Board 6: Work in Progress: Alternative Lab Reports for Biomedical Engineering

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Abstract

This paper is a Work in Progress to describe the implementation of alternative lab reports in biomedical engineering curriculum. Communication skills are critical for engineering students to succeed in a wide variety of careers. This necessity is recognized by ABET in student outcome 3 "an ability to communicate effectively with a range of audiences" [1]. Despite this, students may not view written communication skills as an important skill for engineers. Technical writing instruction and practice is often implemented in undergraduate laboratory courses where students write standard lab reports (abstract, introduction, materials and methods, results, discussion) that most closely resemble a scientific journal article. In an effort to demonstrate to students how they might communicate about experimental data in different ways and to prompt them to consider communicating data to a range of audiences and for varying purposes, we developed alternative lab report assignments for a biomedical engineering laboratory course offered to sophomore undergraduates. In addition to developing written communication skills, the writing assignments were designed to demonstrate to students how they might write in careers in the biotech industry. Here we describe the implementation of alternative lab reports for a cell and tissue engineering lab course. We present the implementation of the report structure, associated rubric used for all reports, preliminary student feedback, and limitations of the approach.

Introduction

Effective and efficient communication is a necessary skill for engineers. Communication skills are often recognized by educators and employers as critical for undergraduates [2]. The recent revision in ABET criterion 3 from g "an ability to communicate effectively" to 3 "an ability to communicate effectively with a range of audiences" [1, 3] highlights the importance for students to learn to tailor communication to the intended audience. Despite the importance of communication skills, engineering students' lack of technical writing skills remains a problem nationally [4]. Engineering students may not believe they are good writers, with some even citing a perceived inability to write as a motivation to study engineering. Further, the misconception that writing is not a skill required for engineering professionals can contribute to poor student attitudes towards writing.

In an effort to engage students and demonstrate the necessity of technical communication skills in a variety of engineering professions and provide situated-learning [5] development of writing skills, faculty have developed alternative lab report formats (i.e. memos, narrative reports, letters) and delivery mechanisms (i.e. presentation, poster, written document) [6-8]. To build on this work, as well as provide specific examples in biomedical engineering, we sought to develop lab activities coupled with technical writing prompts to demonstrate the connection between experiment and technical communication. Towards this goal, we developed four class modules (plasmids and bacteria, mammalian cells, pharmaceutical drugs, and enzymes) with corresponding technical report prompts meant to demonstrate technical writing by biomedical engineers to different audiences. Here we describe the implementation of the alternative laboratory reports in a cell and tissue engineering lab course for sophomore students.

Course Description

Cell and Tissue Engineering Lab is a 2-credit lab core course for sophomore students in the Bioengineering major. The course is comprised of a weekly 50-minute lecture and a four-hour laboratory session. Enrolled students are required to have completed an introductory molecular

and cellular biology course. Experimental techniques covered in the course are shown in Table 1. Students complete four lab reports each worth 5% of the final grade, for a total of 20% attributed to lab reports. Students are also evaluated on electronic lab notebook documentation, participation, problem sets, pre-lab quizzes, a lab practical, and a cumulative exam.
The course is designed in four modules with each having an associated written report (Table 1). For each of the four reports, students are presented with a scenario where they collect data on one of four biologicals: a plasmid, a mammalian cell line, a drug, and an engineered enzyme (Table 1). For each of these biologicals, students prepare a different type of technical report to share and discuss their data with different audiences (see Appendix 1 for rubric).

Table 1. Labs, Experimental Techniques, and Reports in Cell and Tissue Engineering Lab.

Lab	Title	Experimental Techniques	Report
1	Lab Orientation and Safety	Use of micropipettes, pipet-aids, and safety mechanisms	None
2	Bacteria Growth	Culturing and plating bacteria,	Plasmid
3	Bacteria Transformation	Transformation by heat shock	Plasmid
4	qPCR for Plasmid Copy Number	DNA prep and qPCR	Plasmid
5	Mammalian Cell Culture: Growth and Differentiation	Basic cell culture and differentiation	Mammalian Cells
6	Cell Lysis and Cell Freezing	Preparing cell lysates and freezing cells	Mammalian Cells
7	Fixing and Staining Cells	Fixing, staining, and imaging cells	Mammalian Cells
8	Fluorescence Microscopy	Fixing, staining, and imaging cells with fluorescent stains	Mammalian Cells
9	Protein Quantification	BCA assay	Pharmaceutical Drug
10	Protein Detection by Western Blot	Western blot	Pharmaceutical Drug
11	Restriction Enzyme Kinetics	Restriction digest, gel electrophoresis	Enzyme

For each of the four biologicals investigated, biotech companies whose products and/or services work with the biological are presented in the lecture along with background knowledge. Students are presented with a prompt that asks them to imagine themselves in a particular role at a biotech company and the technical document they will write after collecting their data. Prior to the submission of each lab report, students complete a problem set where they complete detailed calculations and analysis on the collected data. The problem sets are designed to prompt students to consider the meaning of the data before presenting it in a report. The problem sets also allow instructor feedback before students prepare the report.

Lab and Report Prompts

For each prompt, students were instructed to write a different type of technical report, including a validation report, a product report, a conference abstract, and a quality report. Prompts included a brief description of the different technical documents and examples from a variety of industries were shared with the class (see Appendix 2). Technical document types and their intended audiences were discussed in class before students prepared their reports.

Student Feedback

The alternative lab report format has been utilized in the Cell and Tissue Engineering Lab course for eight semesters with several revisions to the prompts and rubrics. Overall, student feedback has been positive. Before submitting reports, students were asked in an early course feedback survey whether they felt prepared for technical writing based on their previous coursework. Of students responding, approximately 77% indicated that they did not feel prepared from previous coursework to write technical documents (n = 69, approximately 74% response rate). In final course evaluations, students frequently listed "technical writing skills" or "scientific writing" in response to the course evaluation question "What aspects of this class were most beneficial to you?" In the open response feedback, students often stated that they felt the reports helped them to develop technical writing skills: "The reports were good technical writing experience" and "…I actually really appreciate this opportunity to improve as a technical writer". In response to the open-ended question "Comment about grading procedures and exams" negative comments about the reports were most frequent in the first semester offering and centered about fairness of grading (including between teaching assistants) and expectations for the reports not being clear enough (e.g. "Some expectations are slightly unclear and just assumed to be known"). Intra-grader reliability in the course was addressed in subsequent semesters by enhancing teaching assistant training where teaching assistants graded a set of mock reports to discuss together with the instructor, and by "blinding" teaching assistants to points on rubrics to emphasize evaluation of the rubric statements instead of assessment of points [9]. Since addressing these issues in separate interventions, negative feedback on grading and expectations has largely decreased. A few students expressed their dislike of technical writing assignments, with one student commenting: "Technical writing assignments are tedious and distract from the intriguing topics being taught". In final course evaluations, students described their appreciation for the context given to the labs and reports in the open-response. One student wrote, "I feel like I am doing something real with my knowledge and skills". Other students specifically commented that they felt the assignments were more interesting because they gave perspective on technical writing in industry. One student wrote, "Thank you for also making these assignments interesting! Especially from the perspective of a student who wants to go into industry." No students gave negative feedback about the imagined scenarios that framed the labs and reports.

Conclusion

Here we present four lab and assignment prompts developed for a bioengineering laboratory course. For each set of experiments, students were presented with an imagined scenario of conducting work in the biotech industry. These imagined scenarios gave context to the experiments being conducted and gave students examples of utilizing the techniques in the "real-world". For each set of experiments, students were presented with a report prompt that matched the imagined scenario for the experiments. The implementation of alternative lab reports described here has several limitations. While switching report types provides an opportunity to expose students to different technical documents and practice for students in communicating to different audiences, it does not give students the opportunity to iterate and apply gained knowledge in a new report of the same format and purpose. This limitation could be minimized by implementing re-submission opportunities for students [10]. In the present study, we found that some students struggled with the idea that the scope and purpose of the report changed for each assignment, showcasing the challenge in communicating to varying audiences. Further, a limitation of the data presented here is that course evaluations are not compared to the same course being offered with standard lab reports. While overall response from students is positive, future work is needed to determine the value of these alternative lab reports compared to standard lab reports and across formats for both student engagement and development of technical writing skills.

Appendix 1. Report Rubric

	Excellent	**Satisfactory**	**Unsatisfactory**	**Incomplete or Missing**
Data Presentation (35)	Figures and diagrams are well-designed and are the best representation of the data. (5)	Figures and diagrams adequately show the data and are mostly well-designed with a few minor issues.	Figures and diagrams are not well-designed. The choice of data presentation is an inaccurate representation of the data collected.	Figures and diagrams are not included in the report.
	Figures/diagrams use space in the report effectively (i.e. no large white areas, images are cropped appropriately). (5)	Figures/diagrams mostly use space in effectively.	Figures/diagrams do not use space effectively and would benefit from redesign.	
	There is no extra information, coloring, gridlines or other features on the figures/diagrams. (5)	There are a few minor instances of extra information, coloring, gridlines or other features on the figures/diagrams.	There are several instances of extra information, coloring, gridlines, etc. on the figures/diagrams.	
	All axes, symbols, legends, etc. are appropriately labeled with correct units. (5)	Axes, symbols, legends, etc. are appropriately labeled with correct units with one or two minor exceptions.	Axes, symbols, legends, etc. are not labeled, have incorrect units, or are missing.	
	Figure captions contain the appropriate details for the data presented. (10)	Figure captions contain most of the information needed to interpret the figure but may be missing one or two minor details or include unnecessary detail.	Figure captions are lacking key pieces of information or experimental details or include unnecessary detail.	Figures do not have captions.
	All figures, diagrams, and tables have descriptive and succinct titles. (5)	All figures, diagrams, and tables have appropriate titles that contain the necessary information to interpret the data.	Some figures, diagrams, and tables lack appropriate titles.	Figures and tables lack titles.
Analysis (15)	Data analysis is accurate and complete. (10)	Data analysis is mostly accurate with few minor errors.	Data analysis is largely incorrect and/or incomplete.	Data analysis is incorrect or missing.
	Calculations and/or analysis are fully described and all units are shown. (5)	Calculations and/or analysis are adequately described and all units are shown.	Description of calculations and analysis is incomplete and/or incorrect and units are incorrect and/or missing.	There is no description of calculations and/or models.
Objective/ Purpose (10)	The report is written for the correct audience and the objectives are clear. (5)	The report is largely written for the correct audience and the objectives are mostly clear.	The audience for the report is not clear and the objectives need to be more clearly stated.	The report is not written for the correct audience and objectives are not stated.
	The report contains the necessary information in various sections of the report and is well-organized. (5)	The report contains most of the necessary information in the appropriate sections of the report and is mostly well-organized.	Information is scattered throughout the report and/or some information is missing. The report would benefit from reorganization.	Several pieces of necessary information are missing from the report and the report is not organized.
Discussion (20)	The report shows the author has a thorough understanding of the experiments performed and data collected. (5)	The report shows the author has a satisfactory understanding of the experiments performed and data collected.	The report shows a lack of understanding of several important concepts regarding the experiments performed and the data collected.	The report shows a lack of understanding of the cocepts and experiments performed.
	All statements are accurate and appropriate scientific vocabulary is used. (5)	Statements are mostly accurate but may have a few minor errors or misconceptions. Appropriate scientific vocabulary is used.	Statements are inaccurate and there are several instances where scientific vocabulary is not used or used improperly.	All statements about results are inaccurate or missing.
	Sources of error are identified and thoroughly discussed. (5)	Sources of error are identified but not fully discussed.	Sources of error are not reasonable or are not supported.	Sources of error are not addressed.
	Conclusions drawn from the data are reasonable given the data collected and are fully discussed. (5)	Appropriate conclusions are drawn from the data but are not fully discussed.	Conclusions are not drawn from the data or are unreasonable or not supported.	No conclusions are drawn from the data.
Writing (20)	A strong, formal voice is used throughout the report. (4)	A formal voice is used throughout the report.	Some of the writing and vocabulary in the report is informal or inappropriate for a technical document.	The writing and vocabulary used in the report is informal and inappropriate for a technical document.
	The writing is concise and word choices are precise. There is no ambiguity in the writing. (6)	The writing is mostly concise and word choices are mostly precise. There is little ambiguity in the writing.	The writing is wordy and includes unnecessary lead-ins and/or is repetitive. Word choice is largely not precise and is often unclear. There is consistent ambiguity in writing and word choice.	Writing is consistently wordy and repetitive. Word choice is not precise. Ambiguity in the writing and word choice makes the report difficult to read.
	All figures and tables are appropriately referenced in the text. (3)	All figures, tables, and diagrams are referenced in the text but not in the appropriate place.	Some figures, tables, or diagrams are not referenced in the text and/or are inappropriately referenced.	Figures and tables are not referenced in the text.
	The report contains no spelling or grammatical errors and is easy to read. The report looks professional and follows assignment guidelines (page limits, etc.). (3)	The report contains one or two minor spelling or grammatical errors and is easy to read. The report looks mostly professional and follows assignment guidelines.	The report contains several spelling or grammatical errors and is difficult to read. The formatting and appearance of the report is unprofessional and distracting and/or assignment guidelines were not followed.	The report has numerous spelling and grammatical errors. The report appears unprofessional. Assignment guidelines were not followed.
	References are used appropriately and properly formatted. (4)	References have one or two minor formatting issues.	References are not formatted properly.	Necessary references are omitted.

Appendix 2: Prompts

Plasmids and Bacteria

In the plasmids and bacteria module, students are asked to validate a plasmid that they receive from a scientist wishing to deposit the plasmid in a databank. Given a plasmid map and described plasmid features, students conduct experiments to validate the features of the plasmid (antibiotic resistance, transcriptional regulator, gene of interest) and determine the copy number, in addition to analyzing sequencing data.

Plasmids and Bacteria Lab Prompt:

> You are an engineer at a biotech company that maintains a repository of plasmids generated by scientists. You received an aliquot of pGLO plasmid with a map (showing araC, GFP, and bla genes as presented in lecture) and a sequence (available in the electronic lab notebook) from the depositing scientist. The scientist also states that the copy number in *E. coli* DH5-α is 200-400. Before making this plasmid available to other scientists, your job is to validate the plasmid and deposit a stock of the plasmid DNA in your company's repository.

Plasmids and Bacteria Report Prompt:

> Using the data you collected in lab, your job is to write a validation report that verifies the pGLO plasmid submitted to your company. Your **validation report** should include three sections:
>
> - **Executive summary**: A few (1-2) sentences that explains the purpose and result (pass/fail) of the testing described in the report.
> - **Description (very brief!) of pGLO plasmid and features** (including a figure with a plasmid map).
> - **Validation of pGLO plasmid features**: Data that demonstrates the functionality of bla, araC, and GFP genes. For each gene, describe the test (Means of Verification or MoV), the Findings (expected result compared to the obtained result), and whether the test confirms the functionality (Pass or Fail).

Mammalian Cells

In the mammalian cells module, students learn to culture, differentiate, freeze, and thaw 3T3-L1 cells. Through image analysis, students determine the doubling time of 3T3-L1 cells.

Mammalian Cell Lab Prompt:

> Imagine the following scenario. You are an engineer at a biotech company that first isolated and studied 3T3-L1 cells. After isolation, you characterized these cells by examining cell growth, inducing the cells to differentiate, freezing, and thawing cells.

Mammalian Cell Report Prompt:

Now, you need to provide documentation, in the form of a **product report**, to other scientists who will buy and use these cells. Your task is to write this product report describing 3T3-L1 cells given the data you collected in lab and information covered in lecture **only**.

Your report should include the following sections **with supporting data** collected in lab:

- **Description and images of 3T3-L1 cells**. Brief description of 3T3-L1 cells that was covered in class (what type of cell, what species, differentiation behavior (you do not need to use additional information about the cells if we did not cover it in class)). You should include a brightfield image, image of differentiated 3T3-L1s, and merged fluorescence images of differentiated and non-differentiated 3T3-L1s. Images should include appropriate titles and captions.
- **3T3-L1 characteristics**. Cell characteristics, including doubling time, morphology, adherent vs. non-adherent, etc.
- **3T3-L1 culture conditions. Briefly** describe the growth requirements and maintenance of 3T3-L1 cells (media, BSL, etc.). You do not need to include protocols.
- **Uses of 3T3-L1 cells**. *Based on your data*, propose what research area(s) and experiments 3T3-L1 cells are well suited for and why.

Pharmaceutical Drug

In the pharmaceutical drug module, students imagine they are working at a pharmaceutical company studying a new drug. Students learn about the intended target of the new drug and the signaling pathway. Cell growth inhibition by the drug is analyzed through image analysis and cell lysates are collected for signaling pathway analysis.

Pharmaceutical Lab Prompt:

> Imagine the following scenario. You work as a bioengineer at a pharmaceutical company in the Drug Discovery department. Your team performed a screen and identified MEK1/2 as a good protein target to inhibit cell growth. You have been working with a team of chemists who synthesized a new drug (inhibitor) that should target MEK1/2. Your job is to characterize this new drug in 3T3-L1 cells and submit your work to an academic conference (after your company has patented the compound!)

Pharmaceutical Drug Report Prompt:

> You will be submitting your results to the Biomedical Engineering Society (BMES) annual conference and will prepare a 1-page abstract that includes an Introduction, Materials and Methods, Results and Discussion, Conclusions, and References. See the BMES abstract template on the course website for more details. Abstracts are limited to **1-page** including figures and references.

Enzymes

In the enzyme module, students use two different restriction enzymes to digest a fluorescently tagged PCR product. One of the enzymes is a native enzyme and the second is an engineered enzyme marketed has having improved kinetics. Samples of the fluorescently tagged PCR product are digested for various time and the resulting digests are separated and analyzed by gel electrophoresis. The resulting gel image can be quantified at each time point for a measurement of product formation. The data acquired is then used to calculate the Michaelis-Menten constant for each enzyme.

Enzyme Lab Prompt:

> Imagine the following scenario. You are a scientist at a biotechnology company that engineers enzymes. Your colleagues recently engineered the BsaI enzyme to improve its kinetics (BsaI-HF). This new enzyme will likely be appealing to customers, but they will want to see data that shows that the enzyme is in fact better than the original and that it does not have off-target (“star”) activity (to convince them that it is worth the higher price tag!)

Enzyme Report Prompt:

> As the quality engineer at your company, you will prepare a **quality report** to demonstrate that the newly engineered enzyme performs to the specifications that you are claiming (faster restriction digests). You will also need to provide data to prove that your newly engineered enzyme does not exhibit “star” activity (that it does not digest DNA that does not contain the BsaI site). Your report should include a figure of DNA gel showing BsaI and BsaI-HF timecourse and the reported Km values for each enzyme. You should also show data demonstrating lack of BsaI-HF star activity.

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