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Keywords

technical writing, project-based instruction, engineering students

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Introduction

Technical communication is an important skill for students across disciplines. Ironically, it also becomes one of the most challenging skills for college and university students, particularly for STEM students. Compared to students in humanities and arts, STEM students may have fewer opportunities to write, due to curriculum design, instructional pedagogy, and assessment methods in their programs. However, STEM students with great communication skills including speaking and writing skills will make them stronger candidates in the job market, and even bring them more benefits in career path than those who are not proficient in communication skills.

Based on a project-based instruction (PBI) method, this paper described the design, implementation, and assessment of a technical writing course for engineering graduate students. The paper first addressed an increasing demand for engineering students with great communication skills through analyzing the existing literature and industry criteria. It then introduced the concept and characteristics of PBI and explained why PBI is a fit pedagogy in teaching technical writing to engineering students. Next, it elaborated components involved in the holistic design of the PBI course, including participants, timeline, designed units, and rationale. This paper then talked about the teaching effectiveness of this course through the course evaluation. Through the instructor's critical reflection, the paper finally discussed challenges in implementing and assessing a PBI method and also ways to improve in curriculum design for this engineering course.

Technical Communication for Engineering Students

Ever since 1990s, the Accreditation Board for Engineering and Technology (ABET) has been listing technical communication as one of the top skills that need to be assessed and acquired for engineering students in general. While ABET issued assessment criteria for different engineering majors or programs, it consistently included technical communication as one essential criterion across different programs. For example, as stated in Criteria for Accrediting Computing Programs 2019-2020, computing engineering students need to "communicate effectively a variety of professional contexts" (ABET Computing Accreditation Commission, 2018, p. 3). Likewise, the American Society of Civil Engineers (ASCE) reported in Vision for Civil Engineers in 2025 (*the Vision*) that an ideal, skillful civil engineer by 2025 should be someone who can "communicate with technical and non-technical audiences, convincingly and with passion, through listening, speaking, writing, mathematics, and visuals" (ASCE, 2006, p. 11). To comply with *the Vision*, ASCE (2009) then published Achieving the Vision for Civil Engineers in 2025 and stated that educators should "ensure that communications knowledge and skills are embedded in every civil engineer's education and encourage their continued enhancement throughout every civil engineer's career" (p. 59). Kirkpatrick (2013), through talking about the results from Surveys of Academic, Industrial, and Early Career Engineers, reported that professional skills, in terms of interpersonal skills, negotiating, conflict management, innovation, and oral and written communication were typically the weakness of the contemporary engineering graduate students.

With the demands from the industry and the academic associations, different engineering programs across the nation unanimously highlighted the importance of technical communication and incorporated course credits or units connected with this important skill into their programs. For example, the instructor's affiliated departments designed program outcomes to meet the demands (see Figure 1).

	Description
PO 1	Be able to demonstrate an understanding of advanced knowledge of the practice of software engineering, from vision to analysis, design, validation and deployment.
PO 2	Be able to tackle complex engineering problems and tasks, using contemporary engineering principles, methodologies and tools.
PO 3	Be able to demonstrate leadership and the ability to participate in teamwork in an environment with different disciplines of engineering, science and business.
PO 4	Be aware of ethical, economic and environmental implications of their work, as appropriate.
PO 5	Be able to advance successfully in the engineering profession and sustain a process of life-long learning in engineering or other professional areas.
PO 6	Be able to communicate effectively, in both oral and written forms.

Figure 1. Program Outcomes

To cater to the program outcomes, instructors in teaching technical communication or graduate writing seminars in the program were required to brainstorm ways to design a fit curriculum and also select a fit pedagogy to teach the designed curriculum. The instructor tentatively chose PBI as the pedagogy and incorporated in the curriculum design.

Project-based Instruction (PBI)

Scholars and researchers interchangeably use the terms PBI and PBL (problem-based learning). To a large extent, it depends on scholars' or researchers' perspective. Specifically, if they would like to emphasize on the student part, they would use the term PBL and focus on student performance and learning assessment; however, if researchers or scholars focus on the curriculum design and pedagogical implication, they would use PBI instead. In this paper, as the instructor talked about how the specific pedagogy was used in designing and assessing a curriculum, he used PBI instead of PBL. However, tenets behind these terms share the common places.

An introduction to task-based instruction (TBI) and PBI helps understand the designed features of PBI. In a typical TBI, instructors design specific tasks for students and make their assessment or evaluation based on student completion of these designed tasks. Therefore, the core or focus for TBI for a communication course is not learning any structure and grammar points but instead the tasks. It should be mentioned language proficiency still helps, as it improves student completion of these tasks through peer communication or self-reflection.

Similar to TBI, the PBI approach is also a learner-centered approach. However, it also shows some differences. First, a PBI approach takes longer time to research, design and implement a project. Specifically, a TBI approach designs a task for each lesson, whereas a PBI approach may design a project for the entire semester or even the whole year. Also, a PBI approach is more learner-centered or takes the learner-centeredness to a higher level. If instructors design tasks in a typical TBI approach, then students take a leading role in designing and implementing a project on their own.

Thomas (2000) identified five distinguishing features of PBI:

- Meaningful projects are the central part,
- Intriguing questions should be the drive force,
- A constructive way of inquiry in the projects,
- Student-centeredness should be considered seriously,

- Real world problem-based should be the essence.

Due to the unique feature of engineering majors, courses offered in the engineering programs largely provide students with opportunities to solve real-world problems. Because real-world problems are dynamic, ongoing, and unexpected, they require students to make timely decisions and constant deliberation. To achieve the goal of solving real-world problems, course instructors need an effective medium to guide their students. With the designed features mentioned above, PBI meets the expectation in providing a flexible platform for students to solve the real-world problems. While these features helped explain what makes a meaningful PBI, they also provide challenges to instructors or researchers to make appropriate connections between the features and actual practice in implementing a PBI-based curriculum. To achieve the expected program outcomes (see Figure 1) and also design a fit curriculum, the instructor through talking with the course coordinator and peer instructors made the following course learning objectives (see Figure 2):

CLO	Description
1	Be able to extract information from presentations, be able to pursue further information from such a starting point and be able to present the results of such an investigation.
2	Understand the concept of plagiarism and recognize instances of plagiarism.
3	Have been exposed to a diverse set of communication styles and have had practical experience in exercising them.

Figure 2. Course Learning Objectives

Curriculum Design and Implementation

Student Sample

The course included 25 graduate students majoring in either computer engineering or software engineering. Classes were given once a week for 16 successive weeks throughout the whole semester. Most of the students were from India and a few others were from China or other Asian countries or regions. As this course was a required writing course or a pre-requisite course tailored to their graduation thesis, the students taking this course were either in their second semester or up to their third semester.

Timeline

The instructor scheduled due dates for several big, signature writing tasks throughout the whole semester. Generally, a signature task was collected every month. The students were ensured of appropriate amount of time in completing every single task and also appropriate internals to submit different writing tasks. Specifically, the students were required to turn in their first job-related writing task set which included both a resume and a cover letter in the first month, the analysis of journal articles and literature review tasks in the second month, the research design and timeline in the third month, and then final research proposal in the finals week. In addition, the students were also required to turn in an individual portfolio including all the revised writing tasks throughout the whole semester in the finals week. In addition, the students were required to attend lectures, complete in-class quizzes or weekly writings, and make revisions based on feedback from their instructor and peers.

Sections, Units, and Assignments

Through introspection, the instructor believed the course of technical communication should include two major types of communications: written communication and oral communication (see Figure 3). While most of the sections in the course were focused on the written communication, a few sections on how to improve the presentation and oral communication skills were still highly needed.

Figure 3. Technical Communication Components

The instructor divided this course components into different units in different sections: some sections about career-related writing tasks, some sections about writing ethics, some sections about oral presentations, and the others about writing a research proposal (see Figure 4).

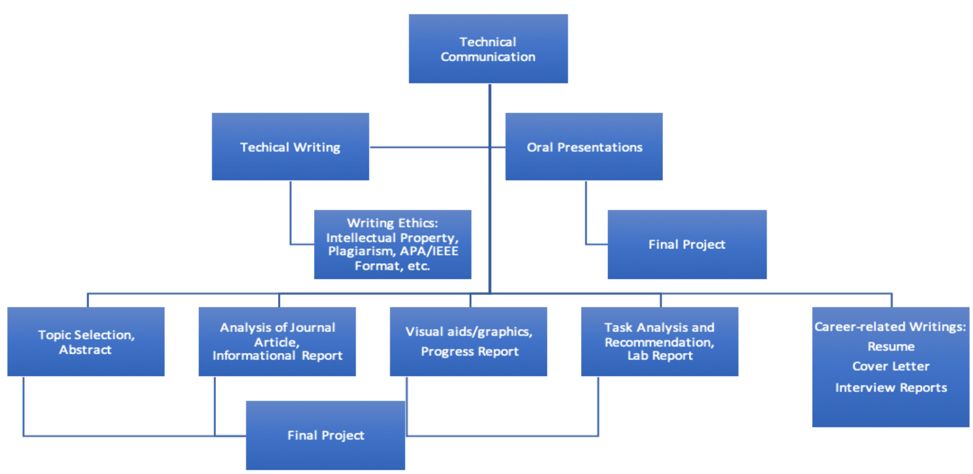

Figure 4. Componential Units in Technical Communication

Overall, the instructor collected students' assignments as an individual portfolio at the end of the semester. Totally 10 items were included in the portfolio with the majority of the items centered around their final project (see Figure 5). Through instructor timely feedback and multiple required revisions, students were able to turn in a project proposal or report in the portfolio and also able to understand and complete basic components in a research project.

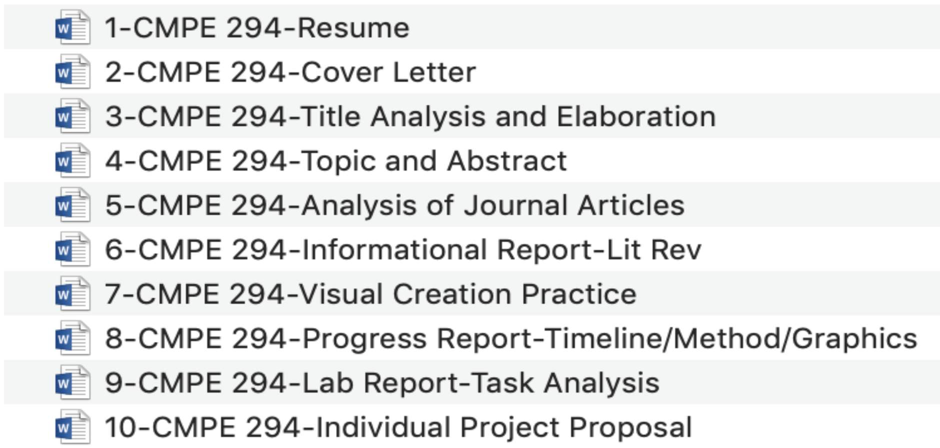

Figure 5. Individual Portfolio Checklist

Rationale and Principles

Under the big umbrella term of PBI, the instructor also used some specific principles and rationale to plan and design the tasks tailored to the final project. Specifically, the instructor took the following points into consideration when designing the course.

1. *Matching objectives with program outcomes*

To match specific course learning objectives with program outcomes, the instructor followed a matrix (see Figure 6). Some course learning objectives can be assessed from multiple perspectives and some can be assessed from a single perspective. However, all the learning objectives were well included in the matrix as necessary indicators to assess the program. Figure 6 shows how the course learning objectives met the required program outcomes in a matrix.

CLO	**PO**					
	1	**2**	**3**	**4**	**5**	**6**
1			X			X
2				X		
3					X	X

Figure 6. Program Outcomes (PO) and Course Learning Objectives (CLO) Matrix

2. *Incorporating both soft knowledge and hard skills*

The instructor believed that a great course should include both soft knowledge and hard skills for students to acquire. The soft knowledge includes concepts, theories, and philosophies that students need to understand. These concepts or theories guide students to sharpen their hard skills and also help them avoid possible mistakes in their career. In this typical writing course, concepts or guidance related to writing ethics were then defined as soft knowledge and included in the curriculum design. The soft knowledge included teaching units in intellectual property, plagiarism, copy rights, APA/IEEE format.

On the other hand, a hard skill is something that students need to master in order to meet professional needs and employer expectations. These skills equip them with basic qualifications for a specific job market or industry. For the engineering students in the paper, their hard skills included both written and oral communication skills. For this course, students were required to master these hard skills through different writing tasks.

3. *Including both group work and individual deliberation*

The design of this course considered student efforts in both team work and individual portfolio. For individual portfolio, the students were required to turn in their individual proposals or reports which were the embodiment of their individual projects at the end of the semester. The portfolio included all the writing tasks in the semester. In addition, the students were also required to develop their teamwork sense and cooperative learning skills throughout the whole semester. To achieve this goal, the instructor designed a few units for teamwork assignment. For example, while students' research proposals or reports were their individual work, they were required to share their first draft with members in class, find their peers who had conducted research in a similar topic, and then make connections among their individual works. Then, students were required to present their proposals and reports in group and show their connections to the other students in class. In addition, peer-evaluation on each other's proposal or report was also used as a way to develop students' teamwork sense.

4. *Providing differentiated instruction*

Before teaching this course, the instructor spent time designing this course to fit students on different career paths. While most of the former students in the program went to industry companies, the instructor still wanted to make this course not only for students who aimed at jobs in the industry but also for students who might think about applying for a Ph.D. program after graduation. Therefore, the instructor included extra components to each lecture and catered to students' future plans. For example, when the instructor gave the lecture on how to write a cover letter and resume, he explained how cover letter for industry employers may differ from the cover letter in graduate school application. Also, he showed students the differences between a resume for industry and a C.V. for higher education. The instructor also gave specific examples to better student understanding of the nuances and differences between writings in the same unit. Students then were allowed some wiggle room to complete their writing assignments according to their career paths or future plans.

5. *Designing procedure and connected tasks*

The most important principle for designing and implementing this PBI course is to make all the designed tasks for the final project procedural, consistent, and connected. For the instructor, the process of designing this course is itself project-based. Specifically, the instructor brainstormed how the students would be motivated to complete all the tasks in a natural order or specific sequence. Students were motivated to brainstorm their topics, proposal their projects, and then complete all the three major reports.

In addition, the way the instructor had designed all the tasks in the final project was consistent. Overall, he used an inductive way to teach his lectures and guide his students. To be more specific, before he asked his students to complete a big, signature writing task, he would demonstrate with writing samples how part of the writing task can be completed. For example, before asking students to complete a 10-article literature review (i.e. Informational Report, see Figure 5), he guided his students to complete one-article analysis first (i.e. Analysis of Journal Articles task, see Figure 5). Based on the demo lecture, the students then completed their own assignments.

The last essential principle in designing this course is all the tasks should be closely connected to each other. The instructor used the template of a basic academic article including introduction → literature review → research methods → data collection and analysis → findings → conclusion to guide his design of all the connected tasks. Specifically, an informational report is the literature review section of the final project proposal, a progress report is analogous to the research methods section, and the lab report is analogous to the data collection and analysis section.

Teacher Effectiveness and Course Evaluation

Teacher effectiveness can and should be assessed through multiple perspectives. Student course evaluation can be one of the perspectives. In this specific context, analysis from the Student Opinion of Teaching Effectiveness Surveys (SOTES) was conducted (see Figure 7). Overall, the SOTES report indicated the instructor evaluation score was higher than the average score across the total 13 items. Specifically, on a 5.0 scale, the instructor's overall evaluation score was 4.7 for this course (see Item 13, Figure 7). In two of items including course content relevance and respect to diverse students, the instructor got the highest mean point of 4.8. The lowest mean score was 4.5 in the item of clear grading criteria.

However, the instructor believed the interpretation of the SOTES scores can only account for one perspective to evaluate the teaching effectiveness. Also, faculty members may have different attitudes toward the interpretation of the SOTES score and some of them may also challenge the reliability and validity of the scores from these evaluation reports.

Therefore, other methods to assess the teaching effectiveness should also be considered. To look at the teaching effectiveness from a critical perspective, the instructor also referred to peer instructor observation, teacher-student talk, SOTES reports across courses, and self-reflection. Overall, the instructor found the implementation of this course met his expectation and was consistent with his lesson plans and curriculum design.

		5A	4	3	2	1D	N	Mean	Grp Med	N/A	Std Dev
Q1	Demonstrated relevance of the course content.	18	3	1	0	0	22	4.8	4.9	0	.52
Q2	Used assignments that enhanced learning.	16	4	2	0	0	22	4.6	4.8	0	.64
Q3	Summarized/emphasized important points.	17	3	2	0	0	22	4.7	4.9	0	.63
Q4	Was responsive to questions and comments from students.	17	4	1	0	0	22	4.7	4.9	0	.54
Q5	Established an atmosphere that facilitated learning.	16	4	2	0	0	22	4.6	4.8	0	.64
Q6	Was approachable for assistance.	14	8	0	0	0	22	4.6	4.7	0	.48
Q7	Was respectful of the diversity of students in this class.	18	4	0	0	0	22	4.8	4.9	0	.39
Q8	Showed strong interest in teaching this class.	15	6	1	0	0	22	4.6	4.8	0	.57
Q9	Used teaching methods that helped students learn important concepts.	14	8	0	0	0	22	4.6	4.7	0	.48
Q10	Used grading criteria that were clear.	15	5	1	1	0	22	4.5	4.8	0	.78
Q11	Helped students analyze complex/abstract ideas.	15	6	1	0	0	22	4.6	4.8	0	.57
Q12	Provided meaningful feedback about student work.	16	6	0	0	0	22	4.7	4.8	0	.45
Q13	Overall, this instructor's teaching was effective.	16	6	0	0	0	22	4.7	4.8	0	.45

Figure 8. Synopsis of SOTES Analysis

Discussion

Critical reflection helps improve teaching effectiveness and pedagogical performance. While the overall evaluation for this course was satisfactory, there were still many aspects that require the instructor to reflect on and improve. Through critical reflection, the instructor found the following challenges to teach this course and particularly to implement the PBI.

Student Motivation

The course, while had been so closely connected with technical writing, was not just a writing course. It was designed as a course to help students improve their communication skills and also develop their sense of research design. However, the instructor perceived a possible stereotype in the students' mind was that this course was more like a writing or language course, than a course connected with research design in their content area. The stereotype may lead the students to have different expectations toward the instructor and the other instructors of the student major courses. This kind of differentiated expectations may lead to students' differentiated criteria to evaluate a course and also time and efforts spent on this course. The researcher and instructor may suggest department deans, administrators and the other faculty members provide support and help students get rid of this stereotype.

Imbalance of Knowledge Repertoire

One of the greatest challenges to implement a PBI course is from the instructor credentials and qualifications. To be more specific, an ideal instructor for this technical communication course to engineering students should have the basic knowledge in the following aspects: content area (engineering), writing (language or linguistics), communication (public or mass communication), and multicultural education (TESOL or multicultural education). Lack of or insufficient in a certain kind of knowledge may impede implementation of a certain units in the designed curriculum. The instructor for this course had a linguistic and TESOL background, accrued experiences in multiple, international conference presentations, and some engineering-related knowledge (i.e. computational and corpus linguistics); however, he still found he might have contributed more to the students' projects about engineering education or computational linguistics than the project topics about data mining or blockchain. The imbalance caused a certain kind of *tensions* or *inconsistencies* between the instructor's beliefs and his actual practice (Gao, 2014).

Deliberation in Grading

While most graduate programs provide professors or course instructors with teaching assistants (TAs), the instructor for this course believed grading all these student assignments on his own would be better than asking TAs for help. Instructors should involve in all the teaching steps of a course including the grading process. While the instructor may train TAs to grade, he still believed it would be unrealistic and irresponsible to give students' timely feedback without grading students' actual work. Some primary reasons include: the instructor needed to see a holistic picture of the students' proposal and report; he also needed to check their progresses in mingling all the pieces into that holistic proposal or report. However, different from a quiz or exam paper, a writing task requires extra work from a rater or grader. For example, the instructor in this course was assigned approximately 250 student writings to grade, apart from other in-class quizzes and weekly writing tasks. With that much grading work to do, the instructor needed to do extra work or spend extra hours every week and throughout the whole semester.

Hidden Craftsmanship in Lectures

While the entire paper focused on the PBI implementation in this course, it should also be mentioned that lectures from the instructor also played a crucial role in guiding the students to understand the concepts and techniques in this writing course. Throughout the whole semester, the instructor used considerable mediators in delivering his lectures and tried his best to make the lectures intriguing. These mediators included YouTube clips, picture books, writing samples, posters, etc. and served as helpful aids in his teaching methodology. As all the students in the class were English as a second/foreign language learners, these teaching mediators and aids assisted them to acquire the basic knowledge in the course (Gao, 2013).

Challenges to implement a PBI in a typical technical writing course for engineering students are not limited to the above-mentioned points. They may also yield the following tricky but unavoidable questions: should the instructor focus on student language proficiency or logics in research design? Even in terms of the language proficiency, should the instructor set different grading criteria in grading students from outer circle of English (e.g., India) and those students from expanded circle of English (e.g., China and Japan)? All these questions require instructors and researchers to further deliberate time and efforts in designing the curriculum.

Conclusion

The paper briefly described a design of PBI and its implementation in a graduate class for engineering students. It also reported the evaluative results and challenges from the PBI implementation. With technical writing and communication being an essential skill in the engineering industry, it ideally requires not only students and instructors of this kind of courses but also other parties including administrators in higher education and industry employers to work together and improve the curriculum design and course instruction. As instructors, what we do is not simply to deliver the lectures but instead to deliberate our time and efforts to fully get engaged in all the steps involved in every course we teach. We also need to reflect on our actual practice and solve any tensions between our beliefs and practice (Gao, 2014). We should also work hard to engage our students and change their stereotype in regarding this course simply as a writing or language course. We may also deliberate our talks with program administrators and employers in the industry and conduct meaningful need analysis for our students. Due to the limited sample size and context, future scholars or instructors' may make changes of the design in the paper and cater to their own classes or research sites.

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