Writing Children’s Stories to Improve Engineering Student’s Communication with Non-Engineering Audiences

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One of the biggest challenges for students in science and engineering is communicating technical information to a non-technical audience. Students may struggle because they are not adept writers, because they cannot divorce the ideas from the jargon, or because they simply don't understand the material well enough to explain it to someone else. To attempt to address this issue, this study proposes the use of children’s stories to help students practice writing for a target, non-technical audience. To measure the efficacy of this method, junior level engineering students in an electronics course in Fall 2018 were asked to write children’s stories to explain the operation of specific electrical devices. The students wrote one story at the beginning of the semester and another at the end of the semester. Using a written communication rubric, the stories were assessed by non-engineers (a biologist, a business person, and a physical therapist) to determine if the stories effectively explain the content to a non-technical audience. Without showing the rubric to the students, qualitative feedback was given on the first stories. By receiving this feedback, average review scores for the second story increased by 28.3%, indicating that the second story better communicated the material to the audience. With promising results, this study will be expanded to other areas of science and engineering.

Introduction
It is no surprise to engineering educators that engineering students could greatly improve their communication and other interpersonal skills. The industry seems to value those engineering graduates who excel in written and oral communication [1, 2]. The importance of communication skills is so valuable in the engineering workforce that ABET requires programs to demonstrate that students meet this outcome [3]. Further research suggests that language proficiency, particularly in the area of professional jargon, is an essential skill in modern engineers [4]. To this point, the literature is rich with examples of studies aimed at improving writing skills in engineering. Some studies aim specifically at fostering technical writing skills, while others take a wider approach.

What is difficult to capture from the literature is the fact that engineering students, in particular, along with students in many other fields, struggle to communicate discipline-specific information to those outside their expertise. This is essential for interdisciplinary collaboration often required of engineers. Cooley [5] describes misunderstandings between team members as being one of the primary barriers to effective interdisciplinary team interaction. There are a number of reasons that students in technical disciplines have difficulty communicating information from their field to those outside the field. The primary reason is that many engineering students are not skilled writers [1]. If this were not the case, there would be much less literature regarding improving engineering student writing skills. The second reason is that students (and professionals) often fall into the trap of only communicating ideas through professional jargon. This valuable skill in an engineering setting [4] can obscure meaning in an interdisciplinary setting. Engineers fail to recognize that non-specialists will find their vocabulary inaccessible. The third reason, observed in this work, is that students may not understand the material well enough to describe it to someone. Concrete understanding of complex material is required to effectively explain it to non-experts. If the grasp on a certain topic is tenuous, it is difficult to provide descriptions that make sense to a non-engineer. Providing opportunities for students to write about new ideas may promote a deeper understanding of the material, particularly if they must write to a non-specialist audience [6, 7].
To attempt to address this issue, this study investigated the use of children’s stories to help students practice writing for a non-technical audience. Inspired by the Baby University series [8], students in a junior level electronics course in Fall 2018 were asked to write stories to a broad audience - children. Common professional jargon of engineers would be completely foreign to children, so this provided an excellent platform to test student ability. The first round of stories, completed early in the semester, was aimed at explaining how diodes work. The second round of stories, completed late in the semester, was aimed at explaining amplifiers. Students were provided with qualitative feedback after the first story which was to be used to improve their second.

The hypothesis of this research was that receiving qualitative feedback between children’s stories improves engineering students written communication skills to lay audiences.

The stories were assessed by three reviewers from outside the field of engineering. The reviewer group consisted of one biologist, one business person, and one physical therapist. Stories were assessed in categories of jargon usage, illustrations, conceptual communication, sentence structure, and audience engagement. After the first round of stories, qualitative feedback was provided to each group, but the rubric and scores were not shared in an attempt to avoid students writing simply to appease the rubric categories rather than learning to communicate more clearly. The same rubric was then used to evaluate the second round of stories.

**Previous Work**

Numerous research projects exist to justify the importance of developing communication skills in engineering students [1, 2, 9]. Donnell, et al. [1] surveyed existing literature to identify disparities in desired communication skills between engineering education and the engineering industry and concludes that further study is needed to identify aspects of communication that are being taught well and aspects that require improvement. Consistent with the goal of this current study, Nicometo, et al. [2] studied what constitutes effective communication in the engineering field, pinpointing the particular theme of being able to effectively speak, write, and interact with audiences outside of their specific discipline, workgroup, or focus. The importance of humanities in engineering, particularly in the fields of communication and interpersonal skills, are examined by Khalid, et al. [9], who concluded that engineering students should not be taught only in technical areas of expertise but also in the liberal arts.

Further research explores communication skills in the context of working in interdisciplinary teams, which necessitates student ability to converse with diverse audiences [5, 10]. Cooley [5] describes intervention methods that train groups in communication skills emphasizing the importance of communication in interdisciplinary teams. Thompson [10] discusses interdisciplinary research and the means of fostering collective communication competence, identifying team building and discussion of language differences (reconciling jargon) as foundational to building this competence.

Studies aimed at improving the technical communication of engineering students have tried a vast array of approaches, which can be sorted into three primary categories: those which see a greater emphasis on technical communication skills in courses already within the Engineering curriculum [11, 12, 13], those which add additional writing specific courses (not relevant to this particular study), and those which employ methods external to courses [14, 15, 16, 17, 18].
Within the first category, capstone courses were evaluated for their impact on technical communication competency by Fries, et al. [11] and Hendricks, et al. [12]. Since many capstone courses are already writing intensive, minor adaptations were made to emphasize technical communication skills. Leitche, et al. [13] discussed the integration of several exercises targeted at fostering technical communication skills into three existing engineering courses, with generally favorable results.

The employment of methods external to specific courses has taken many forms in the literature and has shown promise in improving student technical communication. Milke, et al. [14] details a promising communication skills portfolio method implemented at the University of Canterbury, in which lectures, workshops, tutorials, and writing mentors from engineering practice are employed to help students develop a complete portfolio of written artifacts from their courses. Weissbach and Pflueger [15] as well as Miley, et al. [16] describe peer tutor meetings or writing studios to achieve improved results. A web-based tool called The Coach is detailed by Beams, et al. [17], in which a series of web-based writing instruction modules help students learn to write for audiences of engineers. Finally, departmental wide writing guides are explored in practice at the University of Minnesota Duluth by Saftner, et al. [18].

Although a variety of approaches have been attempted to improve engineering student technical communication, few studies emphasize improving communication skills with audiences that are cross-discipline or outside of the engineering field altogether. Even though these skills are highlighted as highly valuable in the literature [2, 9], it seems that little has been done to foster them, which further motivates the importance of this present study.

**Procedure**

In order to test the hypothesis that receiving qualitative feedback between children’s stories improves engineering students written communication skills to lay audiences, students were asked to write two separate children’s stories in a junior level electronics course. These stories were added into laboratory requirements as an additional graded artifact beyond a laboratory report.

The stories were timed to be topical with the content of the course and the lab. The first story, assigned early in the semester, asked students to write a children’s story explaining the operation of diodes, including light emitting diodes (LEDs) and how they behave in series and parallel. The prompt was minimal, requesting that students write stories aimed at elementary students and that the stories must include illustrations. This story corresponded with a laboratory exercise on series and parallel diodes. The second story, assigned near the end of the semester, prompted students to repeat the original exercise, but this time to explain how an electronic amplifier works. This story corresponded with a laboratory exercise on Field Effect Transistor (FET) amplifiers.

Three groups of 2-3 students each participated in this study by writing and submitting children’s stories. Each story was then evaluated by three reviewers from outside of the field of engineering using the rubric shown in Table 1. The first category by which stories were judged was the use of jargon. If unfamiliar words were used, this could inhibit audience understanding. The second category was whether or not illustrations added to audience understanding. The third category assessed was clarity on the concepts after reading the story. Sentence length and structure was the fourth category, and audience engagement was the fifth category.
Table 1: Rubric for review

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jargon</td>
<td>Many difficult words, would be very difficult for a child to understand</td>
<td>Used a few words that would be difficult for children to understand</td>
<td>Used words that anyone can understand</td>
<td></td>
</tr>
<tr>
<td>Illustrations</td>
<td>Illustrations add nothing to understanding</td>
<td>Illustrations add some understanding, but aren't that helpful</td>
<td>Illustrations help promote understanding</td>
<td></td>
</tr>
<tr>
<td>Concepts</td>
<td>I feel like I do not understand the topics that were discussed after reading this story</td>
<td>I feel like I somewhat understand the topics that were discussed after reading this story</td>
<td>I feel like I clearly understand the topics that were discussed after reading this story</td>
<td></td>
</tr>
<tr>
<td>Sentences</td>
<td>Most of the sentences were too long and confusing</td>
<td>Some of the sentences were too long or confusing</td>
<td>Sentences were clear and concise</td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td>This story was too long or boring. It was a chore to read the story.</td>
<td>I was somewhat interested in the story, I felt moderately engaged.</td>
<td>I was very interested in the story, I couldn't wait to see what happened!</td>
<td></td>
</tr>
</tbody>
</table>

Scores could range from 5 to 25 points, in steps of 1. Although the rubric shows only options of 1, 3 or 5 for the score, reviewers could select values between these discrete scores. Three reviewers were used to reduce the impact of inter-rater disagreement. The three reviewers were from the fields of 1. Biology, 2. Business, and 3. Physical Therapy. With none of the reviewers having a background in engineering, they were excellent candidates for this type of review.

In addition to the rubric score, the review form included accommodations for qualitative comments or feedback. The qualitative feedback from the first attempt was provided to each group to help them improve their stories on the second attempt. However, to eliminate variables and to avoid students optimizing for the rubric, the rubric itself and the quantitative review results were not provided to the students. In fact, even the submission grades were not tied to review results, as assignments were graded before the reviews were completed.

Results and Discussion

Figure 1 displays the group by group results for the two attempts, with the average overall group score displayed. It is clear from observing this chart that each group saw an increase in score from the first attempt to the second. Most noticeable was the increase for Group 2, from 8.33 to 15, a delta of +6.67. This group still had the lowest average score in the second attempt but had great opportunity for improvement over the first exercise. The low score in the first attempt was most likely due to a lack of narrative, preferring to communicate the information like a textbook rather than a story. The second most sizable increase was for Group 3, with an improvement from 12.33 to 18.67, a delta of +6.33. The final group, Group 1, saw only modest improvement (+1.33) but also did the best on the first attempt.
Figure 1 displays the overall average score results for the two attempts, showing a change from Attempt 1 (12.11) to Attempt 2 (16.89) of +4.78. The majority of this increase was due to the sizable increases in score for Groups 1 and 2.

Figure 2 displays the overall average score results for the two attempts, showing a change from Attempt 1 (12.11) to Attempt 2 (16.89) of +4.78. The majority of this increase was due to the sizable increases in score for Groups 1 and 2.
The complete overall score results by reviewer have been collected in Table 2, to unify the information from the previous charts and to illuminate other interesting patterns. This table further makes it clear that each group saw an improvement in score, and that all reviewers saw reasonable agreement in overall score and ranking by group on Attempt 1. On Attempt 2, reviewers 1 and 3 generally agreed on overall score, while reviewer 2 notably disagreed. However, reviewer 2 did generally agree on group ranking with the other reviewers.

While useful to look at overall scores, they can obscure where actual improvement occurred. For example, if scores went up as a result of improving illustrations, this does not accurately measure improvement in communication skills. To this point, Table 3 displays the results by category for each group, so that results can be compared across attempt. There are several key takeaways from these results. The first is that the most noticeable increases were in the categories of jargon (indicating a reduction in the use of jargon) and in sentence length and structure. The reduction of jargon usage was greatly encouraging, and potentially one of the best results of this study. Also encouraging was the increase in audience engagement across the two trials. What was surprising however, is that these improvements in use of jargon, sentence structure, and engagement yielded no measurable improvement in audience understanding of the concepts. The reduction in jargon was not met with an increase in understanding of concepts. The stories submitted for the second round were not as focused on a singular concept to explain or there was confusion among students as to the goal of the story. While the jargon decreased, so did the explanations.

It is unclear what contributed to this result, but one contributing factor could be large disagreement between reviewer 2 and the other reviewers in terms of score on the second attempt. Removing reviewer 2’s reviews, Concepts in Attempt 1 had an average of 3.17, and in Attempt 2 had an average of 3.67 for a delta of +0.50. Other factors that could have contributed to this result include the fact that Group 1 saw such an appreciable decrease in conceptual understanding and description in Attempt 2.
### Table 3: Results by category for each group

<table>
<thead>
<tr>
<th>Category\Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>AVG</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>AVG</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jargon</td>
<td>2.33</td>
<td>1.00</td>
<td>2.67</td>
<td>2.00</td>
<td>4.33</td>
<td>2.00</td>
<td>4.67</td>
<td>17</td>
<td>+1.67</td>
</tr>
<tr>
<td>Illustrations</td>
<td>3.33</td>
<td>1.67</td>
<td>2.33</td>
<td>2.44</td>
<td>2.67</td>
<td>2.00</td>
<td>3.33</td>
<td>2.67</td>
<td>+0.23</td>
</tr>
<tr>
<td>Concepts</td>
<td>3.00</td>
<td>3.67</td>
<td>2.67</td>
<td>3.11</td>
<td>2.00</td>
<td>3.67</td>
<td>3.67</td>
<td>3.11</td>
<td>0.00</td>
</tr>
<tr>
<td>Sentences</td>
<td>3.33</td>
<td>1.00</td>
<td>1.67</td>
<td>2.00</td>
<td>4.33</td>
<td>2.67</td>
<td>4.33</td>
<td>3.78</td>
<td>+1.78</td>
</tr>
<tr>
<td>Engagement</td>
<td>3.67</td>
<td>1.00</td>
<td>2.67</td>
<td>2.44</td>
<td>3.67</td>
<td>4.67</td>
<td>2.67</td>
<td>3.67</td>
<td>+1.22</td>
</tr>
</tbody>
</table>

In addition to quantitative results, some examples of student work are provided in Figure 3 and Figure 4 below.

As the water level increases the tree floats away.

This is like when the voltage becomes great enough to turn on the diode.

Figure 3: Page from an Attempt 1 story about diodes.
While these results are promising, and seem to generally affirm the hypothesis, there is still room for improvement. With possible scores ranging from 5 to 25, it could be concluded that mastery of the topic should certainly be scores of at least 20 points. Since no team achieved average scores of this quality, it is clear that more work and practice is necessary to improve engineering student communication with interdisciplinary audiences. Also concerning is that there seemed to be no measurable improvement in conceptual understanding by the audience across the two trials. Perhaps too much emphasis was placed on reducing jargon in the qualitative feedback and not enough on improving understanding. Although this can be, to some degree, attributed to inter-rater disagreement, this is an area to be explored further.

Factors that may have impacted results include a low number of groups of students. The particular results may be in part due to the specific convenience sample used. Poor prompts that were too open ended may also be a culprit in affecting the results. Another concern is that the topics may have been conceptually inequitable. Finally, more reviewers could be employed to further reduce issues of inter-rater disagreement.

**Conclusions**

This study has demonstrated promising results for improving engineering student communication skills with non-engineering audiences. Students were given the exercise of writing a children’s story on a technical topic, and those stories were judged by interdisciplinary reviewers. Qualitative feedback from the review process was provided, and student results on the second story exercise improved. In particular, the usage of professional jargon was greatly reduced, which may improve overall communication across disciplines. However, further improvement could be made in the ability of students to effectively explain topics without the use of jargon.
While the methodology requires further refinement, the approach will be adapted for a botany course in the Spring 2019 semester, allowing the process to be refined for another technical discipline. In this second implementation of the study, the students will be required to revise a single story based on the qualitative feedback. Furthermore, students will later be given an exam question asking them to explain a complex topic to a child. This will allow for direct comparison of stories as well as assess if the student has further integrated this skill. This approach should be simple to adapt and implement at a variety of universities, and for a number of fields, which could make this study particularly impactful.

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References