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Technical Writing as a Learning Objective: Implementation of A Diminishing Scaffolding Model in a Lab-Based Biomaterials Course

Dr. Sonia Bansal, Duke University

Dr. Sonia Bansal is an Assistant Professor of the Practice for the Department of Biomedical Engineering at Duke University. She has been teaching for the department for 2 years and is researching best practices of curricular integration of technical skills such as writing, computing, and design. She graduated from the University of Pennsylvania with a Ph.D. in Bioengineering in 2020 from the McKay Orthopedic Research Laboratory under the guidance of Dr. Robert Mauck and uses her background in orthopedic engineering to develop courses in the biomechanics and biomaterials space. Dr. Bansal teaches 4 classes a year including BME 221: Biomaterials, EGR 201: Mechanics of Solids, BME 530: Introduction to Tissue Biomechanics, and EGR 101: Engineering Design and Communication. She is the co-director of the Biomedical Engineering Education & Teaching Laboratory (BEETL) at Duke.

Kat M Lazar, Duke University

Kat Lazar is a PhD Candidate in Biomedical Engineering at Duke University. She works in the labs of Joel Collier and Ashutosh Chilkoti to develop protein-based biomaterials to address diseases of the immune system. She obtained her bachelor's in chemical and biological engineering from Tufts University, where she also received a minor in education. Kat has over five years of experience as a teaching assistant in a variety of lecture- and lab-based science courses, including general chemistry, undergraduate level biomaterials, and graduate level biomolecular engineering. She is an NSF GRFP recipient and a fellow at the Duke University Center for Biomolecular and Tissue Engineering, an interdisciplinary consortium that trains students in scientific communication and collaborative skills.

Jaron Shoemaker, Rensselaer Polytechnic Institute

Jaron Shoemaker is an incoming Ph.D. student in the Biomedical Engineering Department at Rensselaer Polytechnic Institute. He will be working under the mentorship of Dr. David Corr on innovative cancer model fabrication and tissue engineering research. He graduated with a B.S.E. in Biomedical Engineering from Duke University in 2025.

Elizabeth Feeney, Duke University

Dr. Elizabeth Feeney is a Senior Lab Administrator in the Biomedical Engineering Teaching Laboratories at Duke University. She coordinates, develops, and teaches labs in biomaterials, mechanics, and physiology. She graduated with a PhD in biomedical engineering from Cornell University in 2020.

Work In Progress: Technical Writing as a Learning Objective: Implementation of A Diminishing Scaffolding Model in a Lab-Based Biomaterials Course

Introduction and Motivation

Technical communication focuses on conveying scientific information in a clear and concise way. It is therefore a learning goal in high-level engineering courses as a preparatory skill for the work force. Accordingly, instructors use a myriad of communication tools such as final projects, lab reports, and poster pitches as deliverables in their courses [1]. These approaches not only test recall, understanding, and application of course material, but also help students analyze and evaluate data and/or primary literature [2]. Indeed, ABET guidelines require that Biomedical Engineering curricula must include "Making measurements on and interpreting data from living systems" (1.d). While vital to the curriculum, students often struggle to meet course-specific and seemingly arbitrary expectations. Coupled with task-focused rubrics, which are essential for efficient and multi-grader agreement especially in large classes [3], students focus on producing work that fits specifications or rubrics, instead of focusing on skill development.

To develop writing as a skill, we have implemented "scaffolding" for students as they write lab reports in our Biomaterials course. This course is a required, 200-level course that is most commonly taken by 2nd semester sophomore students or 1st semester junior students. It is the pre-requisite to multiple 300-level "Area Core" courses which expose students to core topics within Biomedical Engineering. As this is a required class, enrollment during the Fall and Spring semesters ranges from 35 to 55 students per semester.

Scaffolding was first introduced by Wood and colleagues in 1976 [4] to describe creating support within an assignment to support student performance. It is particularly useful when a skill is in the "Zone of Proximal Development", the area between what a student can do without help and what a student cannot yet do [5]. In general, it is meant to decrease cognitive load for learners and additionally help students accomplish tasks in the present while improving performance in the future [6]. Broadly, scaffolding has been used across disciplines and student levels, and it is for this reason that we believe it can be applied to technical writing.

A core strategy in scaffolding is to reduce assistance over time, allowing students to progressively grow skills and build independent mastery [7], [8]. "Scaffold fading", as implemented by Chang and colleagues, supports this framework by reducing the amount of support given to students in subsequent assignments. In this study, scaffold fading was found to be an improvement over the control group [8].In this study, we use a "diminishing scaffold", which serves the same purpose as "scaffold fading" in conjunction with high-feedback grading on lab reports. Our goal is to interrogate if providing high feedback and diminishing scaffolds for lab reports leads to higher quality lab reports at the end of the semester, and if students' perceptions of writing skill is improved by this support.

Study Design

The course has four laboratory experiences, each of which requires students to perform two or three connected experiments around a theme (Metals, Polymers, Hydrogels, Surfaces). Students

work in teams to complete the experiments, which work together to provide context into the design decisions that are made in biomedical devices. Students then complete independent lab reports in which they analyze data and provide recommendations for how a device should be designed or implemented. Lab reports are independent submissions due 10 days after completion of the lab.

Starting in Spring 2024, two aspects of this lab were scaffolded: the written protocol and the assigned lab report. First, the protocol is set up as a worksheet with guiding questions, prompts, and space to brainstorm figures. These worksheets are designed to inform their data analysis, discussion, and figure generation in the report. The worksheets are collected and graded for effort, and TAs provide clear and detailed feedback identifying incorrect interpretations of data or inappropriately formatted figures - guiding students to make smart decisions in their written report. Specifically, feedback is given on hypotheses, theorized mechanisms behind the findings, data entry tables, figure design, and statistical plans. The number of questions and associated points on the worksheet (**Table 1**) decreases from the first lab (many required questions, thirty points) to the last lab (few optional questions, zero points).

Table 1: Points and number of questions on each lab protocol in total and by type of question.

	Total Points (questions)	**Hypotheses and Mechanisms** Points (questions)	**Data acquisition and observations** Points (questions)	**Figures and statistics** Points (questions)
Lab 1	30 (20 Q)	12 (7 Q)	12 (10 Q)	6 (3 Q)
Lab 2	20 (12 Q)	10 (5 Q)	4 (4 Q)	6 (3 Q)
Lab 3	10 (10 Q)	5 (5 Q)	3 (3 Q)	2 (2 Q)
Lab 4	0 (9 Q)	0 (5 Q)	0 (2 Q)	0 (2 Q)

The complementary scaffold is for the lab report. These are suggested outlines for the written report and are optional for student use, though highly encouraged. The scaffold for the first lab is detailed and suggests specific, key, topics to expound on in the introduction and discussion sections. These topics are organized into sample paragraphs. The scaffold also features suggested figure captions and styles and example phrasing for objectives and procedure sections. The scaffold becomes more general in the second lab, focusing on themes to cover instead of exact topics to discuss. In the third lab, the scaffold is even more generalized, with some sections (procedure, objectives, conclusion) blank, and other sections suggesting that students write about material-nonspecific concepts. The goal of this penultimate scaffold is to be entirely generalizable, so that students could use the same guidelines to write the third and fourth lab report. The last lab's scaffold is blank. The teaching team provides detailed feedback and returns reports at least one week before the next report is due to ensure continuous improvement. As scaffold support decreases, the points associated with the report increase (first: 20 points, last: 50 points), such that the total score for each lab is out of 50 points.

After submitting the lab report, students complete a self-reflection including two Likert-style and four free-response questions. Likert-type questions (1 – Strongly Disagree, 2 –Disagree, 3 –Neither Agree nor Disagree, 4 – Agree, 5 – Strongly Agree) include "I was able to follow the protocol for this lab" and "I feel confident that I can write a lab report". Free-response questions ask students to share the "muddiest point", their most and least favorite aspects of the lab, and any additional comments if applicable.

Historical data from Fall 2023 (prior to study initiation) was collected, and students were consented for their participation in this study so they may serve as a control group. Students in the Fall 2023 cohort performed similar experiments under the guidance of the same teaching team, but experienced traditional, non-scaffolded lab protocols and reports. Fall 2023 students did submit the same post lab reflections as the 2024 cohorts.

All reported scores are presented as a percentage of the student's score on the lab report with respect to the total points associated with that lab to allow for comparisons across lab reports regardless of report "weight". Data were analyzed using Graphpad Prism (v 10.4). Data were analyzed using either a 1-way Repeated Measures ANOVA (lab report scores) or a Kruskal-Wallis test (student self-reported confidence from the Likert-style, "I feel confident that I can write a lab report" question). Tukey's post hoc tests were used to determine if lab report scores were significantly different between each lab experience. An unpaired t-test was used to compare final lab report scores between cohorts. A Mann-Whitney test was used to compare final self-reported confidence between the two cohorts.

Human Ethics Statement

This work was approved by Duke University IRB under protocol #2024-0218. Primary outcomes will include scores on each report, responses to the Likert-type questions, and coding of free-response questions. Secondary outcome measures include trends in lab report scores across reports to determine the impact of continuous feedback and reflection and trends in student confidence over time.

Results

In the first semester (Spring 2024) of this study, 24 of 34 total students (70.6%) provided consent. This course was also offered in the Summer session in 2024, and there, 6 of 8 students (75.0%) provided consent. The number of consented students in the Fall 2024 cohort (total: 53 students) is unknown at this time. Nine students from the Fall 2023 cohort (control cohort, total: 36 students, 25%) provided consent for this study.

Preliminary analysis indicates that students from the 2024 cohort improved upon their lab reports (**Figure 1**) from the first lab (77.78 ± 9.28 %) to the third (84.29 ± 14.00 %, $p = 0.02$) and fourth labs (84.80 ± 12.01 %, $p = 0.001$). There were no statistically significant differences in student scores between the first and second labs (80.85 ± 13.65 %, $p = 0.65$). Interestingly, the students from the 2023 cohort (no intervention) showed no significant differences between lab reports ($p > 0.085$ for all comparisons). When considering student self-evaluation of writing confidence, we saw no significant differences in either the 2024 cohort ($p = 0.13$) or the 2023 cohort ($p = 0.34$) across lab experiences (**Figure 2**).

When comparing students from each cohort, there were no statistical differences in the final score (2023: 82.11±11.99 % vs 2024: 84.80±12.01 %, $p = 0.56$, **Figure 3**). However, there was a modest difference between the self-reported confidence of students in each cohort (2023: 3.57±0.53 / 5.00 vs 2024: 4.10±0.90 / 5.00, $p = 0.08$**, Figure 4**). Qualitative coding of data has not yet been performed.

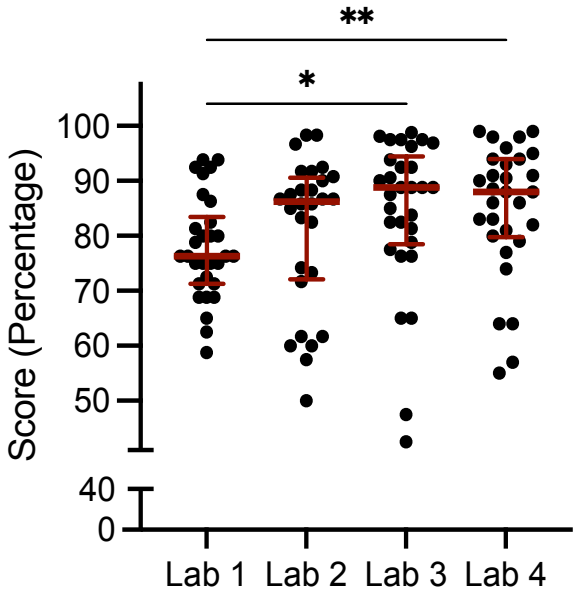

Figure 1: Student scores on each lab report in the 2024 cohort. Scores reported as a percentage. Red lines indicate median and interquartile range. Statistical significance denoted by asterisks, (* = $p < 0.05$, ** = $p < 0.01$)

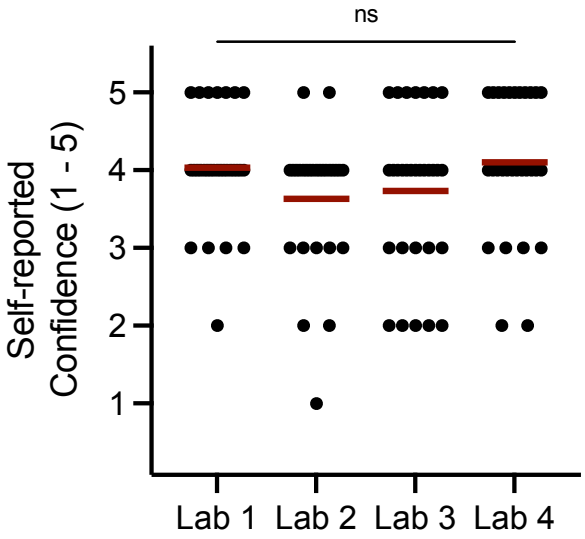

Figure 2: Student self-reported confidence (Likert-type question) after submission of each lab report in the 2024 cohort. Scores reported as an integer value between 1 and 5. Red lines indicate mean.

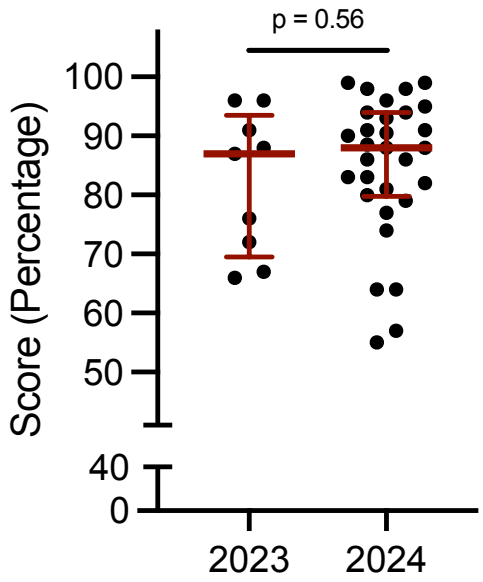

Figure 3: Student scores on the final lab report in both the 2023 and 2024 cohorts. Scores reported as a percentage. Red lines indicate median and interquartile range.

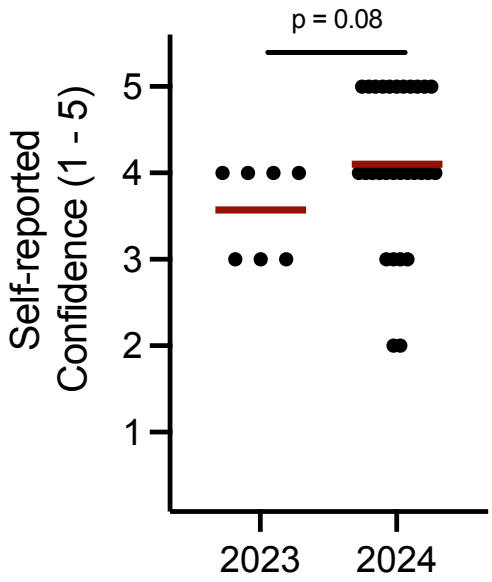

Figure 4: Student self-reported confidence (Likert-type question) after submission of each lab report in both the 2023 and 2024 cohorts. Scores reported as an integer value between 1 and 5. Red lines indicate mean.

Discussion and Conclusion

Overall, this work in progress paper indicates a mild improvement in student scores given a scaffolded lab report approach, particularly in the later half of the course. These data suggest to us that at least two scaffolds are needed to establish expectations and provide guidance on content and organization. We believe that the third scaffold creates a transition for students to start thinking more generally and is therefore valuable. Interestingly, students had similar final scores on labs between cohorts. On the flip side, while student self-reported confidence did not improve from lab to lab in the cohort who experienced scaffolding, the scaffold cohort (2024) was more confident in their skills at the end of the semester compared to the untreated (2023) cohort.

This study has many limitations, the most salient of which is that the TA and Grader team was not constant over time. While there is a rubric for each lab report, the graders themselves are a variable in this study. One of the TAs who supported this course in the Fall 2023 semester returned for Spring 2024 and Fall 2024, so future analyses will check for inter-TA agreement with the returning TA as the benchmark. An additional limitation is the small sample size for the control (2023) cohort. This group of students was consented for their data after the end of the semester, which is likely why the consent rate was so much lower than students in the 2024 cohort. In general, the students who choose to consent to their data being used in a pedagogical study could be more inclined towards metacognitive goals, which may make them more receptive to active feedback loops. Therefore, this is another limitation in this study. Lastly, the Spring 2024 cohort was the first group to experience the scaffolds and worksheets, and the teaching team has made tweaks to the scaffolds due to student feedback. Specifically, scaffolds for Labs 2 and 3 were adjusted after Spring 2024 due to student perceptions that the Lab 3 scaffold removed too much from the Lab 2

scaffold. To address this, the teaching team generalized the Lab 2 scaffold and added more detail to the Lab 3 scaffold before the summer offering.

Next steps of this study will focus on quantitative data analysis of the Fall 2024 cohort in addition to coding free response questions for all students. We plan to use the qualitative responses to provide context for if students found the scaffolding useful and if they liked having a scaffold to guide both the experimental and technical writing aspects of the lab report. Through this study, we hope to develop best practices in teaching technical writing for long-term skill development. Additional work will investigate persistence of writing skill into other courses.

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