several engineers described the skills required to engage with others by stating that they valued those colleagues who, as a result of strong background research and data gathering, were able to formulate good questions and therefore were more efficient with the time and talent of others they were engaging.

Beyond being merely willing to communicate with others, was the subtheme of being willing to teach others and debate ideas. An excellent example of this came from a group of engineers working on a problem at Porter & Young. Initially, one engineer had been tasked with solving a problem that was not tied to any of his colleagues' projects. However, at lunch one day, he posed the problem on a break room white board and had a brief discussion about it with several other colleagues. Over the course of two days, several people came into the break room and added new information or insights into the solution until finally, the group together arrived at the best answer. None of the other engineers had a stake in solving the problem, but they were intrigued by it and wanted to assist the person tasked with it to arrive at the right answer. From a research standpoint, this incident was brought up independently in interviews with three out of the five main participants in our study at this campus of Porter & Young. All three cited this incident as an example of either being a strong communicator or an effective engineer.

As this incident poignantly illustrates, the engineers who are most valued by their organizations seem to greatly value those who are active and willing communicators. While instilling motivation in engineers to communicate with others presents significant challenges to engineering education, it is clear that efforts must be made to reinforce these skills and attitudes early and often in the curriculum.

Theme #3: Being a good listener.

While conventional thought often decreases communication to a mere information transfer, the ability to listen carefully to others was mentioned repeatedly as a trait of both effective engineers and as an essential skill associated with strong communication practices. Like one's willingness to communicate, being a good listener is part of a "complex social interaction" as described in a similar study by Trevelyan⁴; indeed, its complexity often makes it difficult to observe, measure, and teach. However, in the technical professions, it seems that it is well noticed and valued based on the fact that we saw "listening," "hearing," and "being open to ideas" mentioned with only slightly less frequency than the term "communicate," which was the most highly valued skill identified by engineers by far.

Some pointed examples of this theme were observed in discussion with engineers at the case study sites. One such observation occurred during a meeting at Northwestern Construction Engineering in which an engineer described a client meeting which involved meeting with some surgeons and hospital staff for a new operating room design. The engineer managing the project remarked, "We found out from the surgeons that they think they want it to be 65 degrees [steady temp in the operating room], - but they don't *really* [tonal emphasis], since they actually need to control certain fluctuations." From his interactions with the medical team, the engineer had discovered that their stated desire was not going to meet the clients' actual physical needs in reality. Only through listening carefully to them and adjusting his design team's plan was the space his team designed going to truly meet the needs of the client. Another engineer from Geminid put this skill another way, stating,

I think it is important for us to listen to understand what they are trying to do. When a person first comes to you and says what they want, [it] may not actually be the solution

that they need. It is really up to us to try to understand what you are trying to achieve and then have an open mind to consider the possible options. That's one that I think is a big one

For most engineers in our study, meeting with clients or colleagues and trying to determine their needs was a challenging and satisfying part of their work lives, as this engineer's experience illustrates:

I like meeting with the clients and hearing what they have to say and either agreeing with them and trying to come up with a great solution together or sometimes we butt heads and I say, 'This is what everybody else is doing; this is what I read about'. And they ask me to prove it and it is a challenge and sometimes it's a headache, but sometimes it's fun.

As with the other themes identified by this study, the challenge is not necessarily in naming these practices as evidence of how successful engineers do their jobs, but rather in discovering authentic ways of teaching them and developing them in our engineering students.

Conclusion

While the themes identified here are still somewhat preliminary and require additional analysis, they clearly demonstrate some dissonance with the traditional academic teaching and assessment of engineering communication practices. Similar to Trevelyan's findings, our themes indicate that engineers must communicate extremely well to be successful and that the communication practices they employ are not often the same as those we assess for at the undergraduate level⁴. Indeed, like Trevelyan's study, our examination of engineering practices indicate that aptitude in interpersonal communication and understanding of the broader audience are key skills that help engineers develop into the sort of communicators that engineering practice will require today and into the future.

In light of our findings, it seems that assessment methods for engineering communication experiences and coursework, at the very least, need to be examined and revised to address this gap between educational preparation and practice in the field. It seems clear, based on this work and associated work of others, that to become "more than just engineers," in the field, our engineering students require more authentic, situated, and socially complex preparation than much of what the curriculum currently provides.

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