Preparing First-Year Engineering Students for a Career where Communication Skills Matter

Dr. Leila Keyvani, Northeastern University

Dr. Keyvani is an assistant teaching professor in the First year engineering program.

Dr. Kathryn Schulte Grahame, Northeastern University

Dr. Kathryn Schulte Grahame is an Associate Teaching Professor at Northeastern University and a member of the first-year engineering team. The focus of this team is on providing a consistent, comprehensive, and constructive educational experience that endorses the student-centered, professional and practice-oriented mission of Northeastern University. She teaches the Cornerstone of Engineering courses to first-year students as well as courses within the Civil and Environmental Engineering Department. She is a recent recipient of the Outstanding Teacher of First-Year Students Award and is interested in research that compliments and informs her teaching.

Preparing First Year Engineering Students for a Career where Communication Skills Matter

Abstract

This complete evidence-based practice paper describes the techniques used in the project based first-year Cornerstone of Engineering courses at Northeastern University to address the need for building communication skills for our first-year engineering students. Although this skill can be taught and assessed, the results of past surveys show that engineering students are inadequately equipped to meet this need.

This need is addressed by teaching and assessing the three pillars of engineering communication: written, oral and graphical through a series of lectures, activities and group assignments. For instance, a series of biweekly group assignments, designed to assess and improve the three pillars of engineering communication are woven into the project-based curriculum, culminating with a final project exhibition and written reflection. These assignments, not only assess the presentation, graphical communication and writing skills of the teams but also their individual leadership skills. In addition, recommended materials for preparation, implementation guidelines, and best practices for engineering communications are discussed.

Based on the anonymous quantitative survey data, students overwhelmingly reported that they have improved their proficiency in the three pillars of communication through the course. Qualitative data showed that students think that mastery of the different pillars will make them better team players and give them the flexibility to effectively communicate with a variety of audiences. The majority of students reported oral communication as their skill that requiring the most work and many reported fear associated with public speaking. The end of semester survey results showed that the students recognized that all their communication skills were a work in progress mirroring the initial course message that engineers need to be lifelong learners. With this understanding, we hope that they would pursue other opportunities to sharpen their communication skills.

Introduction

The three pillars of communication are considered to be one of the important professional skills in engineering practice [1]. They are reported to be even more important than technical skills [2].

Graphical communication, one of the pillars that is unique to the engineering practice, covers technical requirements of drawing and visual skills. Most students have shown to struggle in presenting and understanding, graphically, ideas that require high visualization skills [3]. Visualization skills can be enhanced by teaching and training the students from early stages [4-

5]. Studies have shown that failure to master visualization skills will, indirectly, impact their ability to master other concepts in engineering that are based on visualization.

Oral presentation, on the other hand, is not simply the formal presentation of the material to a technical audience. Engineers spend 50% or more daily, communicating either with colleagues working on the same project or with individuals outside the organization. The audiences with whom engineers engage are many and complex. Engineers speak to other engineers, to clients, to government agencies, and to support staff. Skills such as clarity, negotiation, discussing team challenges, and listening are key to success in a highly collaborative working environment [6]. Studies have shown that involving students in engineering projects helps improve technical and interpersonal communication within teams, with the suppliers of technical parts, and non-engineers. It has also helped improve English writing skills for international students [7].

One would expect engineering students to possess high levels of these skills upon graduation; however, the results of past surveys show that engineering students are inadequately equipped to meet this need [8-9]. Although engineering students are typically required to communicate their design to a broader audience at the end of the senior capstone course, there is not much emphasis and attempt to provide a similar opportunity for first-year engineering students to engage in activities that might occur in industry. In the Cornerstone of Engineering at Northeastern University, a similar opportunity is provided to the first-year engineering students and the results are discussed in this article.

Background

Cornerstone of Engineering is an integrated design and problem solving through programming course for first-year students at Northeastern University. The course consists of two 4-credit classes either given over two semesters or stacked into one, depending on a given student's needs. The work done for this paper will examine students' experiences from the 'stacked' course, where all learning objectives are met in one semester by meeting with the students for 8-credit hours of time.

Cornerstone of Engineering is in its fourth full year of iteration at Northeastern University. Through benchmarking and iteration, we have learned how to weave programming and design concepts into one course, creating an interdisciplinary learning experience for our first-year students [10]. The culture necessary to support this effort has also evolved over time with the course taking on two versions, both of which are supported by personnel and equipment in our First-Year Engineering Learning and Innovation Center [11].

Cornerstone of Engineering courses are offered with a theme chosen by the instructor. Sustainability, Robotics, Music, Resiliency, and Security are some of the themes offered by the

First-Year Engineering Program at Northeastern University. This allows the students to work on open-ended engineering projects where a real need is identified by the students through research and presented to the class. Studies have shown that the students who conduct research, throughout their undergraduate study possess better communication skills where the increase in skillset is attributed to poster and paper presentation given by the students [12-13]. Through group reports (with CAD drawing and Excel table requirements), posters, and oral presentations to their peers, instructor and broader audience, our undergraduate students practice the three pillars as part of their development of a final project.

All the tasks are completed within teams of four. Students with different backgrounds, oral, writing and graphics communication skills, and discipline often work together towards one goal. They face teamwork, interpersonal, and leadership challenges throughout the semester, often requiring intervention by the instructor to help them practice and possess better communication skills.

Methodology

Two of the four professors teaching the 'stacked' Cornerstone of Engineering class use the Sustainability and Resiliency themes in their courses, which for this work, included over 90 students. These themes are woven into the final project design through asking our students to create interactive museum exhibits that teach about a chosen topic within the theme. The importance of the projects' quality are further enhanced by a partnership with a local museum where students present their final work at the end of the semester to real clients (local children!)

To set the framework for the semester, students are introduced on the first day of class to communication as one of the necessary skills (See Figure 1 for the full list of topics discussed in the introductory lecture) to being an engineer and using the Engineering Design Process.

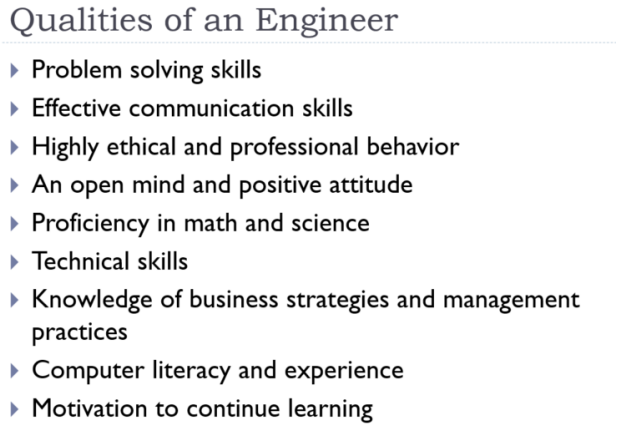

Figure 1: Introductory slide framing the skills and qualities necessary to become a successful engineer

During this introduction, the three pillars of communication (oral, written, graphical) are presented as skills we will practice throughout the course. The importance of each one and its relevance to being a successful engineer is discussed and students are assured that they will have opportunities to hone each skill in this course. They are told that skills on this list must constantly be honed and adjusted as technology and client needs change. The humility of being a lifelong learner who can always improve their skill is emphasized.

The following week, an official communications lecture is presented with an emphasis on the three pillars and the expectations for quality in the Cornerstone of Engineering class. The relevance of each of the pillars to the assignments on the syllabus are also pointed out. Specifically, students are told that they will be weaving their communication skills into a course-long project to design a product. They are introduced to the expectations of oral, written and graphical products that will be used to disseminate their ideas to the class for feedback. A document laying out the assignment titles and due dates is then reviewed with the relevance of the pillars of communication to each assignment mapped. Table 1 summarizes the relevance of the course assignments to communication pillars.

Table 1 - Course Assignments mapped to Communication Pillars

Activities	Written Communication	Oral Communication	Graphical Communication
Team Contract	✓	✓	
Project Manager	✓	✓	✓
Milestones 1 - 7	✓	✓	✓
AutoCAD Homework			✓
Solidworks Homework			✓
Matlab Labs	✓		✓
C++ Labs	✓		
Poster and Final Presentations to judges	✓	✓	✓

To get to the final product for the course, the students will also hone their writing skills through a series of seven graded milestone reports that detail the progress of their design process. The first six reports are group submissions with the rotating Project Manager in charge of the collection of data to ensure all members of the group are contributing and getting a chance to hone editorial and leadership skills. The seventh and final milestone consists of two parts. The first is a cumulative report that asks the students reflect back to the whole semester (looking back to the written milestones predeceasing) and detail the process used to complete the work, their specific contributions, and lessons learned through the semester. This document is written alone but submitted as a group with a joint abstract, cover letter, and appendices. The second part of the final milestone is the physical project, which has an accompanying poster. Since the project is a museum exhibit, the language on the poster must balance brevity and detail to provide the desired learning objectives to our intended users - museum going children - while also holding their attention.

Oral Communication

In this course, the skill of oral communication is practiced both informally, through negotiation and team management/motivation, and formally, through two presentations (one individual and one as a group.) The Team Contract is the first foray into negotiations and informal oral communication. Having our students talk through many of the points covered in a norming phase of group formation allows them to express their needs and allow their desires to be placed in the open for the purpose of creating a better teaming environment. (The rubric for the Team Contract is included in the Appendices.)

With individual desires for group performance expressed early (and also in writing!), team management is a little more straight forward during the milestones where a given student must be the Project Manager. While students must hone their oral communications skills to motivate all group members to work towards the common Milestone goal, it is emphasized on a weekly basis that the skill of motivating people is one that must constantly be honed and approached as a skill with lifelong development. At the conclusion of each Milestone, the Project Manager must give a brief formal presentation (~ 4 - 5 minutes long) where they summarize their group's efforts and present the project's progress to the rest of the class. At the conclusion of their presentation, they must solicit feedback from the class and field questions on behalf of their group. Students are reminded that the professionalism students present in both the practiced presentation and the unpredictable questions session following are both touted as evidence that they are building their communication skills.

The second formal presentation comes during the seventh and final milestone. At an open exhibition on campus, groups present their projects to both college students and a series of three faculty judges. Judges are given a rubric (included in the appendices) of presentation expectations and interact with a given group to see if they: are knowledgeable about their subject matter, can motivate the judges to want to learn more, and can defend their design choices in a professional manner. Groups are advised to create a sales pitch style presentation

where they cover the points on the rubric and anticipate for questions that the judges may ask any member to answer on behalf of the group.

Graphical Communication

Many students enter into the Cornerstone of Engineering course with no formal graphical communication experience. For the first time, they are being asked to create drawings to express their ideas and to identify measurements and technical aspects of their creations. Thus this can be the hardest for some as it is the most foreign. However, students are also taught that graphics can also include tables of data and graph or charts (from Excel) as well.

We begin graphics by introducing a series of four AutoCAD labs where students are not only creating assigned drawings, but they are also creating personalized logos and title blocks to begin creating an individual design identity. By the fifth lab, students are asked to create a 3-D box to be laser cut from the 2-D AutoCAD drawings. Having the students understand the importance of graphics is achieved through submitting their designs and materials to be cut at the library's laser cutting studio. They learn sometimes through trial and error the importance of precision of their measurements and design clarity when their designs go awry. Next, we move to 3D modeling in Solidworks. Through four labs we have the students create individual parts, formal orthographic drawings, part assemblies, and motion videos. The students are then encouraged to take their modeling skills and create a part for assembly for 3-D printing in our first-year design studio; again creating a physical object from graphical programs. Many of these parts make their way into our final projects as unique pieces that personalize their exhibits.

In the middle of the semester, we have a short lesson in table and chart creation utilizing Excel. Students are taught the importance of a good layout of data for a given audience to understand what you are trying to communicate. Topics covered range from picking the right type of chart to proper axes or header labeling.

Lastly, all milestone reports must include (1) either AutoCAD or Solidworks drawings that include the measurements and depictions of their projects, (2) tables that summarize hours and funds spent on the project, and (3) Gantt Charts showing the progress they have achieved thus far. These three different methods of graphical communication tell the different aspects of the design story each milestone. These three items are also presented to the class each week by the Project Managers and provide the necessary visuals to paint the picture of a group's progress.

Measuring Progress

Formative assessment

Throughout the semester the individual assignments (see table 1 for the skills covered) in AutoCAD, Solidworks, Matlab, and C++ are graded on a weekly basis and students receive feedback as to their writing and graphical communication progress. The milestones reports and project manager presentations are given bi-weekly and extensive feedback is provided through grades as well. (The Team Contract, and Milestone #3 assignments are provided in the appendix as an example.)

Summative Assessment

Each time a unit of content is complete a summative assessment is given. Since this is a design course, we do not administer quizzes or tests for assessment; instead, we challenge the students to combine their new skills with the design process to make a physical product. These larger design assignments include the laser cutting AutoCAD project, the SolidWorks 3-D printed part project, the Project Manager presentations, and the final Milestone's poster presentation and paper.

Reflection Survey

At the end of the semester, 53 students enrolled in two of the sections of the 'stacked' sustainability-themed Cornerstone of Engineering, taught by one full-time first-year Engineering faculty, were asked to complete a private and anonymous reflection survey on their perceived progress in the areas for written, oral and graphical communication. The quantitative questions ask the students to measure their perceived abilities in each of the communication pillars both before and after the course based on a 10-point likert scale. Additionally, two qualitative questions were added to capture additional detail as to the students' perception of their abilities. These questions included:

1. WHY do engineers need to be proficient at communicating through writing, orally, and graphically?
2. What skill(s) do you think you need to work on most and WHY?

Results and Discussions

Quantitative Results

The quantitative results are summarized in Table 2 for better comparison. The results of the survey, regardless of the type of the communication, show a meaningful positive change in the level of the students' confidence in each category at the end of the semester, with the largest change belonging to the graphical communication. In addition, we carried out a paired t-test on the average of the data for each skill. The p-values calculated for each category were almost zero

showing that there are significant differences between the average of the students' confidence level at the beginning and end of the semester.

The results of the survey, according to Table 2, suggests that the students are more confident in their writing and oral skills at the beginning of the semester compared to the graphics. The change in the standard deviation, in all categories, suggests that upon graduating from Cornerstone of engineering, students possess a more uniform level of skill sets.

Table 2 - Summary of the Survey Results

	Writing			Oral			Graphics		
	Beginning	End	% change	Beginning	End	% change	Beginning	End	% change
Mean	6.6	8.0	21%	6.0	7.8	30%	4.4	7.6	72%
Median	7.0	8.0	14%	6.0	8.0	33%	4.0	8.0	100%
Standard Deviation	1.5	0.9	-42%	1.8	1.3	-29%	2.3	1.1	-51%
p-value	0.00			0.00			0.00		
t-value	-19.14			-17.46			-18.79		
t-critical	2.01			2.01			2.00		

For each of the three communication pillars a histogram is created based on the results of the quantitative section of the survey (Figures 2-4) as well. Three graphs, shown in this section, compares the frequency of the responses for each rating in the beginning and end of the semester. In addition, for each graph cumulative percentages is added to quantitatively evaluate the total percentage of the students rated themselves below average.

As mentioned previously and is evident from Figure 2, there are students from a variety of backgrounds, proficiencies, and confidence levels in writing at the beginning of the semester. Looking at the cumulative percentage at the beginning of the semester, about half of the class rated themselves below average. However, there is a meaningful increase in the students' confidence levels at the end leading to a class with more uniform writing skills. An interesting outcome of the survey is that the students did not rate themselves excellent in writing. This may be due to the significant and consistent feedback they receive from the instructor regarding the quality of their group write-ups throughout the semester, which helped them realize that there is more work to be done.

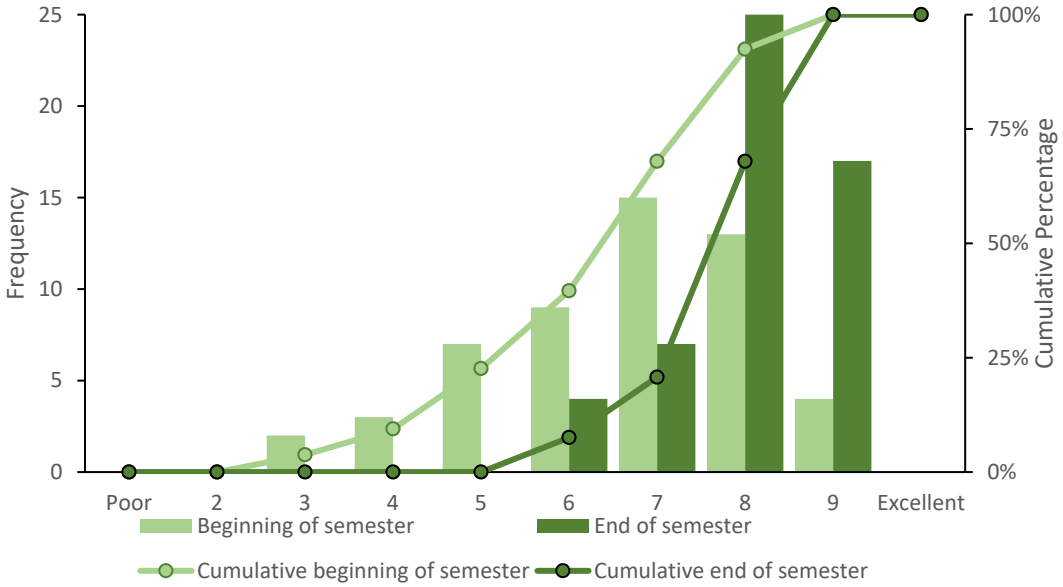

Figure 2 - Students' Ratings of their own Writing Communication Skills

Similar to the writing category, there are various skill and confidence levels in oral communication at the beginning. Unlike the writing category, the class seems to not achieve a uniform level of oral skill upon completion of the course. Looking at the cumulative graphs in Figure 3, there are about 10% of the students that still do not feel confident in oral communication - at the end rating their oral skills below average. This can be also seen in the qualitative responses where students consider oral communication to be one of the most important skills that they still need to work on. It is worth mentioning that there were no international students in the class.

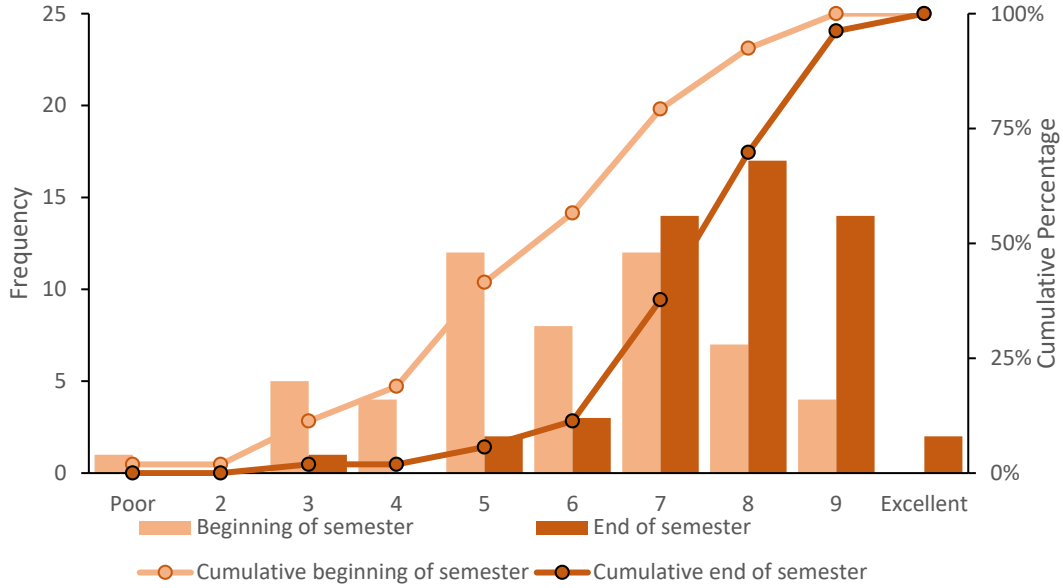

Figure 3 - Students' Ratings of their own Oral Communication Skills

In Cornerstone of engineering about one-third of the semester is dedicated to teaching and assessing graphical communication of design ideas. The average of the students' confidence in graphical communication, according to Table 2, shows about 70% increase at the end of the semester, meeting the course objectives.

The level of confidence and proficiency in graphics is very scattered since having prior graphics knowledge is not required for this course. As the cumulative charts suggest (Figure 4), about 70% of the class rated below average at the beginning of the semester. However, similar to the writing skill graph, the class graduates with a more uniform and above average skill sets at the end. The gap between the two cumulative charts shows significant improvement in four months for the first-year engineering students.

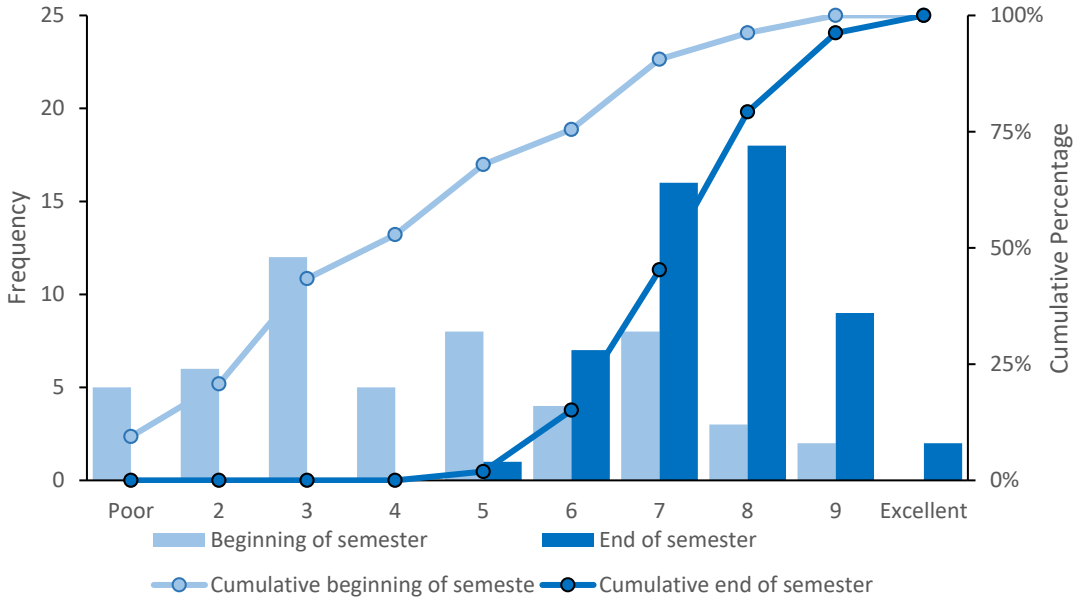

Figure 4 - Students' Ratings of their own Graphical Communication Skills

Qualitative Results

Q1: WHY do engineers need to be proficient at communicating through written, oral, and graphical methods?

The most common theme that students reported to answer this question was that proficiency in the various communication pillars provides them with the flexibility to communicate with a variety of audiences including: clients, colleagues, and the public. They also reported that proficiency makes them a better team members since they recognize that engineers do not work alone. The following quotes are excellent examples of these themes:

> *"No individual person has the time, energy, or range of skills necessary to undertake a major project single handedly. Large endeavors require contributions from multiple*

people with a range of skills. For these ideas to integrate effectively, each team member must be able to share their ideas clearly and accurately so that others can comprehend them and connect their own ideas."

"Engineers aren't paid to work on something on their own and then move on when they're done. Engineers work in teams of different types of engineers and lay people, and a good engineer can communicate seamlessly with these people. This means that their written work needs to be clear and general enough for someone with no experience to understand, but also technically specific enough for experts in different fields to read and analyze it. Oral communication is important for presentations and meetings that engineers will often take part in. Presentations should be informative well-planned, and brief in order to hold the attention of the room. Graphical communication is important as well because engineers deal in numbers and physical objects. Numerical data can be confusing and unhelpful if not presented well. Diagrams and sketches of physical parts need to be accurate and standardized so they can be understood by people who fill different roles on a project."

Q2: What skill(s) do you think you need to work on most and WHY?

When coding the results to this question we found almost every student felt the need to choose one skill that they wished to work on. The numeric breakdown, reported in figure 5, showed that students self-reported that they needed to work most on their oral communication skills. Anecdotally the faculty disagreed with our students' self-assessment and a quick look at the grade book shows that students did not assess the lowest in this category (writing is actually the biggest struggle according to the grade book!) However, this form of communication can be the most informal. At times, it requires the students to think on their feet and it cannot always be practiced and perfected when used in answering questions and in group dynamics. Considering this, we surmise that grades do not always reflect a student's confidence in our course goals.

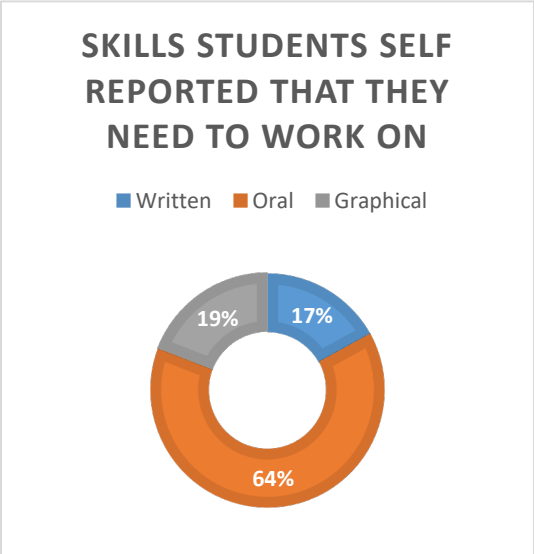

Figure 5 – The numeric break down of skills that requires more work

Looking further into the data, we separated the responses by pillar and looked for common themes:

Written Communication

17% of students chose writing as the skill they needed the most work on - the lowest of the three. Just comparing this to the lower scores in the grade book and the anecdotal faculty feelings about the quality of first-year students' technical writing, this was a little surprising. Comments frequently mentioned students wanting to improve their writing by becoming more: succinct/concise, descriptive, and clear. According to one student:

> *"I certainly still need to work on my writing presentation, which while I think is neat and written professionally, is sometimes a little too concise to begin with and is then stretched out using fluff material. This can muddle the meaning of the words, and can lead to miscommunications. I need to work on making sure that my writing is fleshed out without worrying about page length, rather making sure that it has enough detail to present a point of view and not enough words to be opened up to irrelevant interpretations. "*

Oral Communication

The largest group of students (64%) reporting that they needed to improve their oral communication skills. At first glance, this did not match the data from the quantitative portion of our survey and our anecdotal grade book assessments. Upon coding their comments, it became a little clearer that confidence and grades were just not linked in their minds. There is one theme involved with this pillar that is not in others - fear. Students reported commonly that they wished to improve in this pillar by being more persuasive, being more confident, being clearer, overcoming fears and nerves they have in front of a crowd. According to one student:

> *"I think I can definitely improve on my oral communication skills. I practiced my part of what we said as a group to the judges many times, and I definitely had that locked down during Milestone 6, feeling very confident about it. However, my presentation skills when I'm in front of a large group need work. I get nervous before these presentations, which in turn makes my oral communication worse. It is important to be able to give a speech or presentation, because oral communication is probably the most effective way to get through to an audience. Persuasive speakers are able to convince a client that a pitch is right for them, and speakers that present with clarity are able to convey an idea and receive constructive feedback from peers. I think that if I take any opportunity to speak in front of a group, I will start to improve my oral communication skills."*

Similar results were reported in another study where participants gave considerably larger weight to the speaking skill. The majority of the responses identified audience analysis, interpersonal communication, persuasion, confidence, and teamwork skills to be more important to engineering work [6].

Graphical Communication

With 19% of students selecting graphical communication at their area to work on this was the second most common pillar. Students reported that this category was the newest to them but they realized that graphical communication was an important engineering skill needed to obtain a job. Anecdotally, faculty agreed that students' lack of attention to detail in graphics was the biggest issue in this category. However, students tended to focus on their comfort with the software as their hurdle to overcome within this pillar. This intrepidness can be seen as one student reported:

> *"I think I need to work the most on graphical design and communication because I am not completely proficient in softwares such as AutoCAD and have never used softwares such as Solidworks before. I feel as though skills in these would be useful in any profession."*

Conclusion

In an 8-credit, themed Cornerstone of Engineering course offered at Northeastern University, first-year engineering students are offered an opportunity to build communication skills necessary for their career success through specially designed group and individual assignments as well as a semester-long open-ended group project. The writing skills are assessed by individual memo, cover letters as well as group assignments such as Team Contract, and series of seven graded milestone reports that detail the progress of their design process. Oral skills are practiced both formally and informally through negotiation and team management/motivation, and two presentations (one individual and one as a group) to various audience including their peers, course instructor and other faculties and visitors (child and adult). Graphics are introduced and assessed through a series of individual CAD, orthographic drawings, data visualization (charts and tables), 3D printing and laser cutting assignments. All the skills are then utilized in the design, documentation and production of their final group project. The students' performance are then assessed throughout the semester by providing continuous peer to peer and instructor to student feedback. As a final assessment, reflection surveys collected at the beginning and end of the semester on the students' perceived progress in the areas for written, oral and graphical communication. The survey assessed the results through quantitative and qualitative questions.

According to the quantitative results of the survey, a common trend is a class with variety of skill sets in the three pillars of communication in the beginning of the semester graduated the Cornerstone of Engineering with almost uniform and above average sets of skill in all categories. Graphics being the most foreign topic to the students had the most scattered level of confidence among two other categories in the beginning of the semester. Self-reported values obtained show that the techniques used in the project based Cornerstone of Engineering throughout the

semester, helped improve students' proficiency and confidence in the three pillars of communication by various degrees. Average graphical skills and confidence level, for instance, increased by about 70% at the end of the semester. This was the largest degree of improvement among other skills.

On the one hand and according to the qualitative results, students realized that proficiency in the three pillars of communication not only makes them a better team player but also gives them the flexibility to communicate with a variety of audiences, recognizing that engineers do not work alone. On the other hand, the majority of the comments indicate that oral is the most important skill that requires more work seemingly contradicting the findings in the quantitative section. Similar results were found in another study where considerably unequal weight was given to the oral communication in engineering practice by the participants compared to the writing skills. The challenging nature of interpersonal communication in teams seems to be one of the leading factors of this discrepancy in the results. In addition, unlike writing and graphics skill, the students see the oral presentation as a solo act (The project manager put on the spot and assessed in front of the class). Thus, fear, commonly reported, seems to be one theme involved with this pillar that is not in others. Students seem to realize the importance of selling the idea, i.e. being more persuasive, engaging and confidence in oral presentation than simply presenting the material, which was one of the key instructions given to the students during class discussions on effective presentation techniques.

Works Cited

[1] Abet.org. (2015). ABET—Accreditation Criteria and Supporting Documents. Retrieved December 1, 2014 from http://www.abet.org/accreditation-criteria-policies-documents/.

[2] Evans, D. L., Beakley, G. C., Crouch, P. E., & Yamaguchi, G. T. (1993). Attributes of engineering graduates and their impact on curriculum design. Journal of Engineering Education, 82, 203–211.

[3] National Science Foundation, (2006) *Tools, multimedia tutors developed to teach visualization skills.* The National Science Foundation.

[4] Wiley, S.E. (1989). Computer graphics and he development of visual perception in engineering graphics curricula. *The Engineering Design Graphics Journal,* 54(2), 39-43

[5] Baartmans, B.J. & Sorby, S.A. (1996). *Introduction to 3-D spatial visualization.* Englewood Cliffs, NJ: Prentice Hall.

[6] Ann L. Darling & Deanna P. Dannels (2003) Practicing Engineers Talk about the Importance of Talk: A Report on the Role of Oral Communication

[7] Andrea I. Schäfer & Bryce S. Richards (2007) From concept to commercialisation: student learning in a sustainable engineering innovation project, European Journal of Engineering Education, 32:2, 143-165, DOI: 10.1080/03043790601118689

[8] Goldberg, D. E. (1996). Change in engineering education: One myth, two scenarios, and three foci. Journal of Engineering Education, 85, 107–115.

[9] Rogers, D., Jr., Stratton, M. J., & King, R. E. (1999). Manufacturing education plan: 1999 critical competency gaps. Society of Manufacturing Engineers and SME Education Foundation.

[10] S. F. Freeman, C. Pfluger, R. Whalen, K. Schulte Grahame, J. L. Hertz, C. Variawa, J. O. Love, M. L. Sivak and B. Maheswaran, (2016) Cranking Up Cornerstone: Lessons Learned from Implementing a Pilot with First-Year Engineering Students," in ASEE Annual Conference & Exposition, New Orelans.

[11] R. Whalen, S. Freeman, L. O. Jennifer, K. Schulte Grahame and H. L. Joshua, (2018) Evolution of Cornerstone: Creating a First Year Culture with a Multifaceted Approach, in ASEE Annual Conference & Exposition, Salt Lake City.

[12] Seymour, E., Hunter, A.-B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. Science Education, 88(4), 493–534. doi:10.1002/sce.10131

[13] Carter, D.F., Ro, H.K., Alcott, B. et al. Res High Educ (2016). “Co-Curricular Connections: The Role of Undergraduate Research Experiences in Promoting Engineering Students’ Communication, Teamwork, and Leadership Skills “ 57: 363. https://doi.org/10.1007/s11162-015-9386-7

Appendix

Rubric for: Team(Team name) Contract

	Item	Points
Part 1	**Contact Information** ▸ List in a table the following for each team member: ▸ Name ▸ Email ▸ Phone Number	**10**
	Respect (full sentences) ▸ What will be your policies on work lateness? ▸ What will be your policies on punctuality? ▸ What will be the procedure if someone violates these policies? ▸ How will you ensure everyone's voice is heard? ▸ What will you do when there is a disagreement?	**15**
	Commitment (full sentences) ▸ What will your expectations for quality be? ▸ How will you measure this value? ▸ What will be the procedure if someone violates these policies? ▸ What hours do you expect people to be available?	**12**
	Transparency (full sentence) ▸ How will your team make decisions? ▸ What will be consensus? ▸ How will you ensure all information is shared and open to all?	**9**
	Inclusion (full sentences) ▸ Identify the method by which you will primarily communicate with each other. ▸ How will you ensure everyone contributes? ▸ What will be the procedure if someone stops contributing and/or contributing?	**9**
	Fairness (full sentences) ▸ How will you ensure the workload is equitably distributed? ▸ How will you resolve conflict?	**6**
Part 2	**Team Goals** ▸ Make a list of 4 or more goals as a team for completing this course ▸ Make a list of 2 or more goals for each individual	**12**
	Team Roles ▸ Make a list of who will be the project manager for the first four milestones (PM role should rotate between group members)	**4**
	Team Calendar ▸ Create a Google calendar and mark any events you have in the next 14 weeks ▸▸ Vacations, other job hours, doctor appointments, holidays, etc. ▸▸ Due dates for Milestones are clearly marked ▸ Include **screen grabs** of this completed calendar for all 14 weeks	**8**
Format	**General** • Document has been checked for grammar and spelling • Sections are clearly marked and separated • Uses complete sentences unless instructed otherwise • Is signed by all members as a form of agreement to the terms listed. o Take a picture of your signature and insert as a picture • Upload to BB as a PDF	**15**

Milestone Three Description & Rubric

	Item	Points
Group Submission	1. Evaluate your Sparkfun kit and explore the Sparkfun website then make a list of the components to be used or purchased. Make sure each of the components are Arduino/RedBoard compatible (check Sparkfun/adafruit etc websites for walkthroughs). a. How many inputs do you have and what are they? b. How many outputs (including the visuals) and what are they?	10
	2. A clean and easy to follow flowchart of how your proposed codes will interact with the user and other parts of the exhibit. a. If you are planning to use more than one Redboard, include a separate flowchart for each.	20
	3. Prepare all the visuals/user interface that you are planning to show on the touchscreen (or your laptop screen). Add a short blurb on how you would use these visuals and in what order. What is the storyline, if any.	20
	4. An updated and projected Budget (how much have you spent and how much are you planning to spend).	10
	5. Using the AutoCAD sketch prepared in Milestone 2 for your exhibit, develop a model of your exhibit with household items. The model should show intended functionality and have all the details (inputs, outputs, visuals, and theme). During the demo, using the visuals you have prepared in part 3, walk the class through your exhibit.	20
	6. A photo of your preliminary prototype showing all the details!	10
	7. An updated Gantt chart with team member responsibilities.	10
Project Manager	The **project manager** shall: a. Present a summary of 1-5, then extensively demo your prototype detailing the main design features, how the user will interact with it, input, output, and visuals.	60
	b. Present a summary of the written feedback received in class at Townhall #2.	10
	c. Be responsible for editing and updating the corresponding sections in the report template.	20
	d. Solicit (at least 3) and answer questions at the Town hall meeting	10

Judges Rubric of Final Project and Presentation expectations

	Missing	low/ poor	neutral / fair	moderate /good	high/ excellent
Clarity of Theme (addresses ethics/3Ps)	0	1	2	3	4
Educational Quality of Exhibit (clear take away objective)	0	1	2	3	4
Overall Quality of Exhibit Visuals (Poster + Stamper)	0	1	2	3	4
Overall Quality of Exhibit Tangibles (Sparkfun/ computer)	0	1	2	3	4
Flow of Exhibit & Ease of Use	0	1	2	3	4
Exhibit Engagement (Fun?)	0	1	2	3	4
Creatively incorporates Sparkfun wire kits to engage users	0	1	2	3	4
Electronics provide feedback to user in a useful way to **promote learning**	0	1	2	3	4
Professionalism of Presenter(s) (Appropriate Dress, Language)	0	1	2	3	4
Knowledge and Evidence of Preparation of Presenter(s)	0	1	2	3	4