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Exposing First-Year Engineering Student to Research-Based Technical Communication Through the use of a Nanotech Project

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Abstract

This complete evidence-based practice paper will explore a first-year engineering (FYE) course that includes an eight-week-long project involving various technical communication components. First-year engineering programs have increased in popularity over the past decade in engineering, primarily due to their success in introducing undergraduate engineering students to engineering experiences. Although the content and structure of these FYE courses vary from institution to institution, their purposes remain the same: To prepare engineering students for their engineering education experience, as well as future engineering positions. Popular content choices for a FYE course include engineering design, mathematics, design/programming software, and technical writing. Of all these content areas listed above, technical writing is arguably one of the most difficult. Many students come into their collegiate engineering experience formally writing only for English classes, and have a hard time adjusting to writing technically when they are asked to write about engineering assignments, labs, or projects.

This paper will outline a FYE course that includes an eight-week-long project involving multiple technical communication components. This course is the second in a FYE sequence that emphasizes the importance of technical writing. In the first course of the FYE sequence, students are taught to write either a lab report, memo, or abstract over labs that they complete on a weekly basis. In the second course of the sequence, students are exposed to different types of technical communication. To complement their research project, students are asked to read assigned journal articles related to the research project, as well as find journal articles of interest and present them to the class in groups. The final deliverables of their projects include a grant proposal, a journal article, a technical presentation and a research poster. The goal of this course's project is to expand students' exposure to and experience with technical writing beyond lab reports and abstracts, and push them to engage with other forms of communicating technical research.

FYE students elect to take the research project-based course as the second in the sequence, as opposed to a robotics design course. These students frequently choose this option because they are interested in engineering research, or learning what engineering research looks like at the collegiate level. The learning objectives of the course include that students should gain experience in designing experiments, performing hands-on research work, and presenting their findings in a meaningful way. It also incorporates heavy design components, the engineering design process, and teamwork. The selected forms of technical writing align with these objectives and encompass real-world standards and restrictions to give students realistic experience should they choose to present at a conference, apply for research funding, or publish their work throughout their academic careers.

By exposing students to research-related technical writing such as proposals and journal articles, students gain an expanded understanding and appreciation for the technical communication and are better prepared for their own engineering research experiences, should they choose to have them.

Introduction

First Year engineering courses have become very popular in the last few years with nearly sixty percent of engineering programs having some sort of incoming first-year engineering course or class sequence [1]. These FYE programs vary based on content and focus, but many of them, employ methods such as project-based learning, as well as design projects [2]. These methods of teaching, as opposed to traditional lecture settings, have been shown to increase student learning, as well as improve the student experience [3]. Although project-based learning, problem-based learning, and design projects have their place and have been shown to be beneficial, if not done well they may fall short in conveying what a realistic design or engineering project may look like to students based on resource limitations or poor execution of the learning experience [4]. It is important for FYE instructors to be diligent and continuously look for ways to improve and diversify their FYE experiences as to not fall into a pattern of complacency with regards to the content or how it is presented.

One way that FYE programs expand FYE courses beyond typical early engineering experiences is through the incorporation of technical communication components. Technical writing is component of many FYE courses that has found its way into curricula due to its lack of exposure in many other engineering courses. Industry leaders have identified communication as a deficient skill of some graduating engineers [5]–[7]. FYE courses have worked to incorporate technical writing and technical communication into their curricula through the use of lab reports, abstracts, and technical presentations accompanying labs and assignments [8], [9]. These technical writing and technical communication experiences do expose students to a form of technical writing, but with a very narrow scope. Not all engineers will be required to write or read abstracts or lab reports. The scientific community has various ways to disperse technical content, such as technical talks, poster presentations, conference proceedings, journal articles and editorials, grant and funding proposals, and calls for proposals. Many of these forms of technical communication go unnoticed and untaught in engineering teaching communities.

Research experiences are not as common as internship experiences for engineering students, but these opportunities introduce engineering undergraduates to an entire community of practice that exists to advance learning and knowledge. These early research experiences have benefits such as introducing students to teaming in a collaborative work environment, developing problem defining and problem solving skills, exposure to a variety of technical communication devices such as research posters and forums, and many other academic advantages [10]. Little has been published about how early research experience exposure can be incorporated into FYE courses to develop the skills that research experiences can provide to undergraduate engineering students. Research-based technical communication such as journal articles, grant proposals, and poster presentations can expand students' understanding of the importance of technical communication and the role it plays in the dissemination of knowledge.

Course Background and Description

[University's] College of Engineering requires all students to complete a two-semester introductory FYE course sequence. The first semester course offerings give students experience with engineering design, problem-solving processes, computer programming, and a weekly laboratory experience that introduces students to different engineering disciplines and teaches technical writing through assignments given after lab experiences. The second semester courses contain graphics and computer-aided design content, as well as consisting of a multi-week project that students work on in teams. Table 1, below, shows the first semester course options that students select, as well as the typical second semester options that follow the completion of the first semester course. The focus of this paper is on the content and structure of the nanotechnology project in the fundamentals of engineering honors sequence.

Table 1: Table of first-year engineering students course options in their first two semesters.

First Semester	Second Semester
Fundamentals of Engineering	Design Project
Fundamentals of Engineering Honors	Integrated Business and Engineering Project
	Robotics Project
	Nanotechnology Project

The nanotechnology option is commonly selected by students in engineering majors that are more popularly known for biological research and consists of two concurrent projects for about 40 students. Figure 1, below, shows the enrollment of students in the Spring 2019 Nanotechnology course by major.

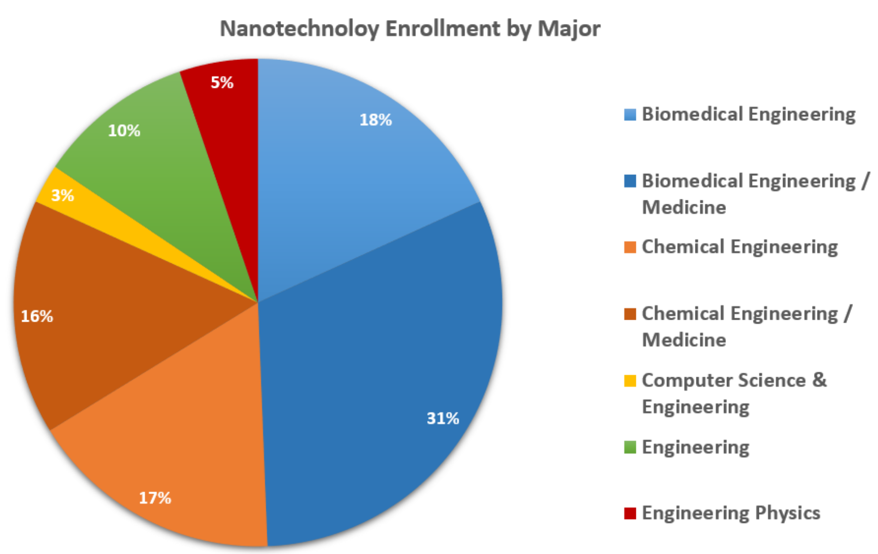

Figure 1: Enrollment in Spring 2019 Nanotechnology course by student declared major.

The first project assigned to students is an experimental research project focused on microfluidics, where students select a variable and test its effects on yeast cell adhesion in a polymer microfluidic channel. Student teams design and mold their own microfluidic silicon chip. They troubleshoot, collect. and analyze data. Finally, they present the results in a journal article-style report. The second project, focused on nanotechnology, is the theoretical design of a lab-on-a-chip device to test for a disease from a small bio-fluid sample. Students conduct literature reviews, select a disease or condition, and design and model their point-of-care device in detail. They write a mock grant proposal and give a poster presentation on their design that focuses on its importance and what future work would be needed to create a functioning prototype.

An instructional team for a Nanotechnology course section of up to 32 students consists of a faculty instructor, a graduate teaching associate (GTA), and three undergraduate teaching assistants (UTA). The instructor and graduate assistant both act as lecturers, the undergraduate assistants act as graders and additional student resources. Instructors and GTAs hold weekly office hours, and UTAs staff evening open labs in which students are encouraged to come run experiments and seek answers to questions they may have while working on their projects and assignments. Grading is done by the team of UTAs and the GTA who share grading responsibility and frequently grade together to ensure inter-grader reliability.

Course Project Description, Structure, and Deliverables

Course Overview

This research based FYE project offers students an opportunity to develop a strong understanding of engineering fundamentals including problem solving, the design process, and technical communication. Over the course of an eight-week period, students work to complete two main projects:

1. Micro: designing and carrying out an experiment on a microfluidics chip testing yeast cell adhesion property to a silicon wall
2. Nano: researching and designing a lab-on-a-chip device that utilizes nanotechnology to diagnose a disease from a drop of bio-fluid

Collaborating in groups of three to five, students are ultimately tasked with managing project deadlines, conducting and analyzing experimental research, developing an innovative device based on an accumulation of existing research, and producing several final deliverables as a means of presenting the research that was conducted.

The structure of this course aims to scaffold the students' research experiences. In-class assignments ensure that students are staying up to date on both projects, while also further developing their technical communication skills. Along with these in-class assignments, students are encouraged to begin compiling their research according to the final project documentation guidelines. Two forms of documentation are required for each project. The microfluidics project consists of an academic journal article and an oral presentation, while the nanotechnology project will culminate in a National Institutes of Health (NIH)-style grant proposal and a poster presentation. Students are also required to design a website that will document the entire project experience in detail. All final deliverables have drafts that are reviewed by the instructional staff throughout the eight-week period. Constructive and actionable feedback is given so students have several opportunities to revise their projects and documentation. A detailed explanation of each of these final deliverables can be found in subsequent paragraphs. Table 2 on the next page shows the assignments and deliverables with draft deadlines, as well as when they are incorporated into the course structure throughout the semester.

Table 2: Nanotechnology project assignment and deliverable semester schedule.

Week of Semester	Class Day	Assignment(s) Assigned	Assignment(s) Due
3	F	Journal Club	
4	M		
	W	Project Website, Journal Article - Final, Grant Proposal - Final	
	F	CNTOTD #1, CNTOTD #2, Grant Proposal Annotated Bibliography	Journal Club
5			
6	M	Journal Article Design Stage 1, Grant Proposal Design Stage 1	
	W		Grant Proposal Annotated Bibliography
	F	Journal Article Design Stage 2	Journal Article Design Stage 1
7	M	Lab 1 Worksheet	
	W		
	F	Lab 2 Worksheet, Journal Article Design Stage 3	Journal Article Design Stage 2
8	M	Grant Proposal Design Stage 2	Grant Proposal Design Stage 1, Lab 1 Worksheet
	W	Lab 3 Worksheet	
	F		Lab 2 Worksheet
9	M		CNTOTD #1*
	W	Journal Article Experimental Procedure	Journal Article Design Stage 3
	F		Grant Proposal Design Stage 2
10		**Spring Break**	
11	M	Journal Article Outline, Grant Proposal Outline	
	W		Journal Article Experimental Procedure
	F	Journal Article – Draft 1, Grant Proposal - Draft, Grant Proposal Design Stage 3	Lab 3 Worksheet, Journal Article Outline, Grant Proposal Outline
12	M		
	W		
	F	Journal Article – Draft 2	Journal Article – Draft 1
13	M	Oral Presentation	CNTOTD #2*
	W	Poster Presentation	
	F		Grant Proposal Design Stage 3
14	M		
	W		Journal Article – Draft 2
	F		Grant Proposal - Draft
15	M		
	W		Oral Presentation
	F		
16	M		Project Website, Journal Article - Final, Grant Proposal - Final, Poster Presentation

*Assignment due throughout the week for different teams

Assignment 1: Journal Club

Students are assigned a scientific journal article regarding nano- or micro-scale technology in microfluidics. After reading the article, students compose a short summary of the text and are encouraged to write down any questions they came up with as they were reading. In class, students participate in 20-minute small group discussions related to the content of their journal articles. Superficially, this assignment serves to introduce aspects of research and technology at the micro- and nano-scale in which the students will be working for the duration of the course. However, on a fundamental level this assignment serves as a preliminary introduction to technical communication. Not only are students exposed to scientific literature, they are encouraged to interact with the text – summarizing it in a way that makes sense to them, and discussing the technical information with their peers.

Assignment 2: Cool Nano Topics of the Day (CNTOTD)

This assignment consists of two in-class presentations given over the course of the eight-week project. The project team members deliver 10-minute PowerPoint presentations based on a scientific journal article discussing nano-scale technology that interests them. Following each presentation, peers, TAs, and instructors ask questions related to the content and give feedback on how the presentation went well and how the team can improve. This assignment provides students with opportunities to explore nanotechnology they can incorporate into their design projects, and develops fundamental technical communication skills. Students are responsible for identifying reliable scientific literature, reading and understanding the technical language used, and presenting it in a way their fellow peers will understand. This requires the ability to comprehend technical writing and also consider their audience when presenting the information. Students must have a strong, working understanding of the content so that they are able to clearly explain ideas and answer questions from peers and instructors.

Assignment 3: Laboratory Data Collection

Three labs take place over the course of the eight-week project timeline. The first of the three labs spans two, two-hour class periods and uses SolidWorks flow simulations on the micro-scale. The second lab also spans the two class periods, following the first lab. The focus of this assignment is experimental data collection similar to what students will do for their projects. During this lab, students practice recording raw data in a lab notebook as they conduct a procedure to calibrate water flow through a microfluidic chip. The final lab walks students through the procedure of molding a microfluidic chip. Students are introduced to the basic procedure they will use and modify as they conduct their own research. While communication-based aspects of these labs are less immediately apparent than in previously discussed assignments, students continue to develop these fundamental skills by using technical terminology and taking detailed technical notes in a laboratory notebook.

Deliverable 1: Microfluidic Experiment Academic Journal Article

After four weeks of data collection, all results of the microfluidics project are compiled into a mock academic journal article. Students are encouraged to examine journal articles they read, as well as utilize a template provided with the assignment. The template lays out an example journal article, and encourages students to write an article that contains traditional sections such as an abstract, introduction, methodology, results, discussion, conclusion, acknowledgments, and references.

Deliverable 2: Microfluidics Oral Presentation

Compared to the technical writing of the academic journal article, the oral presentation highlights the importance of professional verbal communication. Students are instructed to create a PowerPoint presentation that encompasses the microfluidics research conducted over the eight-week project. This presentation is given during class and peers are given the opportunity to ask questions regarding the presentation. While similar to the CNTOTD presentations, this final presentation gives a platform in which students are required to analyze their own data, rather than simply summarizing the results of other researchers.

Deliverable 3: Nanotechnology Grant Proposal

The NIH-style grant proposal culminates all the Nano projects students completed. Like the Micro report, this assignment provides students with a real-world opportunity to apply the technical writing skills they have developed over the course of the project. In this proposal, students are required to include the following sections:

- **Specific Aims**: provides a project summary and the three main stages or goals of the proposal
- **Background**: introduces the selected disease with the device's purpose and a brief overview
- **Significance**: explains why the device is needed and relevant to society
- **Innovation**: depicts the differences between the innovative technology and currently existing diagnostic techniques
- **Research and Design Methods**: details all processing steps needed for disease detection or diagnosis, in addition to a rational for each step
- **Summary, Conclusion, and Bibliography**

Deliverable 4: Nanotechnology Poster Presentation

Students also create a poster that captures the need for and innovative design of their nano-scale device. This poster includes background information related to the diagnosed disease, 3D visualizations of the device, materials and methods used for disease detection, and overall project conclusions. The final poster is presented alongside the university's Senior Design Capstone Presentations. At this event, poster presentations are assessed by faculty, graduate, and former FEH undergraduate student judges. This assignment specifically requires students to translate the technical writing from their grant proposal into a medium that encourages visual interaction with their audience. The poster format requires students to consolidate their report into a product that clearly communicates the importance and functionality of the project-based research.

Deliverable 5: Project Website

This final deliverable contains documentation from both projects. This assignment is introduced at the beginning of the projects and is updated throughout the semester. Students are required to upload brainstorms, intermediate design reports, raw data, report drafts, and final deliverables to this site. Students are also instructed to design this website as if their reader is unfamiliar with the structure of the FYE course or the assigned projects so it can be shared with future possible employers. This assignment draws on technical communication strategies developed over the course of the projects, as students work to develop an interactive means for the general public to explore and understand their technical research.

Discussion & Student Feedback

This course exposes students to forms of technical communication beyond typical lab reports to research proposals, journal articles, and poster presentations that some engineering students may never be given the opportunity to practice otherwise in their undergraduate experience. This exposure opens doors to new possibilities of what engineering work students thought they were capable of, particularly within the first year of their college experience.

Student experiences also reflect the course's ability to prepare students for future research experiences and communicate technical content effectively both written and orally. Upon completing the projects at the end of the semester students are asked to complete a survey about their experience in the course. Likert scale-style survey data from 37 spring semester 2019 students is shown in Table 2, below. Students were asked to rate on a scale of one (low) to five (high) the extent to which the Nanotechnology course addressed the learning goals shown on the table. These survey responses show that students found the course incredibly useful in categories such as "ability to design and conduct experiments, as well as to analyze and interpret data", "ability to function on multidisciplinary teams", and "an ability to communicate effectively".

Table 3: Table of student survey responses when asked to rate the extent to which the Nanotechnology course addressed the learning goals listed.

Learning Goal	# of responses 1 (low)	# of responses 2	# of responses 3	# of responses 4	# of responses 5 (high)
An ability to apply knowledge of mathematics, science, and engineering	0	1	3	17	16
An ability to design and conduct experiments, as well as to analyze and interpret data	0	0	2	14	21
An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	0	0	3	15	19
An ability to function on multidisciplinary teams	0	0	1	14	22
An ability to identify, formulate, and solve engineering problems	0	0	4	17	16
An understanding of professional and ethical responsibility	0	8	10	11	8
An ability to communicate effectively	0	0	3	11	23

The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	1	2	9	18	7
A recognition of the need for, and an ability to engage in life-long learning	0	2	7	13	15
A knowledge of contemporary issues in engineering	1	3	6	15	12
An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	0	0	3	19	15

Qualitative survey data collected from students in the same survey echoes these Likert-style question responses. Students were asked in the survey what they thought about different components of the course and what assignments and deliverables they found most beneficial to their learning. These open-ended responses from students were collected and evaluated. From this evaluation, three major themes emerged. These themes were 1) Connection of content to real world applications and future engineering and research opportunities, 2) Improvement of technical communication skills through written assignments and presentations, and 3) Appreciation of scaffolded assignments that provide a platform to receive feedback that directs learning and informs future assignments.

Theme 1: Connecting Content to Engineering and Research

Students who gave comments related to the first theme of connecting the content of the course to relevant applications identified class lessons, assignments, and labs that they recognized as applicable in the future. For instance, one student wrote:

> *"Now that I have started these projects, I am glad they have a strong connection to typical research environments so I can gain experience that will be valuable in the lab later"*

Other students' comments related to this theme connected content to applications to future jobs and research experiences, as well as an idea of what lab work might be like in the future. Shown below are example of these comments.

> *"The fact that we're doing some very high-level things that have serious implications in future engineering work is a milestone in its own right. I have dedicated several lines of my current resume to the Nano and Micro projects because the class has given me several opportunities to show employers that I have relevant skills, knowledge, and experiences"*

> *"The Nanotech course has definitely given me a taste of lab and research experience"*

> *"The project/research experience in the Nano option has really opened my eyes up to the challenge of research and what it will require of me in the coming semesters, but also the reward of completing research"*

Theme 2: Improvement of Written and Oral Technical Communication

Students whose comments helped form this theme identified the benefit of frequent presentations done in class by way of the CNTOTD assignments. They noted that regularly watching and giving these presentations, as well as the TA and peer feedback offered, strengthened their professional communication and presentation skills. Examples of student comments are shown below.

> *"CNTOTDs were helpful because they helped improve public speaking skills as well as skills reading and analyzing journal articles"*

> *"The Micro Oral presentation was helpful because it allowed us to gain more practice in presenting, and it gave us feedback from our peers that made us consider things we had not considered"*

> *"Both CNTOTD helped me learn about how to properly conduct a presentation, and were extremely beneficial in that regard"*

Additionally, comments related to the technical writing aspect of the course were also given. Students noted:

> *"These assignments taught me the importance of hard work and understanding how to prepare an assignment to look and be professional"*

> *"I also learned how to write reports and other formal documents which helped for this project because there is a lot of documentation needed"*

Theme 3: Appreciation of Opportunities for feedback

As pointed out in the course and assignment descriptions earlier in the paper, many of the smaller course assignments and lab experiences are meant to scaffold information for students and provide ample opportunities for the teaching team to provide feedback. The major writing assignments have an outline and multiple drafts due prior to the final, as well as design stage check-ins for both the nanotechnology and microfluidics project to ensure students are correctly on track and timely in their project progress. Many student comments noted the usefulness of receiving actionable feedback through assignments leading up to the final deliverable submissions. Example of these comments are shown below.

> *"They [draft assignments] taught me how to apply feedback I was given to future assignments and projects"*

> *"Receiving feedback allowed us to properly address what we were missing"*

> *"It was helpful to do a draft of both papers because it gave us feedback on specific things to fix for the final"*

"The two outlines were also helpful, because we were able to receive feedback on our proposals before writing drafts"

Conclusion

Although many FYE programs strive to expose students to a variety of disciplines, design and project experiences, and technical communication styles, they sometimes fall short in representing the research component of engineering. Research experiences, such as working in a research lab, are valuable and teach skills such as project and time management, individually driven learning, as well as teamwork and collaboration skills [10]. By providing students opportunities to engage with engineering research through reading and synthesizing literature, performing experiments, and proposing theoretical designs, they are given an opportunity to expand their idea of what it looks like to technically communicate with other scientists and engineers.

This FYE nanotechnology course's approach to exposing students to engineering research and the forms of technical writing and communication that come with engineering research are novel and impactful. The final deliverables serve to showcase the technical communication skills, both written and oral, that students develop over the eight-week long project experience. This development happened throughout the project by assignments being scaffolded and drafted prior to final submission. This gives students the opportunity to interact with prior research in the field and work to develop their technical communication skills in an environment that is designed to provide them with constructive feedback. These assignments and deliverables were intentionally created to closely resemble the technical communication that will be required of students in undergraduate or graduate research positions, as well as post-graduation work experiences. This course and its design project prepare students for future academic and professional work.

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