Investigating Undergraduate Students' Communication Self-Efficacy during an Engineering Design Course

Deeksha Seth and Gabriel N. Carryon
Mechanical Engineering and Mechanics
Drexel University
Philadelphia, PA, USA
deeksha.seth@drexel.edu

***Abstract* – Communication skills are an integral part of the development of undergraduate students as emerging professionals in rapidly changing, multi-disciplinary engineering fields. However, many engineering educators and industry employers continue to express concerns about the quality of these skills in engineering graduates. Many universities and institutions have enhanced engineering education curriculum, with a focus on developing communication skills through design courses and presentation activities. However, a consistent assessment or investigation of these skills remains elusive. One way to learn about students' communication skills is to monitor their self-efficacy in communication (i.e. their belief in their capability to communicate effectively). In this study, we discuss the results from a 32-item survey (subset of a 72-item survey) given to engineering students during the second (N = 103) and last week (N = 82) of a 10-week, hands-on engineering design course. 31 items on the survey were related to specific communication tasks such as explaining product details to customers, and the last item was related to general communication skills. A subset of the 31 items were grouped into two categories related to the audience with whom the students are communicating and the method of communication. A one-way ANOVA analysis, and paired t-tests were conducted to determine if the responses to the items within and across the themes were statistically different, and if there was a significant change in the students' self-efficacy from the second to last week of course. The correlation between the students' responses to general communication skills and specific communication activities were also compared. Students reported a significant increase in their self-efficacy in being able to communicate effectively. However, the data was more nuanced when the self-efficacy in the specific communication items and the grouped items were compared. Self-efficacy is believed to be an essential part of a person's attitudes, abilities, and cognitive skills. By using this assessment and investigation, we can begin to understand how the graduating engineers may approach goals, tasks and challenges related to communication in the real world.**

Keywords— Communication Skills; Engineering Design; Project-Based Learning; Self-Efficacy; Student Assessment; Survey, Undergraduate

I. Introduction

Effective communication skills are essential for engineers and scientists to be successful in the industry and academia [1], [2], especially in leadership positions (e.g. project managers) [3]. A survey of 4,225 alumni of a large Midwestern public university found that the alumni valued "soft skills", such as communication skills (written and oral) and the ability to work in a team, over "hard skills" (e.g. experimentation) [4]. In another survey, 47 business executives rated communication skills as one of two top-rated soft skills necessary for a work environment, the other being integrity [5]. Despite the recognition of the importance of these skills, a comprehensive assessment or teaching strategy for communication skills remains elusive. This is partly because the engineering course-load for students at many institutions is stretched to its maximum, making it impractical to add classes purely devoted to teaching communication skills to existing engineering curricula. To address this issue many universities have integrated teaching practices such as project-based approaches and engineering design that have been shown to enhance students' communication skills into existing courses. For example, in design-based courses, students generally need to communicate with a variety of partners including fellow team members, engineers, machinists, customers, and other stakeholders to share ideas, thoughts, and technical information. While there is a good amount of evidence that design-based courses benefit student's communication skills, less is known about how the structure or specific activities of the course impact the development of a student's communication skills or a student's attitude about communication skills.

One way to understand how the structure of design-based courses may impact students' communication skills is to examine students' self-perception of their ability to communicate while enrolled in a design-based course. A person's confidence in their ability to carry out a task, known as *self-efficacy*, [6] has been linked to qualities necessary for success such as academic performance [7]; [8], [9], career options [10], persistence, and motivation [11]. Curriculum designers can develop an understanding of what aspects of a course are correlated to development of communication skills by measuring self-efficacy in communication skills. From this fundamental understanding future studies can be designed to identify specific relationships between course design and the development of communication skills.

The objective of this study was to monitor student's self-efficacy in communication skills, while the students were enrolled in a project-based engineering design course. In the engineering design course, the students worked in teams, and designed products for real-world stakeholders. The 32 communication-related survey items discussed in this study were a subset of a more comprehensive instrument developed in-house to measure students' self-efficacy in multiple facets of engineering design. The following research questions guided the investigation described herein:

1) Did the students' self-efficacy in the communication tasks change from week 2 to week 10 of the 10-week term?
2) How were the students' self-efficacies in specific communication tasks correlated with the students' self-efficacy in their general ability to communicate?
3) Are the students' self-efficacies different when the audience (i.e. the person which whom the student is communicating) is different?

4) Are the students' self-efficacies different when the method of communication (i.e. the way the students are communicating) is different?

Most existing assessments for communication skills are either limited to general communication items related to engineering [12]–[14] which do not capture the desired details, or are detailed with respect to a field outside engineering such as medical sciences [15], [16]. Several self-efficacy instruments have been developed to measure students' self-efficacy in science, inquiry, engineering, and research [17], however none of them focus on multiple communication skills related to engineering design. The existing instrument for self-efficacy in engineering design, also does not incorporate detailed items related to communication within engineering design [18]. Although the existing instruments are successful in their respective applications, there is a need for an instrument that can help educators monitor students' attitude (in the form of self-efficacy) towards specific communication abilities that are trivial in engineering design as well as in the work-place.

II. Methods

A. Sample and Course Description

Data was collected from 103 students in round 1 (week 2) and 82 students in round 2 (week 10). Out of the total responses, 65 students responded to the survey both times. The engineering students were enrolled in a project-based engineering design course. Of the 65 students 7 students reported as female, 57 students reported as males, and 1 student preferred not to identify a gender. The sample consisted of 24 seniors and 41 juniors. The course ran for one quarter (i.e. 10 weeks).

In the course the students worked in teams of 4 to 5 students, and were tasked with developing a prototype of a mechanical device that can be used by science educators to teach a natural science and an engineering topic to K-12 students. Science educators from local institutions (i.e. museums and aquariums) acted as stakeholders and customers for the students. Throughout the course the students were in frequent communication with stakeholders and experienced graduate teaching assistants. The course details have been described in a previous paper [19].

B. Survey and Data Collection

A 32-item instrument was administered with students enrolled in the design course described above. The 32-items were a subset of a larger (72-item) instrument that measures students' self-efficacy in engineering design. The survey was prepared using Google Forms and was sent to students via email in the beginning of the second and tenth week of fall 2016 quarter (10 weeks). The students were given 4 days to complete the survey and submit their responses. Students' responses were kept anonymous, but each individual response was identified by a unique hash code that the students generated using an online tool. The students were asked to enter the hash code in each round so that individual responses could be matched and the changes in self-efficacy could be monitored for individual subjects.

The 32 items are presented in the first two columns of Table I. The items included on the survey were a result of close observation of course activities in the previous years, pilot rounds of administering initial versions of the instrument [20], and research on specific communication tasks that are important in the engineering design field.

In addition to item 0, which asked the students to rate their confidence in their ability to generally communicate effectively, 31 items that were more specific to what the students were communicating about (i.e. aspects of the design), who the students were communicating with (i.e. fellow team members, engineers, non-engineers, and customers), and how the students were communicating (i.e. written, orally, or using specifications) were added. These 31 specific communication items (1 – 31) were added so that students' self-efficacy in specific communication activities could be compared to that in general effective communication.

Students were asked the following: "*Rate your confidence in your ability to carry out the following tasks*". The students responded on a scale from 1 to 5, 1 being not confident at all and 5 being very confident. Students' responses were collected and analyzed on Microsoft Excel and Matlab.

C. Data Analysis

Self-efficacy average and correlation:

Three main metrics were computed from the data: average and median self-efficacies reported for the communication activities, and the correlation between the self-efficacies in the communication items and the self-efficacy in general communication skills (item 0 in Table I). Upon initial examination of the data, it was recognized that the relationship between self-efficacy in general communication and the self-efficacy in the specific communication activities could be generally approximated as monotonic. Additionally, since the self-efficacies were reported on a finite and discrete scale of 1 to 5, the Spearman's correlation was computed, which a more relevant statistical measure for variables with limited possible values than the Pearson correlation. Unlike the Pearson correlation which was an estimate of the uniform rate of change in the SEs with respect to each other, the Spearman correlation quantified the monotonic relationship between the two self-efficacies.

Grouping items related to the audience in the communication task:

Out of the 31 specific communication items, 15 items were related to students' ability to communicate ideas, designs, benefits, challenges, functions, and details of products to five different types of audiences. The five categories of audiences were: team-members, people outside the team, engineers, people outside the engineering field, and customers. Table II shows how the 15 items were categorized with respect to an audience.

Within each category A1 – A5, a significance test was conducted to see if the responses to each item in the category were different. First, a one-way ANOVA analysis was conducted on the students' responses in each round (week 2 and week 10). Then, a paired t-test and a Mann Whitney U test was conducted for each pair of items in each category.

TABLE I. COMPLETE LIST OF ITEMS MEASURING STUDENTS' SELF-EFFICACY (SE) IN COMMUNICTION, AVERAGE SELF-EFFICACIES FOR ALL ITEMS REPORTED WITH STANDARD DEVIATIONS, AND CORRELTION OF SE FOR EACH SPECIFIC COMMUNICATION ITEM WITH SE FOR GENERAL COMMUNICATION (ITEM 0).

	Communication Item	**Average ± Standard Deviation**		**Spearman correlation with SE in item 0 (General Communication)**	
		Round		**Round**	
		1	**2**	**1**	**2**
0	Communicate effectively	3.9 ± 0.8	*4.3 ± 0.8		
1	Communicate ideas clearly to my team members who work with me on the same project	4.0 ± 0.8	4.2 ± 0.8	0.7	0.6
2	Communicate ideas clearly to my colleagues who may not be working with me on the same projects	3.9 ± 0.8	4.0 ± 0.9	0.7	0.5
3	Communicate ideas clearly to my team members	4.0 ± 0.7	*4.1 ± 0.9	0.7	0.7
4	Communicate ideas to people outside my team	3.8 ± 0.7	4.0 ± 0.8	0.7	0.6
5	Communicate product details	4.0 ± 0.8	*4.2 ± 0.8	0.6	0.7
6	Clarify the different aspects of the design task	3.8 ± 0.9	4.0 ± 0.8	0.4	0.5
7	Clarify the different requirements of the design task	3.8 ± 0.8	3.9 ± 0.9	0.4	0.4
8	Describe the goal of the design task	3.9 ± 0.7	4.1 ± 0.8	0.5	0.5
9	Describe the goal of a design task	3.8 ± 0.8	*4.2 ± 0.8	0.5	0.6
10	Describe the function or use of the final product of a design task	3.8 ± 0.9	*4.2 ± 0.9	0.4	0.6
11	Describe and clarify requirements of a design task	3.9 ± 0.7	4.0 ± 0.8	0.4	0.7
12	Describe a concept (i.e. form, function, technology and principles of a device)	4.0 ± 0.7	4.1 ± 0.9	0.5	0.6
13	Describe the components of a design	4.0 ± 0.6	*4.2 ± 0.9	0.4	0.6
14	Describe the architecture of a design	3.6 ± 0.8	*4.0 ± 0.8	0.3	0.6
15	Describe the function of a design	4.0 ± 0.7	*4.3 ± 0.8	0.4	0.6
16	Describe the technology used in a design	3.9 ± 0.7	*4.2 ± 0.8	0.4	0.7
17	Describe the principles of a design	3.9 ± 0.7	*4.1 ± 0.8	0.6	0.6
18	Articulate thoughts and ideas effectively using written communication skills	3.8 ± 0.8	*4.1 ± 0.9	0.4	0.6
19	Present the benefits of the product to customers	4.0 ± 0.8	4.1 ± 0.8	0.5	0.5
20	Present the benefits of the product to engineers	3.9 ± 0.7	4.1 ± 0.7	0.5	0.5
21	Present the benefits of the product to non-engineers	3.9 ± 0.8	4.1 ± 0.8	0.6	0.5
22	Present the challenges and solutions to non-engineers	3.8 ± 0.9	4.0 ± 0.9	0.6	0.5
23	Present the challenges and solutions to engineers	4.0 ± 0.7	4.0 ± 0.9	0.5	0.5
24	Explain the functions of the product to non-engineers	4.0 ± 0.8	4.1 ± 0.8	0.6	0.5
25	Present the benefits of the product to non-engineers	4.0 ± 0.8	4.2 ± 0.7	0.6	0.5
26	Describe design requirements and constraints using measurable specifications	3.8 ± 0.7	*4.0 ± 0.9	0.5	0.6
27	Communicate the product details in writing	3.7 ± 0.8	*4.2 ± 0.9	0.4	0.5
28	Explain the product details and function to engineers orally	3.9 ± 0.9	4.2 ± 0.8	0.6	0.5
29	Explain the product details and function to engineers in writing	3.9 ± 0.8	4.0 ± 0.9	0.4	0.4
30	Explain the product details and function to non-engineers orally	3.9 ± 0.8	4.1 ± 0.8	0.6	0.5
31	Explain the product details and function to non-engineers in writing	3.7 ± 0.9	*4.0 ± 0.9	0.5	0.5

Note: Shaded rows denotes a statistically significant change in the self-efficacy from Round 1 to Round 2, based on paired t-test.
* Denotes a statistically significant change in the self-efficacy from Round 1 to Round 2, based on Mann Whitney U test.

The use of paired t-test, which compared the means (i.e. class' average response to a given item), was justified because of the large sample size. However, because the students' responses were not normally distributed, the nonparametric test (Mann Whitney U test), which compared the medians, was also used as an additional measure of statistical significance.

For categories A1 and A2, the significance tests were done to see if the responses to item 1 and 3, and item 2 and 4, respectively, were statistically significantly different. For categories A4 and A5, with more than 2 items, all combinations of pairs were tested for statistical significance. For example, for category A5 with 6 items, the total number of combinations was determined by C (6,2) or ${}_6C_2 = 15$. The responses to all 15 possible combinations of items were tested for any statistical significant differences.

If there was no statistically significant difference in the students' responses (means and medians) to the items in the category, the students' responses were averaged and reported under a single communication item related to that category as shown in Table II. Then the means of the averaged responses

TABLE II. Complete items grouped with respect to audience, average self efficacies (SE) for grouped items reported with standard deviations, and correlation of SE for each grouped communication item with SE for general communication (item 0).

Item Number	Communication Item	Combined Communication Item	Mean ± SD		Median		Correlation with SE in item 0 (General Communication)	
			Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2
0	Communicate effectively		3.9 ± 0.8	4.3 ± 0.8	4.0	4.0		
1	Communicate ideas clearly to my team members who work with me on the same project	**A1: Communicate with team members**	4.0 ± 0.7	4.2 ± 0.8	4.0	4.3	0.7	0.7
3	Communicate ideas clearly to my team members							
2	Communicate ideas clearly to my colleagues who may not be working with me on the same projects	**A2: Communicate with people outside my team**	3.8 ± 0.7	4.0 ± 0.8	4.0	4.0	0.7	0.6
4	Communicate ideas to people outside my team							
19	Present the benefits of the product to customers	**A3: Communicate with customers**	4.0 ± 0.8	4.1 ± 0.8	4.0	4.0	0.5	0.5
20	Present the benefits of the product to engineers	**A4: Communicate with engineers**	3.9 ± 0.6	4.1 ± 0.7	4.0	4.1	0.6	0.6
23	Present the challenges and solutions to engineers							
28	Explain the product details and function to engineers orally							
29	Explain the product details and function to engineers in writing							
21	Present the benefits of the product to non-engineers	**A5: Communicate with people outside of engineering**	3.9 ± 0.7	4.1 ± 0.7	3.8	4.2	0.7	0.6
22	Present the challenges and solutions to non-engineers							
24	Explain the functions of the product to non-engineers							
25	Present the benefits of the product to non-engineers							
30	Explain the product details and function to non-engineers orally							
31	Explain the product details and function to non-engineers in writing							

was computed. The correlations between the averaged responses and the SE in general communication skills was computed for round 1 and round 2. Lastly, the changes in self-efficacy and the correlations were compared for all categories, for both rounds.

Grouping items related to the method of communication:

Out of the 31 specific communication items, 7 items were related to students' ability to communicate ideas, thoughts, product details, design requirements or constraints using three different methods of communication. The three methods of communication were: writing, orally, and using specifications. Table III shows how the 7 items were categorized and merged into three categories (M1, M2 and M3) related to the three methods of communication.

The items grouped using this method were analyzed the same way as the items grouped with respect to the audience (described above).

TABLE III. COMMUNICATION ITEMS GROUPED WITH RESPECT TO THE METHOD OF COMMUNICATION, AVERAGE SELF-EFFICACIES (SE) FOR GROUPED ITEMS REPORTED WITH STANDARD DEVIATIONS, AND CORRELATION OF SE FOR EACH GROUPED COMMUNICATION ITEM WITH SE FOR GENERAL COMMUNICATION (ITEM 0).

Item #	Communication Item	Combined Communication Item	Mean ± SD		Median		Spearman correlation with SE in item 0 (General Communication)	
			Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2
0	Communicate effectively		3.9 ± 0.8	4.3 ± 0.8	4.0	4.0		
18	Articulate thoughts and ideas effectively using written communication skills	**M1. Communicate using writing skills**	3.7 ± 0.7	4.1 ± 0.8	3.8	4.3	0.5	0.6
27	Communicate the product details in writing							
29	Explain the product details and function to engineers in writing							
31	Explain the product details and function to non-engineers in writing							
26	Describe design requirements and constraints using measurable specifications	**M2. Communicate using specifications**	3.8 ± 0.7	4.0 ± 0.9	4.0	4.0	0.5	0.6
28	Explain the product details and function to engineers orally	**M3. Communicate using oral communication skills**	3.9 ± 0.8	4.1 ± 0.8	4.0	4.0	0.6	0.5
30	Explain the product details and function to non-engineers orally							

III. RESULTS

1. Self-efficacy and correlations for all items

Changes in students' self-efficacy in all 32 communication tasks

Students' self-efficacy increased for all the communication items on the instrument. However, the increases were only statistically significant ($\alpha = 0.05$) in 8 out of 32 communication items when the paired t-test was used, and in 14 out of 32 communication items when the Mann Whitney U test was used (Table I). The average changes in the SE in the above tasks ranged between 0.3 – 0.5 (± 0.8 – 1.1 SD). The largest increase was reported for item 27 (ΔSE mean = 0.5 ± 0.9 SD), followed by items 10, 14 and 31 (ΔSE mean = 0.4 ± 1.0, 1.1, 1.1 SD respectively). The lowest increase was reported for items 9, 16 and 18 (ΔSE mean = 0.3 ± 1.0, 1.1, 1.1 SD respectively).

Correlations between self-efficacy in general and specific communication skills

During both rounds (week 2 and week 10 of the 10-week term), the SE in general communication skills (item 0) were positively correlated with the SE in the 31 specific communication items. The correlation values were divided into three ranges: low (0 – 0.3), medium (0.4 – 0.6), and high (0.7 – 1.0).

In round 1, the Spearman correlations were low, medium and high in 1, 26 and 4 of the items respectively (Table I). The correlation was the lowest for item 14 (describe the architecture of a design; correlation = 0.3) and the highest for items 1 – 4 (all related to communicating with people within and outside the team; Spearman correlation = 0.7).

In round 2, the correlation was medium and high in 27 and 4 items respectively. The correlation was the lowest (correlation = 0.4) for item 7 (clarify the different requirements of the design task), and 29 explain the product details and function to engineers in writing), and highest (correlation = 0.7) for items 3 (communicate ideas to team members), 5 (communicate product details), 11(describe and clarify requirements of a design task) and 16 (describe the technology used in design).

From round 1 to round 2, the Spearman correlation increased in 13 items by an average of 0.2, decreased in 9 items by an average of 0.1, and remained the same in 9 items. A complete summary of the correlations is presented in Table I.

2. Self-efficacy and correlations for items grouped by the ***audience***

For category A1, A2, and A4 there was no statistically significant difference in the students' responses to the items in the category. For category A5, majority (12 out of 15 means, i.e. t-test results and 14 out of 15 medians, i.e. Mann Whitney U test results) of the combinations of the items resulted in no significant difference in round 1, and all the combinations resulted in no significant difference in round 2. Category A3 only had one item, so a significance test was irrelevant. Therefore, the students' responses to the items categorized with respect to the audience were averaged for both rounds, correlations of the averaged responses and the general communication SE were computed, and the averages, medians and correlations for both rounds were compared. Table II summarizes the average, medians and correlation values.

In general, students' averaged responses to the items related to communication with team members, people outside the team, customers, engineers, and people outside the engineering field were not significantly different (statistical significance, $\alpha = 0.05$). The statistically insignificance between these responses implied that students reported to be similarly confident in their ability to communicate with the five different category of audiences.

Changes in students' self-efficacy in items grouped by audience

Students' self-efficacy in being able to communicate with different audiences increased from round 1 to round 2, but only the increases in A1 (communicate with team members), A3 (communicate with customers) and A5 (communicate with people outside of engineering) were statistically significant (Mann Whitney U test, $\alpha = 0.05$).

Correlations between self-efficacy in general and audience-specific communication skills

The Spearman correlations between SE in general communication and in items A1 – A5 were all significant ($\alpha = 0.05$), positive and ranged from 0.5 to 0.8. Table II provides a full summary of all correlation values.

From round 1 to round 2, the Spearman correlations of students' SE in general communication with A1, A3 and A4 remained the same (correlation = 0.7, 0.5, and 0.6 respectively) and with A2 and A5 decreased from 0.7 to 0.6.

Students' SE in their ability to communicate with team members (A1) had the strongest correlation with their SE in general communication skills for both rounds. This was consistent with the trends seen when the response to the original, individual items was compared in the previous results section. The correlations of items 1 and 3, related to communicating with team members was 0.6 - 0.7 for both rounds. This implied that students who are likely to report a high confidence in their ability to communicate with team members, are also likely to report a high confidence in their general communication skills, with very few exceptions to this trend. This is also consistent with students' general experience in the department's curriculum. Since most of the students are exposed to team projects and group work from freshman year, they intrinsically correlate that being confident in communication skills is accompanied by being confident in communicating with team members.

Students' SE in their ability to communicate with customers (A3) had the weakest correlation (correlation = 0.5) with students' SE in general communication in both rounds. Students with high communication SE are likely to also report high SE in communicating with customers (positive correlation). However, because the correlation strength was the weakest for this item, there might be more exceptions to this trend than in the case of A1 (with the highest correlation coefficient). This could come from some students (in our sample population) lacking the confidence or experience in communicating with customers. Unfortunately, not all students during their undergraduate years get the chance to interact and work with real customers for their products. Even when students work on projects related to a faculty's research interest, students rarely consider the faculty supervisor as their "customer".

3. Self-efficacy and correlations for items grouped by the ***method of communication***

For categories M1, M2 and M3, there was no statistically significant difference between the students' responses to the items in the respective category. In other words, there was no statistically significant difference between the average or median response of the students to items 18, 27, 29 and 31, all related to writing skills or 28 and 30, related to oral communication skills. Therefore, the students' responses to the items categorized with respect to the method of communication were averaged for both rounds, correlations of the averaged responses and the general communication SE were computed, and the averages, medians and correlations for both rounds were compared. Table III summarizes the average, median and correlation values.

In general, students' self-efficacy related to communicating using all three methods of communication: writing, orally and by using specifications, were not significantly different from each other (statistical significance, $\alpha = 0.05$). At a slightly lower confidence level (90%, i.e. $\alpha = 0.1$), there was a significant difference between the students' response to communicating using specifications and writing skills, and communicating using specifications and oral skills in round 1.

The average self-efficacy of the students increased from round 1 to round 2. The students' SE in communicating using writing skills (M1) increased from 3.7 $\pm$ 0.7 SD to 4.1 $\pm$ 0.8 SD ($p = 0.02$). The students' SE in communicating using specification (M2) increased from 3.8 $\pm$ 0.7 SD to 4.0 $\pm$ 0.9 SD ($p = 0.08$). The students' SE in communicating using oral communication skills (M3) increased from 3.9 $\pm$ 0.8 SD to 4.1 $\pm$ 0.8 SD ($p = 0.06$). When using the paired t-test, for a 95% confidence interval, only the increase in M1 was statistically significant, while for 90% confidence interval, the increases in all three items: M1 – M3 were statistically significant. When using the Mann Whitney U test, for a 95% confidence interval, the increase in M1 and M3 were statistically significant, while the increase in M2 was not statistically significant. The significant increase in students' confidence in their ability to communicate using written skills (M1) is consistent with the trend seen when the responses for each individual item was examined (Table I). The students' response to the original individual items 18, 27 and 31 (all related to writing skills) showed a significant increase from round 1 to round 2.

The correlations between the students' SE in their ability to communicate using the three methods of communication (M1, M2, M3) and the students' SE in general communication (i.e. item 0: ability to communicate effectively), were significant, positive, similar in values, and ranged between 0.5 – 0.6 during both rounds. From round 1 to round 2, the correlation of students' SE in general communication with M1 and M2 increased from 0.5 to 0.6, and with M3 decreased from 0.6 to 0.5. The positive correlations implied that students' SE in general communication and in M1 – M3 increase or decrease simultaneously. The correlation coefficients represented the strength of the correlation. A strong correlation implied very few exceptions in the data set that deviated from the trend. A weak correlation implied more data points (in our case students' responses) that didn't follow the positive trend.

In round 1 (week 2 of the course), communicating using written skills and specifications had the lowest correlation with general communication skills. But both these correlation slightly increased in round 2 (week 10 of the course). Although the correlation was positive, implying that a student likely to report a high confidence level in general communication is also likely to report a high confidence level in M1 and M2, the weak correlation implied that within the sample there were a substantial number of exceptions. In other words, there may be students who were likely to report a high level of confidence in general communication skills, while reporting a lower level of confidence in being able to communicate using writing skills or design specifications. Many students enrolled in the course are not familiar with design specifications during the initial weeks of the course. Therefore, it may be possible that students who did not feel confident in communicating with specs, still felt confident in their general communication abilities. Similarly, most of the students' undergraduate experience in writing skills for communication includes homework assignments or lab reports. Not many students may consider the answering of questions on a HW or reporting data from experiments as "communication". The increase in correlation between the two self-efficacies implies a stronger correlation between the items towards the end of the course than in the beginning of the course. This implies that by week 10, there were less exceptions to the positive correlation of M1 and M2 with general communication. In other words, as the course progressed, students who were either unaware of how to use specifications to communicate or who reported to be confident in general communication, but not-so-confident in using specs to communicate, may have shifted their responses to fit the trend better.

In round 1, the correlation between students' SE in communicating using oral skills and SE in general communication skills was slightly higher than M1 and M2. This was consistent with the students' (our sample population) experience with their engineering courses through the years. Although, students are required to do written reports, lab reports etc., students may continue to consider those elements as "homework assignments" rather than "communicating" their learning to the instructor. However, during oral presentations, it is usually made clear to the students that they are "communicating" their ideas, thoughts, and solutions to an audience face-to-face. Therefore, more students might correlate oral communication skills to general communication skills, stronger than they would correlate written communication skills to general communication skills.

IV. Discussion

The results showed that the students got more confident in being able to communicate using writing, oral skills, and specifications than being able to communicate with different types of audiences. This could suggest the benefit of adding assignments in engineering design courses that encourage the students to communicate, at minimum, with their team members, teaching assistants and instructors, using multiple methods of communication. This was mildly supported by the slight increase in correlation between students' self-efficacy in communicating using specifications and in general communication. Between week 3 and week 10, students learned about, and used target specification when communicating about concepts, design, and product details with the instructor and teaching assistant. This could have contributed to the increase in the correlation between students' confidence in being able to communicate using specifications and their confidence in being able to communicate effectively. Large correlations are desirable because to be a well-rounded and effective communicator, students should be able to use specifications during communication. Therefore, it is desirable that students who report high confidence in their ability to communicate effectively, also report high confidence in their ability to use specifications to communicate.

Although there were no significant increases in students' responses to communicating with different audiences, the correlation between those responses and students' SE in general communication skills were high (0.5 to 0.7). Students may not have reported an increase in their confidence to communicate with different audiences, but at a given time (for example round 1 or round 2), a student who was confident in his or her ability to communicate with team members etc., was also confident in his or her overall ability to communicate effectively. The four individual original items related to communication with members within and outside a team had the largest correlations with general communication. This could suggest that course activities that enable students to engage in team work and communicate with people outside their teams may increase students' confidence in their ability to communicate effectively. The engineering design course (during which the survey was administered) is highly collaborative where students are working in teams starting the first day and are repeatedly presenting and communicating their work with the other teams and customers outside the university.

The one type of audience with the lowest correlation was customers (A3). Although, students got a chance to work with a real customer from outside the university, students' SE in communicating with customers (item 19 in Table I or A3 in Table II) did not significantly change over the course of 10 weeks, and the correlation between general communication and this item remained medium (0.5) and did not change either. This was an interesting finding that will be explored further in upcoming years. This could partly be due to students' lack of experience working with real customers or because of the language of the item itself. Only one item on the survey included the word "customer". To understand if students' perception of a "customer" and "a person outside engineering" is different, a further validation study is needed.

V. CONCLUSION

Overall, the instrument was useful in learning about how students' confidence in their ability to communicate effectively (overall) was related to students' confidence in their ability to communicate specific things, communicate with specific audience, and communicate using specific methods. Although the changes in self-efficacy from week 2 to week 10 were low and statistically insignificant in most cases, the average self-efficacies in all 32 items were above 3.5 (on a 1 – 5 scale). The high self-efficacies can mean a positive attitude from these students towards communicating about different aspects of a design, with a diverse audience using different methods. Students' belief in their ability to communicate (self-efficacy) is an important measure, but to detect "over-confidence", which can hamper learning, it is equally important to learn how their beliefs and confidence levels relate to their actual performance.

The correlations between students' SE in general communication skills and specific communication skills can guide us about students' attitude towards the different communication skills. The positive correlations implied a trend that as a student's SE in general communication increase, their SE in the specific communication items also increases. The strong correlations (> 0.7) implied few exceptions to the trend, while weaker correlation (< 0.4) implied more exceptions. The correlations and the changes in correlations helped us understand how students intrinsically might correlate the various communication tasks to overall general communication.

VI. FUTURE WORK

With the current instrument, we are yet to investigate the students' self-efficacy in communicating different aspects of design such as challenges, benefits, details, architecture etc. In the upcoming months, we will conduct an analysis on this category in a similar way as described in this paper.

Based on the construct validity results (described in a separate paper, in progress) and other significance tests (described in this paper), the number of items on the instrument will be reduced. Shortening the survey will allow us to administer the survey more than twice in ten weeks. Students' responses from more than three weeks will allow us to do a linear regression analysis where we will examine if students' SE in certain communication items can predict students' SE in general communication, and even SE in Engineering Design. It will also allow us to add some qualitative items (in the form of open-ended questions) to the survey to better understand some of the trends discussed in this paper.

For us to map students' self-rated belief in their ability to communicate to strategic pedagogical methods, we need to develop assessment tools that can measure students' skill-set as well. In the upcoming months, we will investigate ways to develop assessments for the same design course that discretely allow the teaching assistants and instructors to assess students' communication skills. We will also develop an assessment tool (survey or questionnaire) for the participating customers to learn how they rate the students' communication skills.

ACKNOWLEDGMENT

We want to thank the instructor and teaching assistants of the engineering design course for their cooperation and assistance in administering the survey.

REFERENCES

[1] D. Q. Nguyen, "The Essential Skills and Attributes of an Engineer: A Comparative Study of Academics, Industry Personnel and Engineering Students," *J. Eng. Educ.*, vol. 2, pp. 65–76, 1998.

[2] J. D. Lang, S. Cruse, F. D. McVey, and J. McMasters, "Industry expectations of new engineers: A survey to assist curriculum designers," *J. Eng. Educ.*, vol. 43, 1999.

[3] H. J. Thamhain, "Developing the Skills You Need," *Res. Technol. Manag.*, vol. 35, 1992.

[4] H. Passow, "Which ABET competencies do engineering graduates find most important in their work ?," *J. Eng. Educ.*, vol.

101, no. 1, pp. 95–118, 2012.
[5] M. M. Robles, "Executive Perceptions of the Top 10 Soft Skills Needed in Today's Workplace," *Bus. Commun. Q.*, vol. 75, no. 4, pp. 453–465, 2012.
[6] A. Bandura, "Human Agency in Social Cognitive Theory," *Am. Psychol.*, vol. 44, pp. 1175–1184, 1989.
[7] K. Bartimote-Aufflick, A. Bridgeman, R. Walker, M. Sharma, and L. Smith, "The Study, Evaluation, and Improvement of University Student Self-efficacy," *Stud. High. Educ.*, pp. 1–25, 2015.
[8] M. Richardson, C. Abraham, and R. Bond, "Psychological correlates of university students' academic performance: A systematic review and meta-analysis," *Psychol. Bull.*, vol. 138, pp. 353–387, 2012.
[9] T. Honicke and J. Broadbent, "The influence of academic self-efficacy on academic performance: A systematic review," *Educ. Res. Rev.*, vol. 17, pp. 63–84, 2016.
[10] R. W. Lent, S. D. Brown, and K. C. Larkin, "Relation of self-efficacy expectations to academic achievement and persistence," *J. Couns. Psychol.*, vol. 31, pp. 356–362, 1984.
[11] F. Pajares, "Self-efficacy beliefs in academic settings," *Rev. Educ. Res.*, vol. 66, pp. 543–578, 1996.
[12] A. O'Dwyer, "Learning and Assessment of Student Communication Skills on Engineering Programs: Some Experiences," 2010.
[13] K. L. Gentili *et al.*, "Assessing students design capabilities in an introductory design class," in *Proceedings of Frontiers in Education Conference*, 1999.
[14] K. G. Wilkins, B. L. Bernstein, and J. M. Bekki, "Measuring Communication Skills: The STEM Interpersonal Communication Skills Assessment Battery," *J. Eng. Educ.*, vol. 104, pp. 433–453, 2015.
[15] G. Makoul, "The SEGUE Framework for teaching and assessing communication skills," *Patient Educ. Couns.*, vol. 45, no. 1, pp. 23–24.
[16] S. Scheffer, I. Muehlinghaus, A. Froehmel, and H. Ortwein, "Assessing students' communication skills: validation of a global rating," *Adv. Heal. Sci. Educ.*, vol. 13, p. 583, 2008.
[17] A. Ibrahim, M. W. Aulls, and B. M. Shore, "Development, validation, and factorial comparison of the McGill Self-Efficacy of Learners For Inquiry Engagement (McSELFIE) survey in natural science disciplines," *Int. J. Sci. Educ.*, vol. 38, no. 16, 2016.
[18] A. R. Carberry, H.-S. Lee, and M. W. Ohland, "Measuring engineering design self-efficacy," *J. Eng. Educ.*, vol. 99, pp. 71–79, 2010.
[19] D. Seth, J. J. Carr Jr., A. D. Wenger, L. D. McNair, and J. L. Tangorra, "College and nonprofit industry partnership: coupling undergraduate projects with K-12 outreach program to enhance engineering education," in *121st ASEE Annual Conference & Exposition*, 2014.
[20] D. Seth, J. Tangorra, and A. Ibrahim, "Measuring Undergraduate Students' Self-efficacy in Engineering Design in a Project-based Design Course," in *Frontiers in Education Conference*, 2015.