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Paper ID #16068

Improving Scientific Writing Capability in an Undergraduate Population Using a Fading Paradigm Scaffolding Approach

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Introduction

The Accreditation Board for Engineering & Technology (ABET) requires that engineering students graduate with "an ability to communicate effectively"[1], hence the need for problem based learning approaches that also foster scientific writing skills. This need is typically met through student hands-on experiences and follow-up laboratory reports. Research indicates science concept understanding improves with the use of unstructured context maps and that *writing-to-learn* practices can greatly improve student learning and engagement; however, these practices are often lacking in STEM [2,3,4]. To incorporate these research findings, we developed a fading paradigm scaffolding approach to maximize engineering students' communications skills. Our goal is to elevate the writing capability of undergraduates to the level of graduate students by utilizing a fading paradigm scaffolding approach, where writing templates become less structured over time. We hypothesize that this approach will increase the average writing ability of engineering undergraduates and by the end of one semester, undergraduates will write at a level comparable to entry-level graduate students.

Background

Bioengineering Mechanics I is a junior level course for biomedical engineering majors (BME), and Orthopaedic Biomechanics is a cross-listed course for both senior level mechanical engineering majors (ME) and graduate students from a variety of backgrounds including BME and ME. Both courses take place over a 14-week semester (Fall 2012-2015). In both courses, students complete four lab exercises. Each lab explores concepts in statics, mechanics of materials, and orthopaedic biomechanics. Because the focus in the lab is primarily technical, little formal writing instruction (i.e., lecture) is presented to the students; instead, to improve students' abstract writing, feedback is provided on each abstract they submit. Furthermore, depending on level of study, undergraduate versus graduate, the lab write-up requirements were varied. For all labs, graduate students received an abstract formatting template with only subheadings. In contrast, for the first two labs, undergraduate students received a template with a completed Introduction and Methods section, modeling expectations for these sections. The undergraduate students were required to write the results and conclusion sections in the context of the provided introduction and methods. For the last two labs, undergraduate students received the same templates as the graduate students, forcing them to develop all sections of the abstract and apply the general introduction and methods structure they saw modeled in the first two abstracts. This gradual removal of the abstract template and phase-in of students' abstract writing constitutes a fading scaffold paradigm.

Assessment

Writing samples for all labs and all students will be used for evaluation. To evaluate writing skills, 4 reviewers will complete writing assessments of completed abstracts, blinded to student identities, time-point and student level. Reviewers for the full data set will include mechanical and biomedical engineering faculty and external reviewers such as engineering professionals and science educators. Writing samples will be assessed using a rubric based on a compilation of

grading schemes used by different professional societies. Reviewers will undergo calibration procedures to increase inter-rater reliability; inter-rater reliability will be measured after reviewers have graded the full set of abstracts. To minimize perception shifts over time, reviewers will be asked to grade abstracts in a 3 week time span after all abstracts are collected, rather than as abstracts are submitted throughout the duration of the course. To test the hypothesis that the fading paradigm scaffolding improves undergraduate students' writing over time, statistical comparisons of the blinded/graded undergraduates' writing samples from across the semester (results and conclusions sections for the 4 labs) will be made using a 1-way ANOVA with post-hoc analysis. Separately, a 1-way ANOVA with post-hoc analysis will be used to determine whether graduate students' writing (which did not undergo the fading paradigm scaffolding) improved throughout the semester with the 4 lab write-ups. To test the hypothesis that by the end of one semester undergraduates will write at the same level as entry graduate students, final lab (Lab #4) write-up scores from undergraduates will be statistically compared to the initial lab (Lab #1) write-up scores of graduate students using a t-test. This assessment will include all sections of the abstract (Introduction, Methods, Results, & Conclusion). Combined, the results of these assessments will be used to identify potential writing mechanisms to develop stronger writing skills in students.

Preliminary Results

As a preliminary study, a total of 38 undergraduate writing samples have been assessed by four graders within a 10 day time span. The graders included two mechanical engineering professors, one biomedical engineering professor, and one biomedical engineering PhD candidate (note that for the full dataset, reviewers representing a broader set of disciplines will be used, along with measurement of inter-rater reliability). Twelve samples were from Lab #1, nine were from Lab #2, eight were from Lab #3, and nine were from Lab #4. At this time, our sample size is too low to make rigorous statistical comparisons; instead, these results can be used to identify potential trends. In this preliminary study, only results and discussion scores were analyzed. We found that results and discussion scores were lowest for lab 1 compared to the other three labs (Figure 1). Focusing on the results section scores, we found that the biggest increase in scores occurred between labs 1 and 2. For the subsequent labs, there were no trends toward increasing score. For the discussion section, scores again increased from lab #1 to lab #2. However, there was a reduction in scores from lab #2 to lab #3 and a moderate increase from lab #3 to lab #4.

In addition to scoring, graders were encouraged to provide feedback in the form of comments. Multiple comments for Lab #1 indicated poor results and discussion. Specifically, figure formatting was an issue: '*Results consisted of a single figure with no text or caption!*' & '*Results-Very poor representation in text. Would have been better as a table.*' In the subsequent labs, the number of negative comments referring to results or discussion was largely reduced. However, there was an increase in the number of negative comments referring to the Introduction section for lab #3 and lab #4, which is when the scaffolding was removed for the undergraduate students.

Discussion

At this point our results seem to indicate that undergraduates' writing skills do improve over the course of a semester when using the fading paradigm scaffolding; however, our preliminary results are limited by sample size. Comments from the graders indicate that for labs #1 and #2,

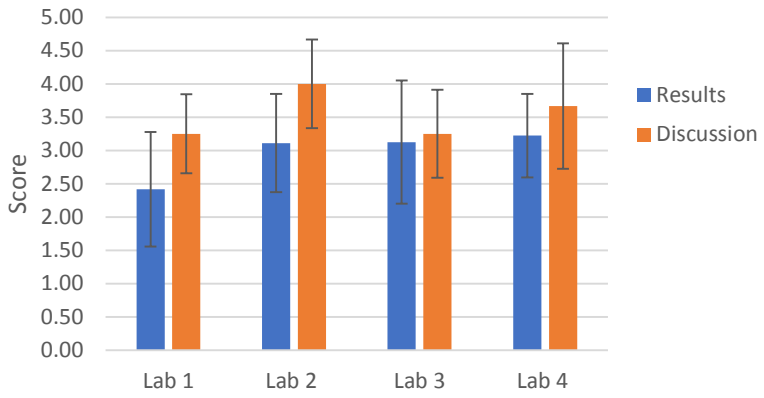

Figure 1: Results & Discussion scores (out of 5 points) for undergraduate students for labs #1-#4. (Avg. ± Std. Dev.)

figure and table formatting was an issue. This issue may have been a distraction from the text contributing to the low scores. Overall, there is still room for improvement with these students. Regardless of section or time point none of the average scores were greater than 4 out of 5 points.

In assessing the sections individually we found an initial increase in score after lab #1 for the results section that remains relatively unchanged for the following labs. This may indicate the initial lab writing experience may provide the biggest opportunity for learning. Since the course did not include lectures on writing, the gains in the results section were likely due to students learning from feedback provided on their first abstract submission. The discussion section scores exhibit an initial increase (lab #1 to lab #2) but that is followed by a decrease in score (lab #2 to lab #3) and then minimal increase for the final lab assignment (lab #3 to lab #4). When transitioning from lab #2 to lab #3, students were required to write all sections of the lab, which may detract effort from other sections of the lab leading to the decrease in score. The minimal increase we see in score from lab #3 to lab #4 may indicate growth in all sections.

In the future, we plan to continue evaluating writing samples in our database, approximately 120 so far, while adding more writing samples to the database from other courses utilizing the same template. Once all samples are graded, we will be able to assess graduate student writing skills and undergraduate writing skills. Additionally, within our graduate student groups we believe further investigation into peer evaluations may lend insight into the contributions of individual students to indicate if senior or entry graduate students contributed more. This information may enhance our understanding of undergraduate writing skills versus graduate writing skills. In conclusion, the preliminary results of this work-in-progress suggest that a faded paradigm scaffolding may improve undergraduate students' writing skills through the semester.

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