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Adventures in Paragraph Writing: The Development and Refinement of Scalable and Effective Writing Exercises for Large-enrollment Engineering Courses

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Abstract

The ability to communicate effectively is a highly desirable attribute for today's graduating engineers. Additionally, the inclusion of communication components in technical courses has been shown to enhance learning of technical content and can be leveraged to satisfy non-technical learning outcomes. However, the incorporation of such components in undergraduate engineering curricula remains challenging due to obstacles such as resource limitations, credit hour constraints, and low faculty and student motivation. This paper reports preliminary results from our ongoing efforts to create effective, transferrable, and low-overhead approaches to implementing paragraph writing exercises in large engineering courses typically devoid of communication elements.

We begin by reviewing relevant literature discussing strategies for incorporating writing in a variety of course types, with particular emphasis on shorter, integrated assignments. We then turn to the development and implementation of paragraph writing exercises in a large civil engineering undergraduate fluid mechanics course (117 students; approximately 15 assignments). A primary focus of this first application and pilot study centered on two key components that must be refined in order for the exercise to be effective and transferrable: (1) the creation and selection of high quality writing prompts, and (2) assessment of student work in light of typical manpower and expertise limitations associated with large classes. Analysis of student paragraphs highlights the importance of the writing prompts in the success of the exercise, indicating that specific word choice, question focus, and supplemental instruction greatly affected the level of writing students submitted. While minimal marking and holistic rubric assessment methods proved effective from a grading resource standpoint, students were frustrated by the lack of feedback associated with these techniques and uncomfortable with the holistic grading approach. Data from student surveys point to the importance of giving meaningful feedback to students and providing them with opportunities to revise their written submissions. The implementation of paragraph writing into a large enrollment engineering course successfully increased the amount of writing students were doing with relatively little overhead needed by the instructor and students. Unresolved difficulties and suggested improvements are also discussed.

Keywords: civil engineering, communication, fluid mechanics, hydraulics, paragraph, rubric, survey, technical writing, writing

Introduction

Technical communication is a highly sought-after attribute among today's graduating engineers, with recent reports from practicing engineers stressing the importance of effective written communication skills. For example, one study that polled a group of practicing aerospace engineers reported writing technical documents a minimum of 19 hours a work week.[1] With the expectation for consistent and quality document development, education in the area of technical

communication education needs to be a high priority in order for universities to produce engineering graduates who can successfully contend in a competitive, increasingly global job market. Further, widespread evidence supports the inclusion of writing in engineering courses as a means to promote the learning of technical content and the development of critical thinking skills ("writing to learn"). Writing exercises can also be implemented in courses in order to achieve and demonstrate non-technical student outcomes, including those pertaining to ethics, global issues, economics, and understanding of environmental and societal contexts.[2]

When the objective is to improve student writing skills ("learning to write"), an integrated, or writing across the curriculum (WAC) approach to teaching technical writing is considered favorable over the alternative of isolated, stand-alone communication courses that often decontextualize writing.[3-4] In the integrated approach, communication instruction and practice is distributed throughout the curriculum and embedded in technical courses, well beyond the standard inclusion of laboratory reports in laboratory classes. Such an approach also maximally leverages the writing process towards the learning of discipline-specific technical material ("writing to learn").

While the adoption of a writing across the curriculum approach is preferred from a pedagogical standpoint, its wide-ranging nature is logistically daunting for many reasons, ranging from the course/instructor level ("how do I include writing in my course?") all the way through the program level ("how can we coordinate, support, and document the inclusion of writing across dozens of courses and instructors?"). At the course level, individual instructors have little incentive to add more to their teaching workload, especially at research-intensive universities; moreover, the inclusion of writing as a new pedagogical element is widely perceived as particularly time-intensive owing to the need to provide students with feedback on their writing.[3,5,6] Furthermore, in spite of writing being important for success in academia, faculty may also feel ill-prepared to provide feedback on student writing. This challenge is often further compounded considering that providing such feedback is also often beyond the skillset of engineering teaching assistants, many of whom are not native English speakers or may simply not be strong writers themselves.

These course-level constraints and concerns often conspire to unconsciously engender the perhaps more common "writing at the beginning and end of the curriculum" ("WBEC") approach, in which embedded writing is included in a book-ended fashion in a student engineer's undergraduate curriculum. Writing is included where resources are most readily available: firstly, in freshman engineering, and again four years later, during a senior capstone course. This approach, unfortunately, leaves discipline-specific technical courses in the second and third years largely absent of writing, leaving a gaping hole where writing would be most contextual, and reinforcing students' notion that writing and engineering are separate and unrelated, and even that writing is less or even not important.

The pilot work presented herein is part of our larger effort to develop, refine, and disseminate instructor-friendly writing exercises that can be adopted in a wide range of technical courses, including large lecture format courses where writing is rarely included because of the logistical complexities. As described in more detail below, our work builds upon recent efforts by Hanson and Williams, who applied an "explain a problem" writing component to sophomore-level statics

classes, and Venters et al., who refined and comprehensively assessed the same technique in a larger course.[6-7] While these techniques were successfully implemented in these trials, more work is needed in order to determine how to adopt and refine such techniques in a wider range of institutional settings, especially in light of varying resource climates and specifically desired learning outcomes.

Our pilot work is predicated on the basic notion that the inclusion of writing in any engineering course is beneficial for the reasons outlined above. However, unless low-overhead techniques can be developed, refined, and readily disseminated, engineering instructors will continue to omit writing from their courses. The pilot interventions primarily focus on the logistics of implementing writing in a large lecture-format course – in this case fluid mechanics – in order to: (1) elucidate the bottlenecks that preclude the more widespread adoption of writing in large engineering courses, especially when support resources are scant or absent; and (2) refine suitable writing exercises and their implementation techniques in order to identify strategies for mitigating these constraints.

Literature Review

Frequency and Context of Writing

Traditionally, many undergraduate engineering students have some of their first encounters with writing in required, stand-alone English or communication courses that are often largely detached from the rest of the curriculum. Subsequent experiences with writing frequently involve students writing lab reports for science or engineering classes and/or end-of-semester project reports for other technical courses. Such reports are typically either formatted as journal articles or as traditional school reports, and are often at least 15-20 pages in length. Other than the assignment of the term report, students are rarely exposed to writing in their engineering courses and usually only receive substantive feedback on their abilities during beginning English and communication courses. Although practice writing reports is important to student development, research indicates that constant student exposure to writing assignments throughout the semester increases writing ability. This improvement has been seen in studies such as one conducted by Wheeler et al., which involved introducing writing into electrical engineering undergraduate courses by assigning six reports throughout the semester covering topics related to lecture material. The researchers reported decreased student resistance as the study progressed, as well as improved writing.[8]

Exposure to writing throughout the semester can help students become more comfortable with topics, but the writing and grading of full-length report assignments is traditionally a drain on resources because of the labor-intensive grading and feedback required. Developing more manageable activities for both the students and the instructors is key to promoting the implementation of writing within engineering courses. Therefore, selecting more concise and condensed writing assignments may be more beneficial for students and instructors.

Types of Writing Assignments

There are two main types of writing assignments: incidental and formal. As the names imply, the main difference between the two is level of formality. Each type is important for students to

understand and practice, and they can each be successfully applied to courses to help students become more proficient at writing.

Formal writing includes the more common examples of writing that people typically associate with engineering practice, including laboratory reports and journal articles, as well as instructional or documentary writing such as manuals or protocols.[5] An example of such an activity within the undergraduate engineering classroom would be to assign students the task of creating a detailed, written solution to a computational homework problem. Not only does this require students to complete the usual calculations desired in the class, but also solidifies the students' knowledge of the information covered in the problem. This approach is based on the premise that it is difficult, if not impossible, to explain or teach a topic without fully understanding it. Another example of a formal writing assignment is completion of a report for the lab portion of a technical elective. Students would be assigned to discuss in detail a completed experiment, along with the relevant background theory. One primary issue associated with formal assignments is that they are traditionally resource intensive. Grading and providing feedback on lengthy submittals can be draining on instructors and subsequently often results in the removal of the assigned writing from the coursework.

The alternative to formal writing assignments is incidental writing. The majority of incidental writing activities are informal exercises that primarily involve free-thinking and reflection.[9] Types of incidental writing include, but are not limited to, activities such as personal journal or portfolio writing, "think pieces", blog entries, and lab books or notebooks. An example of incidental writing includes assigning students to write daily journals discussing their experiences and challenges with homework assignments. The instructor can then choose to review the entries in order to answer questions or clarify confusing information, or the journals can remain strictly for the personal use of the student.[9] Most examples of journaling found in research appear to be successful utilizations with minimum additional work needed from instructors.[5]

The term "think pieces" is a general term encompassing any short, informal writing exercise created to encourage students to organize their thoughts during the introduction of new and potentially difficult material. An example of this would be having students write down their opinions of topics discussed during lecture and submitting them at the end of class. Instructors could then assess what students are having difficulty understanding without the students feeling pressured to ask questions during class.[9]

Such writing exercises are for the students's purpose only and are not focused on communicating information to a particular audience.[9] The primary issue with incidental writing is the ability of the instructor to hold the student responsible for completing the assignment and providing incentives for them to do so to the best of their ability. One of the allures of incidental writing is its ability to encourage students to be open about their opinions, and typical assessment methods used in quantitative assignments could potentially discourage students from fully sharing their views and beliefs. On the other hand, not giving an assessment can potentially lead students to not fully complete assignments and thus not benefit from these learning opportunities. This results in the challenge of balancing completion versus encouraging free and open thought.[9]

One challenge that this project strives to investigate is the proper pairing of the types of informal writing assignments discussed above with the resources available such as instructor time and class size. Although both formal and incidental writing assignments have been shown to be effective in a variety of situations, it is difficult to assign longer (and typically formal) assignments in large classes due to the increase in instructor workload. At the New Mexico Institute of Mining and Technology, for instance, technical writing was incorporated into a mechanical engineering junior and senior design course through design report development throughout the term.[10] The course involved 93 students during the study period, and two professors (one from mechanical engineering and one from technical communication) divided the labor of grading written and computational assignments. Student groups were asked to complete a series of written and oral progress updates and developed sections that would be combined into a design report at the end of the term. This program was ideal given that instructors were able to provide individual support for each group before and after each assignment, as well as provide a concurrent language course with congruent objectives. Yet providing this level of support and integration is unfortunately not possible in most situations, and even the researcher recognized that further growth of the student population would require the department to either enlist additional instructors for the course or reduce the level of feedback and support given to the students.

Developing shorter assignments to incorporate in existing computational assignments could potentially lighten the student and instructor burden substantially. Research conducted by Venters et al. and Hanson and Williams, for example, investigated the method of having students explain computational problems using only words in order to incorporate writing in large classrooms.[6,11] For each assignment students were asked to write out the solution for one end-of-chapter problem instead of only writing the equations needed. Descriptions were limited to one-half page. Both studies indicated minimal increase in time spent grading by instructors. However, teaching assistants in the Venters et al. study indicated that grading written problems required substantially more thought than the regular partial-credit grading approach used for traditional problems. Additionally, students reported no additional time needed to complete written problems, although many voiced frustrations on end-of-term surveys with the grading procedure, viewing it as inconsistent and confusing.[6,11] Yet despite the few reported issues with these studies, both represent successful methods for incorporating writing into large lecture courses without overburdening students and instructors with lengthy assignments.

Paragraph Writing

Despite traditional assumptions, formal (i.e. assessed) writing does not need to be lengthy for students to gain useful writing practice. In fact, some science communication courses feature writing assignments almost daily that are only a paragraph long[12], while Bean described a physics writing assignment in which the answer had to fit on a 5 x 8 inch index card.[3] Sharp, Harb, and Terry similarly suggested use of "microtheme" tasks as short as a paragraph or a notecard, noting that such a small assignment requires "a small amount of writing preceded by a large amount of thinking" (p. 97).[5] Bean praised the microtheme concept as a "short write-to-learn assignment" (p. 87).[3] Hanson and Williams's "explain-a-problem" assignments also took on the daunting task of adding writing assignments by only adding short ones.[6]

In order to combat the resource-intensive nature of formal writing and the difficulty of preserving the full free-thought of incidental writing, this project borrows from some of these earlier studies to suggest use of paragraph writing prompts in undergraduate engineering courses. Paragraph writing assignments can vary in subject and style, so instructors have considerable to develop meaningful and relevant assignments, while providing feedback without stifling student opinions. Also, the naturally shorter length of paragraph writing assignments decreases the overall amount of instructor resources needed to provide feedback, which in turn allows the instructor to assign multiple writing exercises throughout the semester, thereby increasing students' exposure to writing. As a result, students may become more comfortable with the process in a less formal setting. According to a study by Hawkins et al., for example, the implementation of shorter incidental writing exercises in the classroom allows students to practice important writing abilities. As stated previously, the authors describe incidental writing as writing completed particularly for the benefit of the writer, including activities such as journals, lab books, data logs, worksheets, and "think pieces."[9] The majority of these activities can be included in the paragraph writing exercise. This type of practice can also be particularly beneficial to English as a Second Language (ESL) students.[9]

As discussed previously, the traditional mentality relied on writing as an activity required after the completion of the engineering work. However, it has been argued that fully understanding the engineering process relies on the usage of incidental writing throughout the design and problem solving stages.[13] Hence, writing can go beyond the creation of the official end report products to also include informal notes and journal entries. This belief that writing can occur in smaller but more frequent segments during the design process is one core reason that short exercises such as paragraph writing can translate directly to important, real-life engineering skills.

Another benefit to incorporating paragraph writing exercises in undergraduate engineering courses is the assignments' ability to highlight weaknesses in students' understanding. Writing prompts that ask students to discuss and/or explain key concepts from the course provide a confidential way for the instructor to discover weaknesses in student comprehension. This method follows similar logic to the practice of learning by teaching, a practice well-documented starting in the first century A.D.[14] Paragraph writing activities improve student learning by requiring them to investigate topics and develop a cohesive discussion. This helps students identify weaknesses in areas they may not otherwise realize as problematic.[9] By engaging students in the process of explaining important information, they are charged with the responsibility of learning the material well enough to be able to teach it. This concept is discussed in a study by Wheeler and McDonald, where the researchers discuss different situations where applying paragraph writing can help the instructor tailor discussions to help students with their understanding. Through writing about course topics, students quickly learn whether they fully understand the concept.[14]

Description of Intervention

Study Context

Motivated by both the preceding literature and our broader desire to develop and refine writing exercises for use in large engineering classes, our pilot study objectives were to (1) incorporate writing exercises into a large junior-level lecture-format course that traditionally had no writing

component; and (2) to assess the implementation of this exercise from multiple perspectives (student, instructor, grader) in order to identify the most critical challenges that must be overcome, especially in order to optimize the efficacy and transferability of this type of writing intervention so that it can be more widely adopted.

We therefore chose to implement a weekly paragraph writing exercise in a large civil engineering core course at XX University. "Hydraulics" is a required course in elementary fluid mechanics and has a traditional lecture format (three 50-minute lectures per week), weekly assignments, and several evening exams. The course covers elementary fluid mechanics topics, including hydrostatics, flow kinematics, the Bernoulli principle, pipe flow, open channel flow, dimensional analysis, and control volume analysis. It was taught by an instructor who had taught the course three times previously, had no training in writing instruction, and had only included writing on one previous assignment.

The course mainly consists of junior-level civil engineering students. Most students had taken a freshman-level English course and performed some report writing in prior freshman engineering and/or laboratory courses. During the pilot, the 117 students had the following demographic characteristics: 65% male and 35% female; 71% White/Caucasian, 13% East Asian, 6% Mixed, 4% South Asian, 3% Latino/ Hispanic, 1% Middle Eastern, 1% African, and 1% Other; 78% domestic and 22% international; and 86% native English speakers and 14% ESL.

Traditionally, weekly assignments involved 4-6 handwritten calculator-type problems graded by a teaching assistant. Students were not required to explain their solutions beyond showing their work, which mostly involved the usual progression of formulas and answers. For the pilot semester, the instructor attempted to scale back the number of weekly assigned homework problems in order to accommodate the additional work associated with the assigned paragraph writing described below, thereby maintaining a total weekly student workload that was roughly similar to previous semesters,

The course was supported by a single teaching assistant, whose duties were to grade all assignments and provide students with individual assistance as needed (answering e-mail questions, holding office hours, etc.). A non-native English speaker, the teaching assistant did not pass the university-required English speaking test, and was therefore deemed to be unqualified to participate in the assessment of the written paragraphs described below. Thus, a native English speaking civil engineering graduate student was recruited to perform the assessment of the written paragraphs submitted by students. This student had no background in technical writing beyond prior coursework and research. The grader had taken the same course as an undergraduate, and had also majored in Hydraulics.

Data Collection Sources and Procedures

All students were required to submit the writing assignments for the course, representing 2% of their total grade, and 110 of the 117 also agreed to participate in our companion pre/post study of the exercise. Participants in the study completed one survey at the beginning of the course and one survey at the end of the course, and also received 1% extra credit towards their course grade. 96 of the 117 students in the class completed both surveys. All data collection and analysis was

carried out with appropriate human subject research procedures and approvals under University XX IRB no. xyz.

Regarding implementation of the paragraph exercise, students were assigned 3-5 standard "end of chapter" quantitative homework problems every week. In addition, they were required to submit a typed, one-quarter to one-third page paragraph answering a stated question or choice among questions (see Appendix B). These questions were designed to overlap with the course content for the week, and the nature of the questions evolved during the semester in response to student performance and feedback. Toward the end of the semester, we also offered students opportunities to re-write previous paragraphs for a higher grade. Students were given no in-class instruction in paragraph writing, but on the course web site we provided students with resources such as documents about writing, links to online writing guides, and student-produced examples of well-written paragraphs. These materials were accessed primarily during the first few weeks of the course, after the first graded paragraphs were returned to the students.

Assessment of Written Paragraphs

A major consideration with the pilot paragraph writing exercise was assessment of the written work, which is often the most daunting element that precludes engineering instructors in large classes from including writing in their courses. Our class faced many of the challenges outlined in our introduction, namely that the course was already under-allocated with regards to teaching assistants and graders. Moreover, the recruited graduate student grader had no background in technical writing and limited time to allot to grading. Despite these issues, we wanted to assess the paragraphs in order to hold students accountable for their work, as well as provide feedback so they could improve their writing. Keeping these constraints in mind, we adopted an assessment/feedback approach that facilitated rapid assessment of the written paragraphs by a grader using two elements: (1) a holistic grading rubric (Appendix A), and (2) minimal marking.

Our approach was informed by prior research. For instance, Smith studied the difference in grading by teaching assistants with and without using a rubric. She found that use of a rubric resulted in several positive outcomes. Via the rubric itself and in-margin comments on student writing, teaching assistants provided more positive comments and more specific suggestions.[15] Comments associated with the rubric also tended to "coach" students toward success, in keeping with Bean's suggestion to make comments that assume revision and improvement, not just correction.[3] Hanson and Williams similarly found that using a rubric (in their case an analytic rubric) significantly reduced the grading time once the instructor became familiar with it.[6]

Our holistic grading rubric, which assigns a single overall score rather than assigning points to subcategories and then adding them together, was based on a five-point scale that awarded marks based on both technical content and writing mechanics. This type of holistic rubric has the advantage of allowing for quick scoring of student assignments by providing a clear outline to the grader of what each assignment should be awarded. As feedback, the grader simply circled problematic elements in the submitted paragraphs (e.g., misspelled words, incorrect punctuation, etc.), with the idea that motivated students would work to figure out what the markings signified. Starting with the fourth writing assignment, the grader adapted the process to also include short descriptions of problematic areas, especially regarding clarifications of scientific principles. The grading scheme was relatively successful from our specific grading resource

standpoint, requiring only about 2-3 minutes of grading per paragraph (or approximately 5 hours per assignment for 117 students). However, as we discuss in more detail below, many students did not like the grading and feedback scheme, which they found to be cryptic and difficult to understand. This is consistent with Hanson and Williams's observation that students sometimes felt that the instructor and rubric did not provide them with sufficient amounts of detail.[6]

Findings

Writing Exercises

A variety of writing prompts were piloted during the semester, as given in Appendix B. In general, these prompts fell into four major categories. The most common type of writing assignment involved providing a real world example of a fluid mechanics concept in action (e.g., writing prompt #1), such as the Bernoulli concept, or (e.g.) an example of a tall building and its water distribution system. This type of prompt connected in-class concepts to engineering practice, helping to motivate topics and convince students of the subject matter relevance. These "real-world example" questions were, in our case, straightforward to assess, as they involved minimal technical content and allowed the grader to focus on writing mechanics.

The "explain a concept" question was also tried several times during the semester, e.g., "Explain the meaning of Bernoulli's equation" or "How does an air compressor work?" This type of question directly links writing to technical concepts taught in class, additionally testing students' abilities to both write well and demonstrate understanding of technical material and jargon. Yet this type of question is more difficult to assess, owing to the potential need to assess the writing itself and respond to the technical accuracy of the information. The paragraph feedback scheme we implemented was not designed around technical correctness, so paragraphs with low grades due to incorrect technical content sometimes generated confusion among students.

A third type of writing prompt we assigned was among the most popular. It involved asking students to take a position on the proposed Keystone XL oil pipeline, namely by choosing a facet of the project, e.g. environmental, economic, etc., and arguing for or against the project from that perspective. Like the "provide a real-world example" prompts, the Keystone Pipeline question is a good example of a real-world pipe project, thereby linking it to the course's pipe flow unit. However, the more popular element of the assignment seemed to be that students generally had genuine opinions about the pipeline, and this was the first assignment that touched on an issue that they felt strongly about.

Finally, for several of the paragraph assignments students were simply allowed the option to re-write any paragraph for a better grade. This "revise a paragraph" question was discovered accidentally during a week when the instructor did not have the creative energy to compose another paragraph writing question. Yet it proved to be popular for the students and instructor because it provided students a chance to improve their writing scores and to act on some of the feedback received for their previous work. It was additionally incorporated in response to informal student feedback about the exercise, in order to improve student grades and hence morale. In retrospect this is an easy way to incorporate revision in response to feedback – an extremely important element of writing both in instructional and professional settings. Examples of an initial submission and final revision from a student in the class are given in Appendix C.

One issue with having students write formally is selecting and conveying an intended audience for whom they are writing. We struggled to provide an appropriate description of audience, but initially felt this specification was necessary. This was especially true for the "explain a concept" questions, since students needed to know the appropriate background of the audience in order to properly explain the concept. Yet we found that, counterintuitively, providing more information about this fictitious audience engendered more contrived and confusing responses, with the exercise threatening to become one of impersonation. For example, in one question we described the audience as fellow sophomore-level college students. Accordingly, one student wrote his paragraph as a long text message full of emoticons and abbreviations. We eventually stopped trying to frame the perfect audience for each question, and most students seemed to then write in a more natural, straightforward manner, which is presumably an important aspect of helping students to find their natural written voice. As the semester progressed, we also posted examples of high-scoring paragraphs, which helped to clarify the writing style we were seeking.

Student Performance

Performance on each paragraph writing assignment is summarized in Table 1. As indicated, the most common reasons for lower-scoring paragraphs were grammatical errors (spelling and punctuation) and a lack of logical organization. Many of the errors found in the writing tended to be basic form errors that could have been potentially avoided with further proofreading. It was originally thought that grammar and spelling errors would be primarily present among certain demographics (e.g., ESL students), but the majority of the class struggled with this aspect.

Table 1. Student grade statistics for paragraph writing assignments (1-5 scale, n=108)

		Paragraph Prompt Number					
		P1	P2	P3	P4	P5	P9
Original Submission	Mean	3.43	3.19	3.36	3.38	3.33	3.79
	Median	4	3	3	3	3	4
	Std. Error	0.10	0.10	0.09	0.12	0.11	0.13
Resubmission	Mean	3.69	3.45	3.85	3.92	4.05	3.86
	Median	4	3.5	4	4	4	4
	Std. Error	0.12	0.11	0.09	0.11	0.10	0.12

In general, paragraph writing scores improved during the semester. As shown, the assignment scores begin with a mean class score of 3.43 and end with 3.79. The scores also showed consistent improvement through the semester with the exception of writing prompt #2, which had low scores due to a failure by many students to address all of the given requirements of the prompt. We saw no discernable correlation between the paragraph writing scores and gender or major. However, scores did vary between ESL students and native English speakers. Average scores for all six assignments was 2.72 for ESL students (15 students) and 3.53 for native English speaking students (84 students). Figure 1 compares mean scores and standard error for each assignment for native English speakers and ESL students.

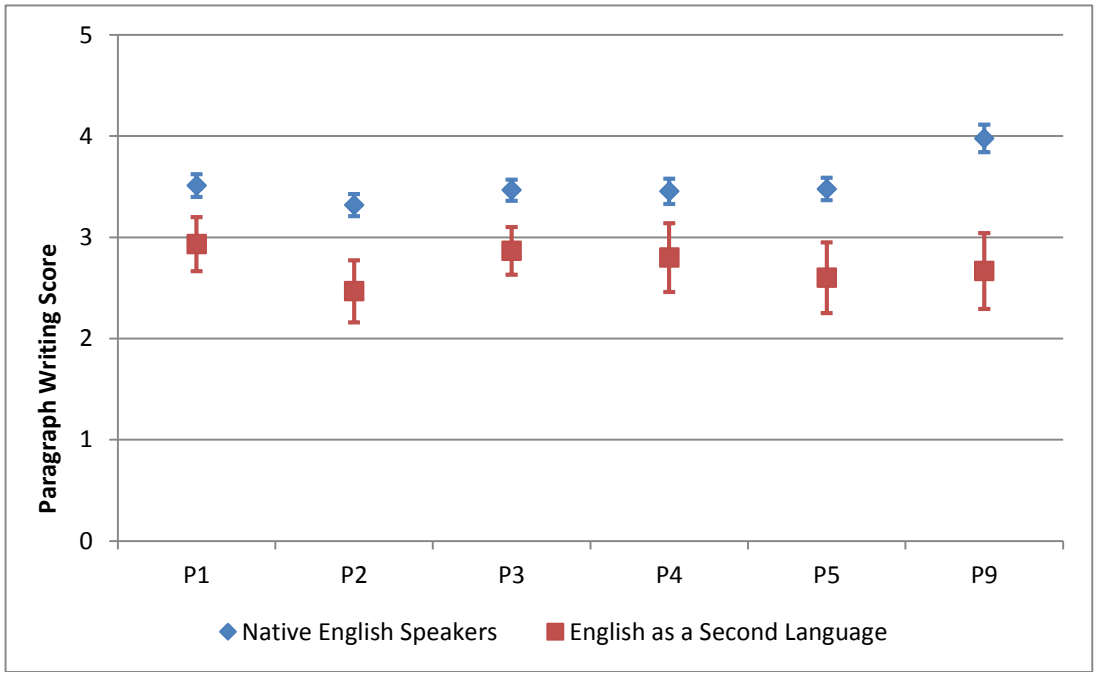

Figure 1. Mean paragraph writing scores for native speaking and ESL students (n=104)

Student Attitudes and Beliefs

In addition to tracking student performance, we developed and administered a pre/post-course survey about student attitudes toward writing. As indicated in Figure 2 below, the survey results show that students generally felt that they were good writers both entering and leaving the class (pre/post-course mean scores of 3.0/4 and 3.1/4, respectively, corresponding to "Agree"), and they recognized the importance of writing in the engineering profession (pre/post-course mean scores of 3.5/4 and 3.4/4, respectively, corresponding to between "Agree/Strongly agree"). Most students also felt that writing skills were best taught in a mix of engineering and non-engineering courses (pre: 63%; post: 69%). Interestingly, there was virtually no change between the pre- and post-course survey results, despite students' expressed dislike of the paragraph writing exercise.

Student Feedback

Student feedback on the post-survey indicated positive response to the revision exercises throughout the semester (mean score of 3.52/4; "agree/strongly-agree"). However, the students also indicated frustration with the grading rubric provided and showed confusion with regards to what constituted a satisfactory paragraph. These results indicate required modifications for both the feedback process and grading rubric. All results from the questions regarding student feedback on about the exercise are present in Figure 3; results are displayed based on a 4-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (4).

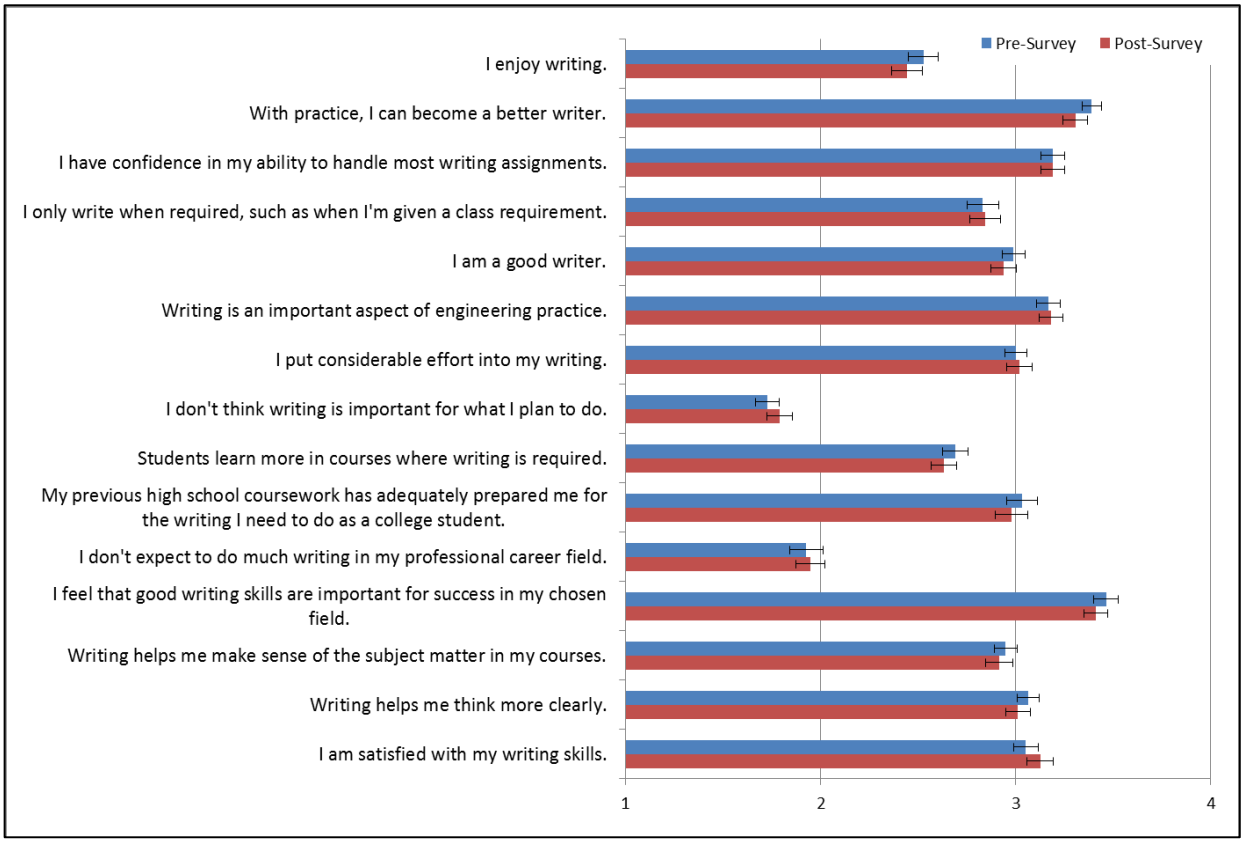

Figure 2. Student pre/post-course attitudes towards writing abilities (n=96, and where 1=Strongly disagree, 2=Disagree, 3=Agree, 4=Strongly agree)

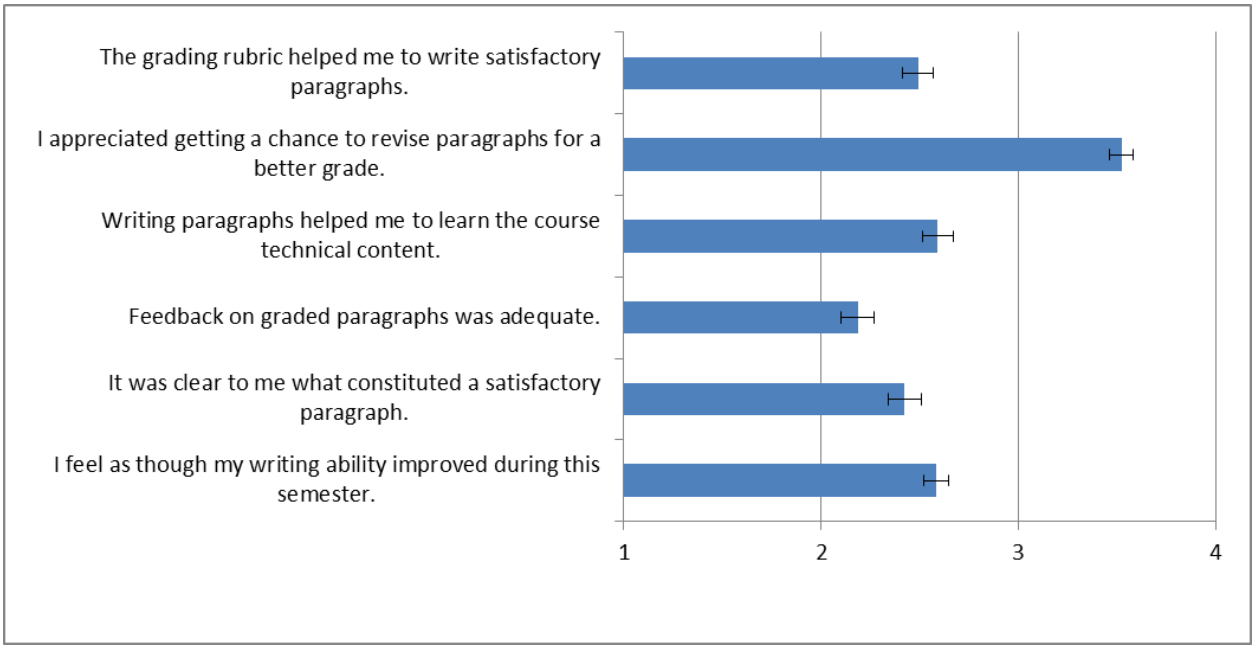

Figure 3. Student feedback about exercises indicated on post-survey (n=101)

Student Utilization of Help Resources

Students were encouraged throughout the semester to seek writing help from the professor, teaching assistant, other students, and/or the campus writing laboratories. Table 2 shows which resources students used to improve their writing, according to the post-course survey. Students were allowed to select all the help method(s) they used. Of the 101 students answering this survey question, 13 indicated they used multiple resources. Perhaps even more notably, 81 indicated that they did not seek writing help from any source, despite the majority of students expressing frustration about not knowing how to improve their writing scores.

Table 2. Types of help sought by students for paragraph writing exercise

Type of Help	No. of Students*
No Help	81
Professor	7
Teaching Assistant	5
Classmate	9
Friend	15
Writing Lab	3
Other	0

* Total n=101; Multiple selections allowed

Instructor Perspectives

Since the assessment was carried out by a graduate teaching assistant, the primary roles of the instructor in the paragraph writing exercise were: (1) creating and tailoring the weekly writing prompts for the assignments; (2) leading occasional, brief, in-class discussions related to the exercise, such as what resources were available on campus for students to obtain help with their writing and some basic paragraph writing tips; (3) holding individual consultations with students seeking clarification on how to improve their writing scores (Table 2); and (4) modifying the exercise as needed to accommodate student concerns and unexpected issues. The development of writing prompts took some practice and iteration, and was sometimes perceived as unwanted work akin to creating a homework problem from scratch. The instructor was unclear as to what elements constituted a good writing prompt, largely because – in retrospect – the pedagogical objectives of the paragraph writing exercise were not entirely well-defined at the beginning of the semester. This was also the first time the exercise was attempted. However, as with any homework problem, the instructor felt that the developed writing prompts could easily be re-used or re-tooled for use in subsequent semesters.

In response to specific requests for help on the written paragraphs, the instructor spoke to several students individually. While it was apparent to him that the paragraphs had flaws in keeping with their rubric-based scores, the instructor sometimes found it difficult to coach the students on how to improve their papers, beyond correcting obvious spelling and grammar issues.

Nonetheless, several simple techniques seemed effective in helping students improve their writing. The most common issue the instructor noticed was simple spelling and grammatical errors, which were addressed with the suggestion that all work should at the very least be spell-checked using the word processor software prior to submission. One additional technique was to have students read their writing aloud to themselves or another person, or to have a friend read

their paragraphs aloud to them. This technique was effective in having students identify problems with logic and organization, as well as to catch grammar and spelling errors previously overlooked.

One very brief in-class discussion was very helpful in teaching students how to improve their writing. Following Strunk and White, the instructor pointed out to students that: (1) every paragraph should be organized around a single topic or point, and (2) that this point is most often expressed as one of the first sentences in the paragraph.[16] This seemed to improve the focus of many students' paragraphs, which could sometimes be unfocused and not strongly allied to any central theme or message. In general, however, the instructor struggled with how and whether to provide additional guidance on the writing exercises, which he thought would have required the preparation of additional instructional materials and the further use of precious class time.

Several other instructor observations are worth noting. The instructor observed that students seemed to better appreciate the importance of the subject as compared to students in previous classes, which he thought may have been attributable to the writing exercises, many of which focused on writing descriptions of real-world fluid mechanics applications (although we did not assess for this in our surveys). An additional observation with the inclusion of the writing exercises was the issue of student morale and satisfaction; the instructor was weary of the (generally negative) student attitudes towards the writing exercises, which he felt undermined other, more positively-viewed course elements.

Discussion

Implementation of Writing into a Large Course: Successes and Future Opportunities
The pilot paragraph writing intervention described in this paper was successful in several ways, but also highlighted several important facets of the exercise that need to be more carefully implemented and require further iteration in the future. First and foremost, following our primary objective, we successfully included a writing component in a large engineering course in which no writing was traditionally included, and at an academic level (junior year) when writing is often absent from technical coursework. Additionally, the assessment trajectories indicate that we improved students' paragraph writing abilities, or at least their abilities to write paragraphs in accordance with our stated rubric. One caveat regarding resources is that our exercise did not technically fall within the nominal resources of the course; as discussed previously, because of the primary teaching assistant's lack of English skills, a secondary graduate student external to the course was recruited to help support the intevention. This student was not paid and participated as a grader because of her interest in our larger study objectives. In general this bias (towards "success" when implementing writing into engineering courses) may be true of many other writing-in-engineering-courses studies: many of these studies are carried out by instructors who believe strongly in the importance of writing (and may orchestrate the study themselves), and by virtue of this may leverage additional resources towards the writing exercises, leading to results that may overestimate the transferability of the exercise to other settings. Our next pilot exercises will be carried out with "less willing participants," thereby hopefully providing more objective and nuanced findings pertaining to the transferability of the paragraph writing exercise.

Paragraph Prompts

The writing exercises, as implemented, often served to help students link the technical material presented during lectures with real life engineering applications. This in turn may have served to convince the students of the technical material's relevance, an important element of engineering instruction. We hope to quantify this effect in future studies. However, this is not the only pedagogical objective that can be achieved with the paragraph writing exercises, and more work needs to be carried out in order to better determine the characteristics that allow for the tailoring of writing prompts to address specific learning objectives.

Instructor Workload

Importantly, the exercise was not overly burdensome on the instructor, and many of the paragraph questions developed for the semester could easily be re-used or re-tooled for subsequent semesters, further reducing the workload associated with implementing the exercise again. Additionally, the writing assignments need not be assigned on a weekly basis, especially when implementing the assignment for the first time. (We found Brent and Felder's sage advice to "don't set out do it all at once"[17] only after the semester had been completed.) Additionally, we discovered that the instructor workload can be lessened by allowing students to re-write.

Importance of Assessment and Feedback: What to do with the Written Paragraphs

The exercise showed that while it was relatively straightforward to assign writing questions on a regular basis, the real challenge in implementing the exercise was how to assess the student writing and provide feedback. This is perhaps the most important issue elucidated by our study. In retrospect, it is not apparent that we needed to provide students with feedback on their writing in order to simply include writing in the course. However, we felt it necessary to evaluate their paragraphs in order to motivate student work and to help them improve their writing.

The assessment and feedback strategy should be determined by (1) the objectives of the writing exercises incorporated in the course; and (2) the resources available for the assessment and feedback work. While the assessment/feedback strategy we incorporated was appropriate for the resource levels associated with the course, in retrospect our study suffered from a mismatch between the grading/assessment strategy and the objectives of the writing exercises. Our stated objective was to simply have students write in large class, and the appropriate assessment and feedback strategy would have been to provide the least amount of assessment and feedback that would accomplish that objective. However, we were concerned that without meaningful assessment and feedback, students would simply not do the assignments or turn in assignments of unacceptable quality. This led us to adopt our grading rubric and minimal marking feedback scheme (Appendix A), which is more appropriate when the objective is to improve student writing and/or utilize writing to have students demonstrate knowledge of technical material. The pilot exercise to some degree became a tail wagging the dog, with the assessment strategy driving the instructor to shift the exercise objective towards the improvement of student writing, which became challenging to do without be ready to share writing instruction strategies in advance. Ongoing work seeks to modify our assessment and feedback strategy to better suit our writing exercise objectives, and better elucidate these objectives at the beginning of the semester.

Student Responses to Assessment and Feedback

Many students felt frustrated with the writing exercises for several reasons, which may have been related to their pre-existing beliefs about their writing abilities. On the whole, students believed themselves to already be somewhat proficient writers, as illustrated by both their pre/post-course survey results. Further, the minimal marking strategy unintentionally led to students to hyper-focus on small grammatical mistakes. While the marking strategy did allow for quick grading of the written paragraphs (2-3 minutes grading each paper), the markings were typically limited to the circling of obvious grammatical and syntax errors, leading students to think that the sole reasons for their (sometimes low) scores were trivial spelling errors and missing commas. In reality, low paragraph scores were commonly associated with poor organization, lack of a clear central thesis, and incorrect technical information. However, these types of shortcomings could not be easily communicated to students with the minimal marking scheme as implemented. In the future, if minimal marking is to be implemented, shorthand notation for organization, logic, focus, and technical content will be added to the scheme.

Another possible solution is to simply give students additional and more explicit feedback on their written paragraphs. However, this is highly undesirable from a resource standpoint, as it would require additional grading time (even at 2-3 minutes of grading per paper, the exercise frequently overtaxed our grading resources). Bean suggests comments that do not at all invoke grammatical language, but simply respond as a disciplinary reader: observations about sections that do not make sense, points that are clearly articulated, or concepts that seem to have been overlooked.[3] Even without these more involved responses, several potential strategies may improve the exercise from the assessment and feedback perspective.

One additional improvement possibility is peer feedback and/or assessment. Students could be required to exchange papers with a classmate prior to submitting their paragraphs, which could eliminate many of the more careless errors that plagued students' submissions. Additionally, editing and providing feedback would then be incorporated into the exercise, which are also important skills. Hanson and Williams have warned, however, that peer mentoring is most effective when restricted to mentors who have already demonstrated mastery and are therefore trustworthy advisors.[6]

Peer grading software is now available and commonly incorporated into writing intensive courses, although it is not yet clear that the adoption of the software affords substantial assessment time savings for classes with moderate enrollment, and the software itself adds a substantial amount of additional organizational logistics and student work.[18] Additionally, peer grading software may prove to be a barrier to the adoption of the writing exercise by faculty unwilling to invest the time and effort to learn another pedagogical technological tool.

Conclusions

The incorporation of writing into engineering courses is important for many reasons. Perhaps foremost, it serves to improve desperately needed writing skills in young engineers, and writing instruction embedded in technical courses is arguably the most effective manner of instruction, provided it is done properly. The embedded approach has the additional benefit of enhancing student learning of the technical material itself (i.e., "writing to learn"). However, such an

approach is often not pursued because it is perceived as being resource-intensive, requiring additional and specialized grading, expert instruction, and taking time away from an already full course schedule. Thus, it is desirable to develop, assess, and refine scalable writing exercises that overcome the above challenges and can be readily adopted into technical courses.

The weekly paragraph writing exercise was successful in incorporating writing into a junior-level fluid mechanics course that in prior iterations typically did not have writing assignments. The exercise did not cause a dramatic workload increase for either the students or the instructor. However, about 5 hours per week of additional grading time was required of the graduate teaching assistant for the 117 student papers. The exercise can be scaled back by assigning fewer assignments as well as providing students with opportunities to revise their work.

A key issue for the exercise was the combined use of minimal marking and a holistic scoring rubric as the assessment and feedback scheme for the exercise. While the scheme was successful in motivating students to put effort into their written assignments, students became hyper-focused on their paragraph scores and markings, and were frustrated by the lack of constructive feedback and clear direction for improvement. Future work will involve the refinement of an assessment strategy for various resource scenarios, defining the key components necessary for motivating paragraph prompts, and the piloting of these strategies in various courses.

Much work is needed in developing materials and strategies that aid instructors in developing and adapting writing assignments for their courses. We suggest that these strategies should take into consideration the following:

1) *Objectives and outcomes related to including writing in courses*: While it is true that the incorporation of writing into engineering courses is in general beneficial, the most benefit will be obtained when the writing exercise is appropriate for, and specifically tailored to, the learning objective(s) that are driving the inclusion of writing in the course.

2) *Available resources:* The adoption of effective writing exercises in a course should also be driven in large part by the available resources for the course, which will in turn help dictate what assessment and feedback strategies are possible. Resources to consider include instructor and grader time, technical and writing expertise, and experience.

By taking these considerations into account, it is hoped that more engineering faculty will be inspired to develop course materials that help their students learn to write, and write to learn.

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Appendix A. Holistic Grading Rubric for Paragraph Writing Exercise

Score	Description
5/A	A 5 paragraph features clear, insightful, thorough development of ideas and is excellent. Writing demonstrates a very strong understanding of concepts. It features a clear thesis statement, persuasive reasoning, and good support and examples. In addition, it shows insight that goes beyond the basic requirements of the assignment. Transitions help the writing flow smoothly from one idea to the next, and there are almost no errors in grammar or spelling.
4/B	A 4 paragraph is clearly competent. Writing demonstrates clear understanding of concepts, but does not display novel or particularly insightful approaches. It features a clear thesis statement and appropriate support and examples. Transitions create a generally smooth flow of ideas, and there are minimal errors in grammar or spelling. This paragraph is good, but not exceptional.
3/C	A 3 paragraph is satisfactory: it meets the requirements of the assignment. Writing demonstrates understanding of concepts, and there is a recognizable point. The thesis statement makes a claim, but support, though present, may be sketchy or underdeveloped. Transitions are somewhat awkward, and errors in grammar or spelling are present.
2/D	A 2 paragraph is unsatisfactory: it fails to meet the basic requirements of the assignment. Failing to follow the assignment automatically results in a grade no higher than 2. Other significant shortcomings that might lead to this grade include one or more of the following: writing demonstrates problems in understanding concepts. The thesis statement does not make a clear claim, rendering support not well-connected to the central claim. There is not a complete argument. Examples may be irrelevant, and errors in logic may be present. The writing is disjointed and may have many distracting grammar and spelling errors.
1/F	A 1 paragraph exhibits serious weaknesses or even severe difficulties. It fails to meet the basic requirements of the assignment in multiple ways, including: writing demonstrates a failure to understand key concepts. The thesis is unclear or missing, and examples may appear arbitrary, not clearly supporting claims. Errors in logic are present, and there is not sufficient development of ideas. This paragraph is difficult to read, full of grammar, spelling, and transition problems.

Appendix B. Writing Assignments Given for Paragraph Writing Exercise

Writing prompt	Median/Mean Student Score	Student Ranking	Notes
1. Describe a Civil Engineering project or common scenario where fluid mechanics played/s an important role that project.	4 / 3.43	Tie for 5	-Relatively straightforward; requires some outside research.
2. Provide an example of a specific tall building water distribution system; provide calculations demonstrating the pressure changes that should occur over the building's height.	3 / 3.19	Tie for 5	-Requires outside research by students -Students not sure how to incorporate calculations into paragraph.
3. The city of Venice suffers from recurring flooding. Write a short paragraph describing the massive engineering project currently underway to alleviate this flooding, including some of the project features, attributes, timing, and costs.	3 / 3.36	1	-Students saw a video on this topic in the companion lab course; still requires some outside research.
4. Choice: a.) Provide a photograph of the Bernoulli principle in action; describe this situation. b.) Describe one of the techniques used to stop the Deepwater Horizon oil spill. c.) How does an air compressor work? d.) Describe an interesting engineering problem involving hydrostatics.	3 / 3.38	Tie for 5	-Students can choose question most to their liking; variety of choices.
5.) In one paragraph, give a summary of the Bernoulli equation (no equations, only words). Possible points to discuss include, but are not limited to: assumptions, applications, conceptual meaning, derivation, etc.	3 / 3.33	4	-Question closely tied to technical content of course; grade additionally based on technical correctness of their answer.

6.,7.,8.,10) Rewrite any paragraph for a better grade.		3	-Easy question to assign during a week when instructor doesn't have time or space for paragraph writing.
9.) Write 1 paragraph discussing a single category of advantages OR disadvantages to the construction of the Keystone XL pipeline, in ONE of the following areas: social, economic, climate, the environment, communities through which the pipeline flows, indigenous communities, safety, climate change, or any other category.	4 / 3.79	2	-Most students have fairly strong opinion about pipeline; information readily available on internet.

Appendix C. Example of Initial Submission and Resubmission

There are several ways high rise buildings have adjusted their water systems to maintain a fairly uniform pressure throughout all the floors. The two most common methods are pumping water to a storage tank on the roof or having a series of pumps carry the water up from the ground level so certain floors in intervals. The single storage tank on the roof seems like the easiest method and allows gravity to do the work once the water has been transported to the roof. This may seem to cause problems with water "falling" many stories; however, the pipes are continuously filled and this simply helps to push the water out through the faucet. The second method, which involves pumping water into a series of high pressure tanks (every 30 stories or so for the Sears Tower) that feed the floors below them. Some fixtures can even feed directly off of these high pressure lines through the use of pressure relief valves.

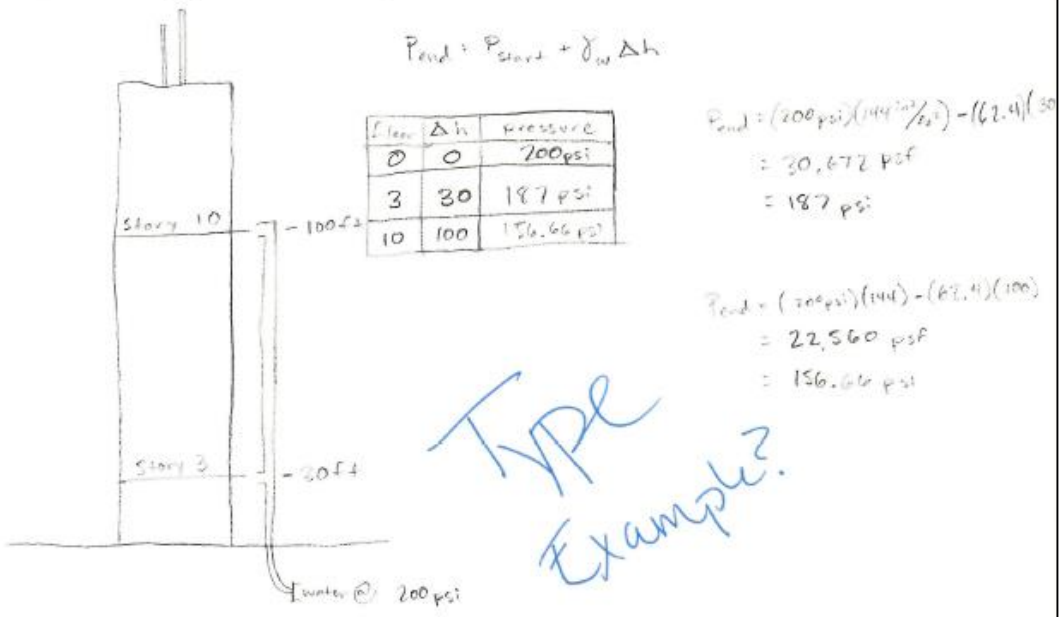

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Figure C.1. Example of paragraph prompt #2 student initial submission; A score of 3 was given with points being subtracted for not following the prompt instructions and not completely responding to prompt.

The Sears Tower in Chicago stands at a whopping 1,729' tall. This creates interesting problems with the fluctuation of water pressure within the building. The operations team for the Sears Tower has compensated for the great vertical height that the water must travel using a series of pumps to carry the water up from the ground level. This method involves pumping water into a series of high pressure tanks at regular intervals throughout the building (every 30 stories or so for the Sears Tower). These tanks in turn, then feed the floors below them with water that has been returned to a safe operating pressure. In addition to the tank storage, some fixtures can even feed directly off of these high pressure lines through the use of pressure relief valves. Both of these methods allow for a regular water pressure to be maintained throughout the building, despite its great height.

$$P_{end} = P_{start} + \gamma_W * \Delta h$$

Floor	Change in Height (ft)	Pressure (psi)
0	0	200
10	100	156.66
45	450	5

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Figure C.2. Example of paragraph prompt #2 student revision; A final score of 5 was given after initial issues were corrected.