Developing Science Communication Skills as a Part of a Summer Research Experiences for Undergraduates (REU) Program

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Introduction

The need for engineering students to develop strong communication skills has been recognized by academia and industry alike since the 1990s, culminating in the addition of a communication student outcome in Accreditation Board for Engineering and Technology (ABET) criteria in 2000[1]. Consequently, universities have created initiatives to develop engineering students' communication skills through various modalities[2,3]. Summer research experiences provide a forum in which students can develop a multitude of technical and nontechnical skills in a brief, learning-intensive period over the summer[4]. This paper examines the implementation and outcomes of a strategic communication intervention aimed at increasing communication skills and self-efficacy among participants of a National Science Foundation (NSF) Research Experiences for Undergraduates (REU) site in biomedical engineering.

Background

Research Experiences for Undergraduates

The beneficial influence of research programs on students' professional and technical development is well established[5]. In a study of multiple REU sites by Hunter and colleagues (2007), faculty reported that students demonstrated specific gains related to the process of "becoming a scientist," with almost half the skills gained related to communication[4]. Furthermore, a survey by Bauer and Bennett (2003) of 2,444 engineering alumni from the University of Delaware showed that those who participated in summer REU programs reported significantly greater enhancement of their communication skills than those who did not[6]. In a

relatively recent review of the state of undergraduate research experiences, Linn and colleagues (2015) identified development of scientific communication skills as one of the key responsibilities of mentors involved REUs[7].

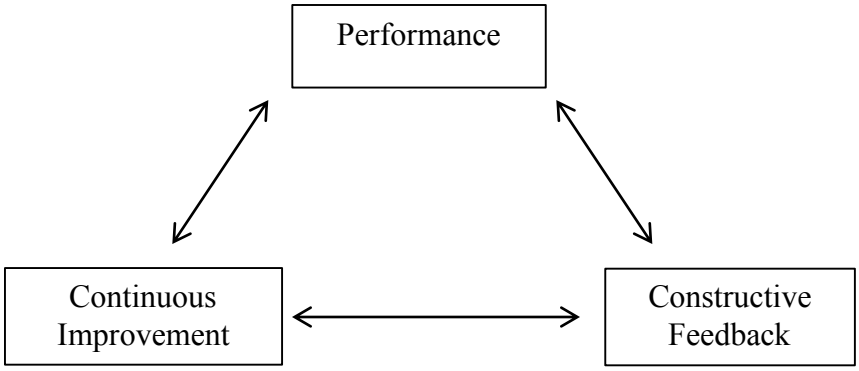
Though there is substantial evidence that REUs have potential to help students develop better communication skills, not all experiences teach communication explicitly. In a comprehensive study of which experiences produce the most gains for STEM students, Thirty and colleagues (2011) found that students most often reported developing oral and written communication skills through coursework rather than research experiences[8]. The authors note that only some of the students in the sample who participated in research presented at professional conferences or formal symposia, which they offer as a potential reason for the lack of communication gains in the summer research setting (2011). It should be noted that overall results suggested participation in research was the most effective way to socialize students into the scientific community. Considering these findings, elements of communication education from the classroom setting have potential to augment skill gains when applied to an REU site. Furthermore, a mandatory professional conference presentation upon completion of the program may incentivize skills practice and enhance the effectiveness of the program. Though many REUs have successfully focused on communication through various modalities, none to date have explicitly documented the use of *deliberate practice* to guide communication interventions.

Deliberate Practice in Communication Interventions

Over the last decade, deliberate practice has become recognized as one of the most effective ways to increase skill gains across a variety of fields[11]. Deliberate practice involves focused, repetitive effort to interactively refine skills through a cycle of constructive feedback

and continuous improvement (see Figure 1) [12]. Feedback is a crucial element to the model, as it allows for improvement at the edge of a students' ability. Developments in video technology have made integrating these aspects into educational experiences easier and more accessible.

Figure 1. Basic Elements of Deliberate Practice



Research from other fields suggests the practice of video recording presentations and receiving feedback yields even greater gains in communication skills. The use of video to record presentations and review for feedback has been referred to as the "gold standard" of communication education, and is widely used in professional education in the "helping professions" such as education, medicine, psychology, and social work[13]. Video recording allows for students to reflect on their presentation at a distance, and offers a realistic picture of their abilities[14]. Furthermore, the video medium offers the ability to parse out specific aspects of communication, such as verbal communication (content of what is being said), para-lingual communication (how it is being said, including intonation, speaking pace and volume), and non-verbal (how it is being displayed, including eye contact, posture, gestures, etc.)[15]. Though many of these elements have been incorporated into communication education for engineers in

various capacities[16], a specific intervention using the elements of deliberate practice to improve communication skills in an REU for BME students is a novel approach.

Present Study

The present study examined the implementation and outcomes of a communication intervention emphasizing repeated practice and feedback on brief, video recorded presentations in a summer REU in at a large research institution. The present paper has the following aims:

1. Describe the communication intervention process and the elements of deliberate practice involved (such as reflection on specific areas of improvement and repetitive practice targeting such areas).
2. Examine the effects of the communication on participants perceived scientific communication self-efficacy and self-assessment of their oral communication skills.
3. Discuss lessons learned and future directions.

Procedures

The present study, protocol number 2016-05-0015, received approval from the institutional review board on June 10th 2016.

Participants

Participants included 11 students who applied and were accepted to a summer REU in the Department of Biomedical Engineering at a large southwestern research institution. Students included 5 females and 6 males from various institutions across the country and represented diverse racial and ethnic backgrounds. Most students were rising sophomores and had varying

levels of prior research experience. Due to the small sample, sample demographics are not discussed in detail to protect student confidentiality.

Measures

Scientific Communication Self-Efficacy Rating Scale (SCSE). The SCSE is a 24-item, three-factor scale developed at The University of Texas MD Anderson Cancer center to measure biomedical students' self-efficacy for writing, presenting, and speaking on scientific topics[17]. Items use a 5-point Likert scale with anchors ranging from "very insecure" (1) to "very confident" (5). Students are instructed, "Please rate your level of confidence, even if you have never done it yet, in your ability to…," and items include the ability to perform or cope with various tasks such as "give an oral presentation at a scientific meeting" or "use the expected scientific style when speaking."

Given the recent development of the SCSE, limited psychometric data is available. A factor analysis included in the initial publication of the scale provided evidence of content validity for the three-factor model (χ 2 (206) = 809.29, $p < .001$; CFI = .96; NFI = .95; RMSEA = .065). A separate study at MD Anderson of 510 graduate students used the scale and reported a coefficient alpha of .91 for the writing scale, .89 for the speaking scale, and .89 for the presenting scale[18]. Statistics were not provided for the Total Scale Score. Despite some limitations, this measure was chosen for its relevance to the goals of the intervention and to the study sample.

Self-Evaluation Rubric. A self-evaluation rubric was developed based on recommendations and examples provided by Spurlin, Rajala, & Lavelle in *Designing Better Engineering Education Through Assessment*[19]. The rubric has not been validated or normed, and was meant to serve as an informal assessment tool rather than a precise measurement of

student outcomes. The rubric included 8 items that asked students to evaluate their presentation on 8 dimensions using a 3-point Likert scale (poor, average, excellent). The evaluation also included 5 free-response reflection questions:

1. "What was your initial reaction to your presentation?"
2. "What was your reaction after watching your video?"
3. "Describe your nonverbal communication (e.g. body language, stance, gestures, rate of speech, tone of voice)."
4. "How did you improve from your last presentation?"
5. "How will you improve on your next presentation?"

The items were adapted as multiple choice and free-response questions and completed by the students through the university's learning management system.

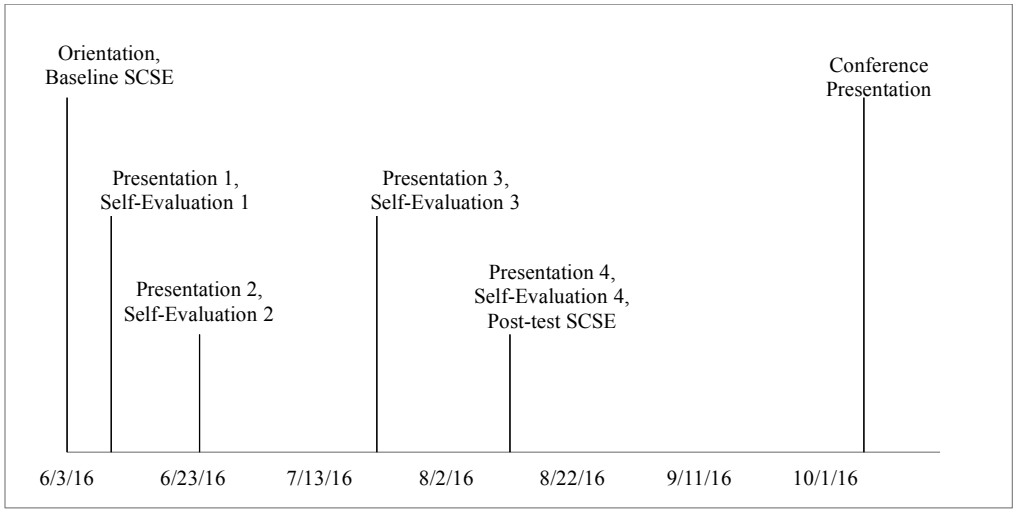
Methods

Shortly after their arrival on campus, students attended orientation for the REU Site. At orientation, they completed the pre-test SCSE measure. As part of the REU, all students worked in a lab with their respective faculty and graduate student mentors and were required to attend a group seminar once a week. The students each worked on a research project under faculty guidance with the end goal of presenting their project in the student poster session at a major professional society annual conference.

In the first weekly seminar, participants were introduced to the communication activity and required to make their first presentation. Each student was asked to present on four different occasions at two- to three-week intervals over the course of the 10-week program. The prompt for each presentation is, "Describe your summer research project in 3 minutes or less." Every presentation was video recorded and then uploaded to the secure university data management

system. After each round of presentations, the group leader facilitated a reflection discussion on the presentation experience before moving to other seminar content. After each presentation day, students were asked to watch their videos and complete the self-evaluation on the learning management system. During the final session, students completed the post-test measure of the SCSE. A few months later, students presented their research posters at the same professional society annual conference, and were informally interviewed about the experience.

Figure 2. Intervention Timeline



Results

Scientific Communication Self-Efficacy Scale. Sample size and survey methods were insufficient to allow for meaningful statistical analysis of the pre- and post- measures of scientific communication self-efficacy. Therefore, the results can only be interpreted descriptively. Mean scores improved by a standard deviation or more on the Writing, Presenting, Speaking, and Total Scales, as shown in Table 1.

Table 1. Pre- and Post-SCSE Means (Standard Deviations)

	Mean (SD)	
	Baseline	**Post**
Writing Scale	35.5 (4.3)	39.8 (4.7)
Presenting Scale	12.3 (3.3)	16.10 (2.5)
Speaking Scale	27 (6.6)	31.6 (3.1)
Total Score	74.7 (11.7)	87.5 (9.7)

Presentation Self-Evaluation Ratings. A Friedman test revealed a statistically significant difference in student self-evaluation scores after each presentation $\chi2(3) = 16.86$, $p = 0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied to test for differences in evaluation scores between each presentation, (Presentation 1 vs. Presentation 2, Presentation 2 vs. Presentation 3, Presentation 3 vs. Presentation 4, and Presentation 1 vs. Presentation 4). The corrected significance level was set at $p < 0.0125$. There were no significant differences detected on self-evaluation scores between Presentations 1, 2, and 3 respectively, despite improvement in ratings upon each presentation. There was, however, a statistically significant improvement between the first (Presentation 1) and the final (Presentation 4) presentations ($Z = -2.807$, $p = 0.005$).

Presentation Self-Evaluation Free Responses.

Student responses to the qualitative questions were reviewed for themes. A sample of representative responses from anonymous students are included below.

What was your initial reaction to your presentation?

> "Horrifying. I thought it went okay, but I was very nervous." (Presentation 1)
> "I definitely have room for improvement, but considering the circumstances it was not bad" (Presentation 1)
> "It was definitely better than last time, I had a better understanding of my project and tried to explained in simpler terms" (Presentation 2)

"I thought it went pretty well. Still stumbling over words, but the organization and descriptions were much better for the most part." (Presentation 3)
"I felt that I have improved greatly since the first one." (Presentation 3)
"I did a pretty good job in this presentation." (Presentation 4)
"I think this was definitely my best presentation and my most well rounded but I could still use more work." (Presentation 4)

What was your reaction after watching your video?

"The first thing I noticed was what I was doing with my hands. They looked pretty floppy in the video." (Presentation 1)
"After watching the video I realized that I had in fact switched up the facts, and that I need to expand more on what I am doing." (Presentation 2)
"Better than the last two times. I said 'umm' a lot, which made me sound really choppy." (Presentation 3)
"I did the best with this category during this presentation. My gestures were small, I could use some more inflection and I could speak a bit quicker." (Presentation 4)

Describe your nonverbal communication (e.g. body language, stance, gestures, rate of speech, tone of voice).

"Looked unsure of myself, voice was forever shaky, always looking up" (Presentation 1)
"My nonverbal communication was, in my opinion, average. I do seem a little insecure in the video, but still am able to speak with good mimicry and a good voice level. I need to improve my stance and try to have more eye contact and less moving around." (Presentation 1)
"Legs kind of bounce, likes to use hands, rate of speech was well varied. Enunciation seems acceptable." (Presentation 2)
"I used way more gestures than last time which was good but I need to stop swaying back and forth as well as using more inflection." (Presentation 3)
"I moved around a bit and tried to make eye contact with different people throughout the presentation. I used my hands and arms to express some of my thoughts. My voice was very clear and confident." (Presentation 4)

How did you improve from your last presentation?

"I was able to keep my hands more still and I got through more of the content." (Presentation 2)
"I better understood what I am doing and was able to give more depth while still using more laymen's term." (Presentation 2)
"I was better at guiding the audience through my project's story. I also engaged with them a bit better." (Presentation 3)

> "As mentioned before I spoke with a lot more confidence since I had already given the speech before during the poster session. I was able to be a lot more concise and was not quite as close to the time limit." (Presentation 4)

How will you improve on your next presentation?

> "Standing in one position and not crossing my arms but have them to either side of my body. Avoid pauses and have complete thoughts flowing that are clear and concise." (Presentation 1)
> "Practice enunciation, breath and relax and take my time." (Presentation 1)
> "Provide the wide example of things and show the application and give more of an idea of what I am doing." (Presentation 2)
> "Plan, plan, plan. Narrow down the background info that is important and relevant." (Presentation 3)
> "I will attempt to highlight the importance of my research and its application." (Presentation 4)

Student responses reflect detailed evaluation of specific areas of improvement. Common areas of improvement identified by students included body language, relevance of information provided, and use of filler words. Students also often commented on achieving confidence through practice. Students tended to have harshly critical evaluations of their presentations after the first presentation, however more positive evaluations emerged later in the program. Most responses reflected recognition of improvement by the final presentation.

Student Conference Feedback. Student feedback was also collected at the large professional society conference, where they each presented a poster on their summer research project. After the session, students were asked to reflect on their presentation. All 11 student responses are included below.

> "Before the conference I was worried about what I would say but then I looked at it again, it brought back all of the memory I had of practicing. Way better than just cramming, I practiced over time, I felt really confident that I knew what I was talking about."

> "Presentations went very smoothly. I didn't get stuck on saying anything because of all the practice that I got. I was able to present more confidently, that is important."
>
> "It helped to know what I was going to say beforehand. I felt more confident. It was uncomfortable doing the presentations at the time, but it made me better. It was important to have the on campus practice before I did this."
>
> "Presentation went well. Practicing helped, because I got peoples' questions, from professors who actually knew what they were talking about. Getting feedback helped me answer confidently. It also eased my nerves. When I finally presented it was no big deal."
>
> "I felt a lot more comfortable on the work I presented. I felt more confident giving the people what they want, that is, catering my position to my audience. Making sure you're not providing redundant information."
>
> "I felt confident, it just went a lot better. It was cool getting feedback from other faculty. Practicing helped a lot, not just for this conference but other times I had to present my research at [my home institution]."
>
> "It was good, people thought it was interesting. The practice helped me be succinct, and deliver a good pitch that was easy to understand."
>
> "The preparation that we did really helped. Everyone at home was asking me what did over the summer, which that really helped with."
>
> "I guess it went well. I hadn't picked it up in a long time. I guess practicing helped."
>
> "They were a lot more picky than I ever thought. Practicing helped."
>
> "I was so happy we practiced, it made it feel more like a conversation rather than forced. I wasn't struggling to think about what to say or reading from my poster"

The majority of the student responses were positive. Though it should be noted that the intervention facilitators conducted the interviews and REU faculty were present, all 11 students mentioned practicing benefited their poster presentation.

Discussion

Students' perceptions of their scientific communication self-efficacy as well as their communication skills improved from pre- to post-intervention. The mean score on the SCSE increased from pre- to post- intervention by more than a standard deviation for the writing,

presenting, speaking, and total score scales. Student evaluations of their communication skills increased upon each presentation, and the improvement from Presentation 1 to Presentation 4 was statistically significant.

Qualitative feedback also reflected student improvement. Student responses to free-response questions on the self-evaluation reflected principles of deliberate practice, such as attention to specific areas of improvement in verbal, nonverbal, and para-lingual communication. The benefits of repetitive practice targeted at areas of improvement were also reflected in the qualitative responses after each presentation. Students evaluated their presentations more positively in later presentations, but continued to find areas to improve upon. Student feedback at the professional conference reflected positive evaluations of their poster presentations, as well as the general belief that the intervention helped them succeed.

Limitations

Analysis was limited by several factors. First, a sample size of 11 makes any meaningful quantitative analysis challenging. Unfortunately, most REU programs only host a small number of students by design. Future research should look into meta-analysis or multisite analysis for a more representative, generalizable sample.

Other significant limitations to the analysis involved errors in survey design and implementation. The identifying information on the students pre- and post-SCSE was lost through the electronic survey medium, which prevented a repeated measures analysis. The already small sample had to be aggregated, thus, means could only be compared qualitatively. Furthermore, the self-evaluation rubric used only a 3-point Likert-scale allowing for little

variation in scores. A 5- or 7-point scale should be used on future rubrics to allow for more incremental and precise ratings.

Several changes to the study design will be implemented to improve future analysis. Faculty evaluations of students' skills will be collected pre-and post-intervention. Faculty evaluation tends to be more accurate than self- or peer-evaluations[20]. Moreover, self-evaluations tend to be inflated, and peer-evaluations are often inaccurate or unreliable[21]. Faculty evaluation data will serve to anchor the student perceptions of skill and improvement.

Peer-evaluations were collected, but ultimately not used for two reasons. First, the peer-evaluation rubrics were similar to the self-evaluation rubrics, relying on only a 3-point scale, which limited variation in scores. Second, variability in the data was further restricted because many students chose to evaluate every peer at the highest ranking (3) for every dimension. Thus, the data collected did not add meaning to the results and was excluded from analysis.

It's possible the students chose to rank their peers highly as to not break rapport within the small group. Evaluations were given in real time, directly after a student's presentation. Though evaluations were anonymous, the setting was not private, which may have inhibited honest feedback. In the future, peer-feedback will be restructured in order to collect more meaningful data. The Likert-scale will be forgone in favor of qualitative feedback that ask students to personally react to well-defined areas of the presentation[21]. Also, students will be assigned only one peer-evaluation to complete upon watching the video after presentation. This will remove some of the burden of evaluating every peer each time, and decrease the pressure of evaluating in the presence of peers. Finally, measuring the participants' reading and comprehension of technical literature as a part of their summer research experience will be considered for future studies with this program.

Conclusions

The communication intervention emphasizing repetitive practice and feedback through video recordings was successful at improving REU student perceptions of their scientific communication self-efficacy and skills. Students were able to identify specific areas of improvement in their presentations by watching their videos. Multiple occasions to practice over the course of the 10-week program allowed for the students to adjust aspects of their presentations and make incremental gains. Despite limitations, the lessons learned in study design and implementation ultimately proved to be strengths of the study. Considering this was the first year of an intervention of this type, this project will continue as a potential model for future implementation of strategic communication interventions in REU programs.

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