Using Writing Assignments to Improve Self-Assessment and Communication Skills in an Engineering Statics Course

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ABSTRACT

This study explores the use of writing as a tool for metacognition in the engineering classroom. We used the "explain-a-problem" type of assignment in the Engineering Statics course for four terms. The objectives associated with the assignments were grouped under student self-assessment, student communication, and administration. Performance on each of four grading criteria for each assignment was tracked throughout the terms. The data indicate that explain-a-problem does help students achieve the self-assessment and communication objectives, although the impact on overall course performance was not as significant as hoped. The assignment evolved to the point that the administrative objectives were also met.

Keywords: engineering statics, metacognition, written communication

I. INTRODUCTION

In the context of the engineering classroom, students are challenged to employ an array of different subjects simultaneously. A student solving a problem in engineering statics must use his or her knowledge of math, physics, and engineering in order to address it. Unfortunately this scenario often does not demonstrate a student's knowledge of the key subject areas, but rather shows his or her ability to insert numbers into an equation or formula that may or may not be suitable to the task at hand, a situation commonly referred to as "plug-and-chug." Students may not be encouraged to assess themselves on two key issues: "Do I understand the technical content necessary to perform this task, and do I know it well enough to apply it to a new context?" In order to engage students in this kind of self-assessment, faculty must encourage students to change their habits by introducing new ways to approach engineering problems. One way can be the use of writing by asking students to explain how they have solved a problem.

Given the increased emphasis on the importance of communication skills in the engineering workplace, it is not surprising that engineering faculty members are adding writing and communication to their courses. Within the academic setting, engineering faculty have used writing and communication to model the engineering workplace, usually through Writing Across the Curriculum (WAC) and/or Writing in the Disciplines (WID) strategies. In these scenarios, instructors design class assignments that help students learn not only technical content but also the modes of communication—such as technical reports, workplace memos, etc.—that are appropriate to the engineering profession. In addition, if the professor asks a student to explain his or her work for the class or to discuss the problem with another student in order to devise a solution, then communication has entered into the context and students have an opportunity to develop their communication skills within that technical context. Such a scenario closely tracks the professional engineering environment as well. As a practicing engineer, the student will have to document his or her work in written form; he or she will also have to present a design to members of a design team and argue for the feasibility of the work. In both the academic and the professional contexts, communication is not a skill tacked onto the technical work at hand. Instead, it is more like the knowledge of math, physics, and engineering that make solutions possible.

We believe there is an opportunity to build on the progress made with the adoption of a WAC/WID assignment; this opportunity lies in encouraging students to use writing as a tool of metacognition, a means the student can use to determine what he or she knows about technical content and to self-assess to determine if he or she knows enough to apply that knowledge to a new context. In finding ways to encourage students to conduct such self-assessments, we believe we can direct students out of the "plug-and-chug" habit. In the case that we describe in this paper, we began our project with the idea that we could develop activities for the statics course that would encourage students to use writing for metacognitive self-assessment.

The course selected for assignment development is Engineering Statics. The students enrolled in the course are predominantly civil, mechanical, and biomedical engineering majors in their freshman or sophomore year. The course lasts ten weeks and is an introductory mechanics course that covers equilibrium of trusses, frames, machines, and parts of those structures in two and three dimensions. We discuss the development of an assignment whose primary goal was to help students engage in metacognitive self-assessment as well as the objectives of the assignment, evaluation of those objectives, the testing of the assignment and subsequent revisions, and the development of evaluation rubrics used to grade it. In addition we correlate student performance on the assignment with several markers of student learning. We also investigate potential bias within the assignment design toward certain personality or learning preferences. Finally we provide recommendations for further development. At the beginning of our project, we believed we would see marked improvements in student self-assessment and learning as a result of the assignment we developed. While the results we obtained do not point in this direction, we feel that incorporating the recommended changes (section VI) and conducting additional testing with larger student populations might bear out the improvement we hoped to see.

II. Literature Review

A review of the literature indicates that the Writing Across the Curriculum/Writing in the Disciplines movements have produced important changes within institutions of higher education over the last 30 years. As David Russell explains, the WAC movement had its origins in changes in higher education brought on by social and cultural transformations during the 1960s (Russell, 1994; McLeod et al., 2001). At large universities such as the City University of New York and the University of California at Berkeley, the increased ethnic, economic, and cultural diversity of students highlighted the lack of writing skills and the need to address their improvement. The trend to increase the emphasis on writing was simultateous with the idea that faculty from outside the discipline of English could participate in the development of these skills. For example, at Michigan Technological University, Toby Fulwiler and Art Young created a WAC program in the 1970s that involved the participation of faculty from the technical and scientific disciplines, not just the humanities (Young and Fulwiler, 1986). From these beginnings, WAC/WID approaches have made a significant mark in the field of engineering education (Brent and Felder, 1992; Carvill et al., 2002; Held et al., 1994; Herrington, 1981; Sharp et al., 1997, 1999).

Often, when engineering educators consider adding writing to a technical course, they frequently believe the best option is to add a formal report, proposal, or series of memos to an existing course. Herrington reports on the incorporation of lab reports, weekly progress report memos, and a formal report in two courses in the chemical engineering curriculum at Rensselaer Polytechnic Institute. The purpose of Herrington's study was to show "the function that writing can serve in introducing students not only to the intellectual activities of a discipline, but also to the social roles and purposes of various disciplinary communities" (Herrington, 1981). Since that time, engineering faculty have located writing assignments at various sites within the engineering curriculum, from the freshman laboratory to senior design (Brinkman and van der Geest, 2003; Fei et al., 2007; Gruber et al., 1999; Harvey et al., 2000; Peck et al., 1999; Swarts and Odell, 2001). In each case, the purpose is to help students develop important communication skills for application in professional engineering practice.

We agree that incorporating writing into the engineering classroom has important benefits for students in improving their writing and communication skills. These improvements are also made within the context of the technical classroom and thus show students that the engineering professor for the course believes communication is an important skill that is worth class time. While added formal writing is beneficial to students, the drawbacks include increased instructor evaluation effort while sometimes perpetuating a distinction in the minds of students between their technical work and the writing (which is sometimes looked upon as an annoying, make-work addition).

In deciding to develop the assignment for this course, we were interested in keeping the evaluation load reasonable while giving students an activity that would be totally integrated with their technical work. For these reasons, we considered the homework problem context and decided that was the best area for development. In particular, we were interested in exploring the use of writing as a means to help students evaluate what they do and do not know, help them visualize the problems on which they are working, and generally assist them in reflecting on their work in the classroom. In this respect, the assignment builds on the foundation of WAC/WID model by emphasizing the role of writing as a metacognitive activity for the purpose of self-assessment and reflection.

Metacognition is a concept introduced by Brown (1975) and Flavell (1976) and can be described as a sequence of steps followed by a person to monitor and improve that person's own cognitive performance in an area. Studies have shown that increased metacognitive activity leads to improved learning (Bielaczyc et al., 1995; White and Frederiksen, 1998), and a variety of techniques have been used effectively to promote metacognitive activity (Karelina and Etkina, 2007; Koch, 2001; Wade and Reynolds, 1989). While the use of writing to promote metacognitive activity has little representation in the literature (Gandolfo, 2001), faculty at Rowan University have experimented with developing metacognitive skills in teams of engineering students using writing exercises (Dahm et al., 2006). Our approach is somewhat different, but we still seek a similar outcome in students. Given these similarities, one might argue, as David Russell did in 2001, that the metacognitive dimension has been implicit since the inception of WAC/WID.

III. Purpose and Research Questions

The purpose of this study was to investigate the impact of the "explain-a-problem" type of assignment when used with freshmen and sophomore students in the Engineering Statics course. Since this was developed as a small-scale pilot study, the assignment was used by only one instructor for four terms. The study terminated when the instructor completed his rotation as instructor for the course. Baseline data was gathered for one term before implementing the assignments. The nine primary research questions for this study address the impact in four areas: student self-assessment skills, student communication skills, administration, and correlation between student performance and student learning styles and temperament.

The primary research questions for this pilot study consisted of the following:

Student Self-assessment Objectives

1. Does an "explain-a-problem" type of assignment help students identify what they do and do not know?
2. Does an "explain-a-problem" type of assignment help students recognize the difference between understanding

how to solve a problem and blindly plugging numbers into formulas?

Communication Student Learning Objectives

3. Does an "explain-a-problem" type of assignment help students develop the ability to communicate the solution process with sufficient detail that another person can reproduce the solution to the problem?
4. Does an "explain-a-problem" type of assignment help students develop a habit of annotating calculations in all courses?

Instructor Administrative Objectives

5. Can an "explain-a-problem" type of assignment be implemented without compromising course content?
6. Can an "explain-a-problem" type of assignment be implemented without causing a significant time burden on students to complete the assignments?
7. Can an "explain-a-problem" type of assignment be implemented without causing a significant workload for the instructor to grade the assignments?

Correlation between Performance and Learning Styles and Temperament

8. Does performance on an "explain-a-problem" type of assignment depend on learning style preference?
9. Does performance on an "explain-a-problem" type of assignment depend on Myers-Briggs temperament?

IV. METHOD

A. Description of Students

The students in this study are freshmen and sophomores studying engineering at a 4-year, private school that emphasizes math, science, and engineering. Most of the students are civil engineering majors, but some are mechanical or biomedical engineering majors. The average grade point average (GPA) for freshmen and sophomores across the institution is typically just below 3.0. The course is Engineering Statics and is typically taken during the spring term of freshman year or fall term of sophomore year.

B. Description of Assignment

In order to achieve the self-assessment and communication objectives, we chose to use the "explain-a-problem" type of assignment. As part of a homework assignment, students were asked to provide a written description of one of the homework problems. Specifically, the assignment stated "For the specified problem, describe the steps followed in order to set up and solve the problem." The particular problem was always selected by the instructor so that every student was describing the same problem. The instructor was careful to choose problems for which answers were provided in the textbook; therefore, students knew whether they had achieved the correct answer before they began the written description. This model is a variation of the "Documented Problem Solutions" classroom assessment technique (Angelo and Cross, 1993).

The students received the assignment description on the first day of the course (Appendix A). The handout describes the self-assessment and communication learning objectives. In addition, the handout provides examples of well, adequately, and poorly written descriptions for an example problem. Students are instructed to provide a written description of the steps used to solve the specific problem, not steps to solve the type of problem in general. The written description must be no more than one-half of a page in order to promote concise communication. The description may be typed or hand written.

C. Assignment Grading

The first term in which this assignment was used was Spring 2003. During that term, students provided a written description of one problem for each homework assignment. There were two homework assignments per week for most of the ten week course. In all, there were 17 homework assignments; therefore, students produced 17 written descriptions in the Spring 2003 term. The second term in which this assignment was used was Fall 2003. During that term and subsequent terms, students provided a written description of one problem per week. Therefore, students produced eight or nine written descriptions in each of the following terms: Fall 2003, Spring 2004, and Spring 2005. The frequency was decreased to reduce instructor workload and student burden (administrative objectives). The reduction did not have an effect on the student self-assessment or communication outcomes.

During the first term, we noted that several students decided not to prepare written descriptions to submit with their homework. Each written description was worth eight out of 100 points for the homework assignment. In comparison, the problems were typically worth 20 to 30 points each. Therefore, several students probably found that the eight points were not worth the time required to prepare the written description. To emphasize the importance of the written description assignments and to encourage increased participation, the instructor increased the value of each written description to 16 points out of the 100 for each assignment in the second and subsequent terms. Table 1 presents the percentage of times students submitted the homework assignment but did not include the explanation portion. Increasing the value appears to have decreased the skip rate. For all terms, homework accounted for 20 percent of the student's course grade.

The assignment description handed out at the beginning of the term also included the four outcomes expected of the students. They are formulated as grading criteria and were the same throughout the four terms. The four criteria are:

1. Has the student provided sufficient detail that I could reproduce the approach to the solution?
2. Has the student demonstrated an understanding of what is being done in the solution process?

Term	Assignments Submitted	Skipped Descriptions
Spring 2003	570	10.2%
Fall 2003	338	8.6%
Spring 2004	364	3.6%
Spring 2005	315	5.7%

Table 1. Percentage of students who submitted homework assignments but did not submit the written description portion.

3. Is the description written so that I can understand what the student means?
4. Is the description focused on the approach to the solution of this problem, not the specific numbers of the solution?

Although graders are used to evaluate the homework problems, the instructor chose to evaluate the written descriptions himself. During the first two terms, the instructor critiqued each assignment then assigned scores for each of the four criteria based on full, partial or no credit. For the last two terms, the instructor used a grading rubric, shown in Figure 1. The instructor developed the rubric to help ensure consistent grading, to possibly reduce the time spent grading, and to provide students with specific guidance on how to do well on the assignment. After the first two terms, the instructor reflected on what he looked for when assessing each criterion and formalized those attributes into the grading rubric. During the terms when the instructor used the rubric, Spring 2004 and 2005, he made it available to the students and encouraged the students to score their own assignments before submitting them. An example of how the rubric was applied to an actual student submission is provided in Appendix B.

D. Support to Students

Students received several different types of support from the instructor. The support was intended to help students produce writing assignments that receive full credit for all of the criteria. The types of support included a demonstrative example, a template on which to type the description, reviews of high and low scoring descriptions, and an in-class workshop. Every student received the description of the assignment (Appendix A) on the first day of class. Included with the description was an example problem with three written descriptions: one that would receive full credit, one that was adequate but would receive only partial credit, and one that was inadequate and would receive little credit. To ensure that students would have the criteria in view while preparing their assignments, the instructor developed a template that he made available to students beginning with the second term. The template listed the four grading criteria at the bottom.

Beginning with the third term, Spring 2004, the instructor tried a variety of in-class supports to try to help students improve performance. The instructor reviewed high and low scoring descriptions at the beginning of class. For the review, he had the class read the low scoring example and score it themselves with the rubric. He polled the class for final scores and asked students why it earned that rating. He then had the class read the high scoring example and repeated the process. That term he conducted in-class reviews after the first, second, and third writing assignments (Homework Assignment #2, #4 and #6).

During that same term, the instructor conducted an in-class writing workshop prior to the fifth writing assignment (Homework Assignment #10). The in-class workshop took the entire class period. During that period students wrote a description of the selected homework problem or a class example problem. After 20 minutes, they were instructed to exchange their drafts with someone in the class and critique the description based on the grading rubric. They continued to exchange until at least three people had reviewed and commented on their descriptions. The in-class efforts did not appear to have significant effect on student performance, so the instructor chose to use less class time the next term.

In Spring 2005, the instructor conducted in-class reviews after the first and fourth writing assignments (Homework Assignment #2 and #10). The instructor did not conduct the in-class writing workshop in Spring 2005.

V. Results

A. Impact on Student Self-assessment Objectives

We began this pilot study with the intent of promoting metacognitive behavior by the students. Therefore, the explain-a-problem type of assignment was chosen so that students would need to reflect on the process they followed to solve a problem in order to describe that process. Implicit in this approach is that if students struggle to articulate the solution process, they should assess whether the problem is their understanding of statics or their ability to communicate. This self-assessment can take place while preparing the written description as well as after receiving instructor feedback.

To promote this reflection, we had two student awareness objectives when creating the assignment: students discover what they do and do not know, and students recognize the difference between understanding how to solve a problem and blindly plugging numbers into formulas. We have measured achievement of these objectives indirectly by comparing assignment average and course average, by observing trends in average criterion scores over the term, and by soliciting feedback from students.

The instructor administered the Engineering Statics course for five terms. The relationship between course average score and writing assignment average for four terms is presented in Figure 2. Each data point in Figure 2 represents one student. The data from all four terms show a positive correlation between writing assignment average and course average score. Note that the writing assignment average is worth less than 2 percent of each student's course average. Figure 3 shows how the average score for Criterion 2, Demonstrates Understanding, changed over the term for all four terms. As the term progressed, the students had to describe increasingly more difficult problems. However, the average score tended to remain the same or drop only modestly. The trends in Figures 2 and 3 imply that students were discovering what they did and did not know, and that they used that information to improve in the course.

The fourth criterion, Focused on Approach, provides a way to measure how well students understood how to solve a problem. Figure 4 shows how the average score for Criterion 4 changed over the term for all four terms. The average scores tended to rise to a high level after the first few assignments and remain there for the term. To achieve a high score in this criterion, students cannot recite values or formulas; they must describe the process. Therefore, the high level of success on this criterion suggests that students achieved the objective of recognizing the difference between understanding how to solve a problem and blindly plugging numbers into formulas. Anecdotal support for this conclusion comes from several comments by students in their course evaluations:

> "I learned so much in this class that I had never even thought about before." (Fall 2003)

> "[The instructor] can make people think and teaches in a way to induce problem-solving behaviors as opposed to the "plug and chug" method." (Fall 2003)

Criteria	Full Credit (4 pts)	Partial Credit (2 pts)	No Credit (0 pts)
Has the student provided sufficient detail that I could reproduce the approach to the solution?	• Identify sequence by which unknowns are being found.	• One necessary equation is not identified.	• Several necessary equations are not identified.
	• Terms used in each equation are identified (e.g. forces that contribute moment in moment equilibrium).	• Terms used are not identified for one equation.	• Terms used are not identified for multiple equations.
	• Body or particle for FBD is identified.	• Body or particle for FBD not clearly identified.	
Has the student demonstrated an understanding of what is being done in the solution process?	• Approach described is fundamentally sound.	• One error in the approach.	• Multiple errors in approach.
	• Each equation used is described in words, not with algebra.	• One equation described algebraically.	• Multiple equations described algebraically.
Is the description written such that I can understand what the student means?	• Description begins with the objective of the problem.	• Description does not begin with objective of the problem.	
	• Description no longer than one-half page (if typed, single spaced lines).	• Description more than one-half page, but less than full page (if typed, single spaced lines).	• Description more than one full page (if typed, single spaced lines).
	• Handwriting is legible. • Pronouns have clear meanings (i.e., "that", "it", are easily interpreted).	• One or two sentences do not make sense because of handwriting, ambiguous pronouns, and/or undefined variable names.	• More than two sentences do not make sense because of handwriting, ambiguous pronouns, and/or undefined variable names.
	• All variable names used in the description are defined.	• One variable used in the description not defined.	• Multiple variables used in the description not defined.
Is the description focused on the approach to the solution of this problem, not the specific numbers of the solution?	• No quantities (e.g., 100 lb, 20°, 3 m) are used in the description.	• One quantity is provided in the description.	• Several quantities are provided in the description.
	• Details are provided about solving this particular problem.	• Description is about how to solve this type of problem in general.	

Figure 1. Grading rubric used by instructor to score assignment.

In Spring 2005, we surveyed students who had taken the first class to use this assignment two years earlier (Spring 2003). Therefore, the students were all juniors reflecting on the experience. One of the questions addressed how well the writing assignments helped them.

> "I found that the written description problems in Engineering Statics helped me better understand and remember how to perform statics problems…"

Very much – 2 Some – 14 Little – 3 None – 1

Although the students did not feel that the assignments had a significant impact on their understanding of Engineering Statics, they clearly felt that it had some positive impact. Table 2 presents the average course scores for all students for each term including the control term. The average scores do not appear to be affected even though the students improved their self-assessment skills.

B. Impact on Student Communication Objectives

The first communication objective is that students communicate the solution process with sufficient detail that another person can

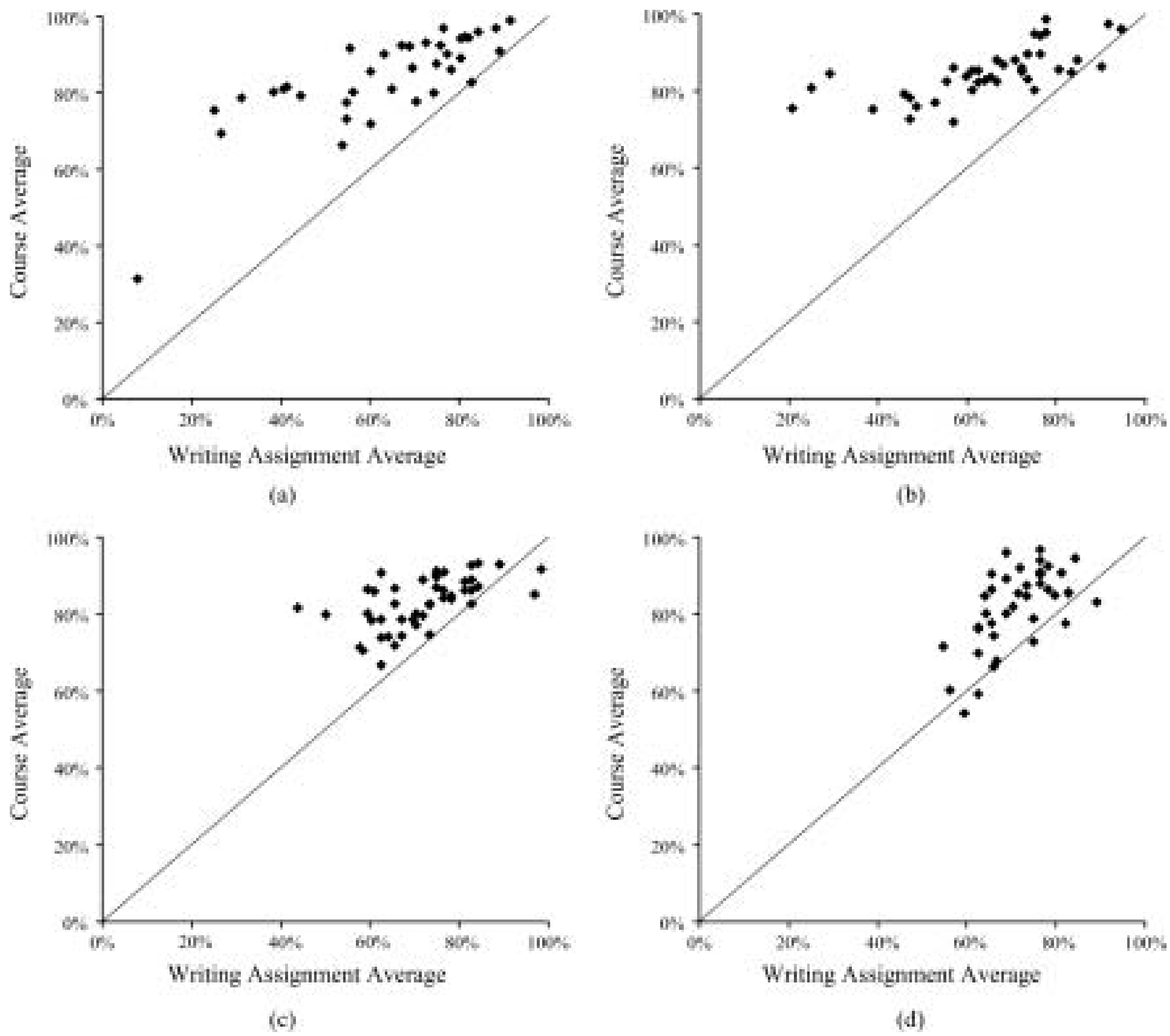

Figure 2. Relationships between writing assignment average and final course average for four terms: (a) Spring 2003, (b) Fall 2003, (c) Spring 2004, (d) Spring 2005.

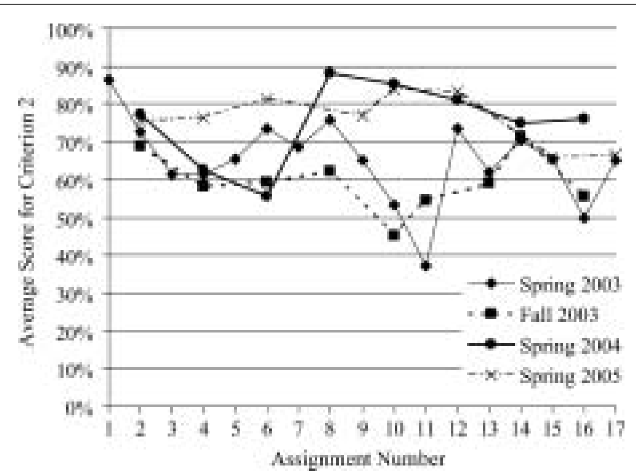

Figure 3. Change in average score for Criterion 2—Demonstrates Understanding, over the course of the term for each term.

reproduce the solution to the problem. Achievement of this objective is indirectly measured by student comments in the course evaluations.

> "I have also learned how to effectively convey my ideas and problem strategies in a shortened format." (Spring 2005)

The objective is measured directly in Criterion 1, Provides Sufficient Detail, and Criterion 3, Written So Can Be Understood. The average Criterion 1 score for each assignment over the course of the term for all four terms is presented in Figure 5. The average Criterion 3 score for each assignment is presented in Figure 6. Performance on Criterion 1 varies greatly throughout the quarter with a general trend of consistently mediocre performance (30–60 percent). The lack of improvement might be linked to the increasing difficulty of the problems. It appears that as the problems become increasingly difficult, the students continue to struggle with how to communicate with sufficient detail that someone could reproduce their work. The

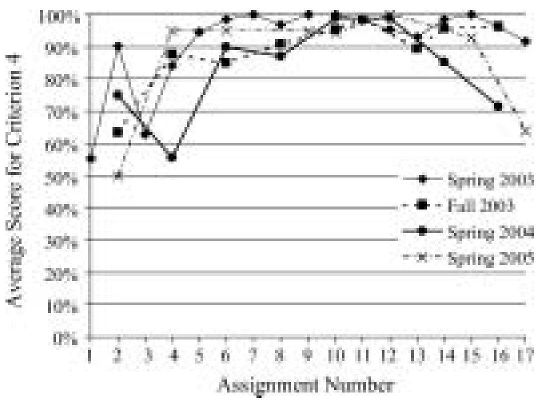

Figure 4. Change in average score for Criterion 4—Focused on Approach, over the course of the term for each term.

Term	Students	Avg. Writing Score	Avg. Course Score
Fall 2002	14	-	82%
Spring 2003	37	73%	84%
Fall 2004	39	73%	85%
Spring 2004	46	69%	83%
Spring 2005	40	67%	82%

Table 2. End of course score averaged among all students for each term.

students do generally demonstrate acceptable performances. However, performance on Criterion 3 increases over the term and plateaus at a high level (85–95 percent). Therefore, students do improve in their ability to write so that they can be understood.

The second communication learning objective is that students develop a habit of annotating calculations in all courses. We gathered evidence about achievement of this objective by surveying the students who took the course in Spring 2003. Those students took a survey in Spring 2005, two years later. One question directly addressed the impact the assignments had on how much they annotate calculations.

> "I find that the written description problems in EM120 have had ... impact on how I annotate calculations on homeworks and projects in my various courses."
>
> Very much – 2 Some – 12 Little – 3 None – 2

In addition, several students provided comments about this objective as part of the survey.

> "Good habit to get started, although I hated it at the time, I still use this method now when it's not required."

> "I am pretty detailed in my solution to homework problems. I indicated where I got all values (from reference tables) and how I calculated numbers."

> "They really didn't help me learn how to document my work."

Although only two students felt that the assignments had a significant impact on their communication habits, most felt that it had some positive impact.

C. Impact on Instructor Administrative Objectives

The first administration objective was to implement the assignment without compromising course content. The instructor was able to maintain the same course syllabus even with the addition of the assignment and the writing support to students. The instructor used time available in "problem-solving" class periods to provide the writing support to students. He did not reduce the length of homework assignments on the assignments that included the problem.

The second administration objective was that students do not experience a significant burden to complete the assignments. The amount of time students spent on homework assignments each week provides a measure of achievement of this objective. The average number of hours spent on homework as reported by the students is presented in Table 3. The students did not report an increase in average time spent on the course. In fact, the students taking the course in the terms where the assignments were used (Spring 2003-Spring 2005) reported that they spent less time than the students in the control term (Fall 2002). Comments from students in the course evaluations, however, indicate that many students were frustrated by an inability to improve their total score on the assignments.

> "Grading of the 'Written Solution Description' was not consistent." (Spring 2003)

> "Professor Hanson could work on the description for problems we do on the HW. By this I mean when we have to describe how we did a problem in words. My grades for that varied greatly, and I thought I did the same thing each time. Maybe a better explanation would help a little." (Fall 2003)

> "Be more consistent with the grading of the essays." (Spring 2004)

> "Give a little more instruction on the written problem solutions." (Spring 2004)

> "[It would help to] meet with you about how to do the description of a problem and the correct set-up because I can never seem to fully present what I am thinking." (Spring 2004)

> "He could improve in being more clear in what he wants when it comes to written descriptions." (Spring 2005)

In a survey, students reflected back two years to their experience in the course during Spring 2003. Several of their comments also reflect this frustration.

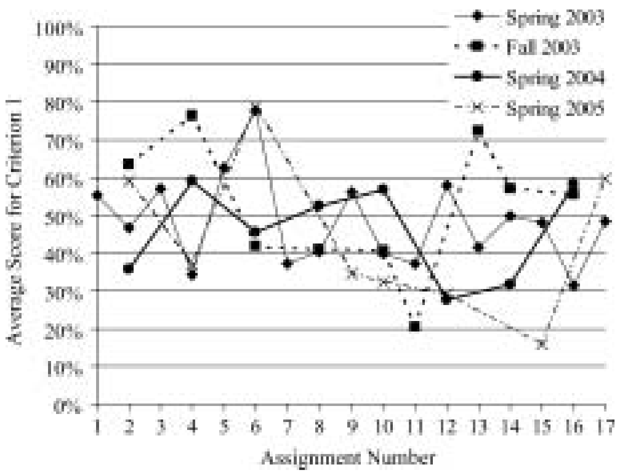

Figure 5. Change in average score for Criterion 1—Provides Sufficient Detail, over the course of the term for each term.

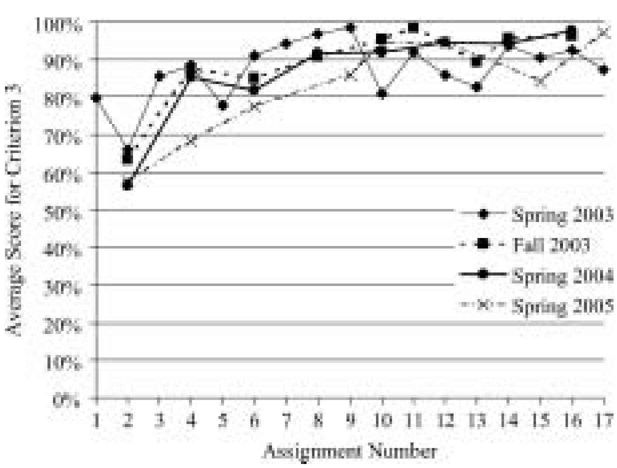

Figure 6. Change in average score for Criterion 3—Written So Can Be Understood, over the course of the term for each term.

> "I remember being really confused on exactly what you wanted."
>
> "I was not a fan of the written descriptions because it seemed I never did good enough on them."
>
> "I don't ever think I understood how to do them which is why I never got full credit on any of them."

Figure 7 presents the average total score on the assignments over the course of the term for each of the four terms. Those averages are relatively consistent across the term. Therefore, the students' frustrations were probably linked to their inability to perform well on Criteria 1 and 2 (Figures 3 and 5).

The third administration objective was that the instructor does not experience a significant workload to grade the assignments. Table 4 shows the average amount of time the instructor devoted to grading each writing portion of a homework assignment. The first term that the instructor used the grading rubric (Figure 1), he devoted four hours per assignment to grading the writing portion. The time dropped significantly during the next term. The reduction in time required is probably due to increased familiarity with the rubric. With the rubric and clear guidance on what is expected, we believe that graders or teaching assistants could perform the grading duties. Therefore, the increase in instructor workload would only be in training the graders and providing quality control.

D. Correlation of Performance to Learning Styles and Temperament

We considered the possibility that the explain-a-problem type of assignment might be more difficult for some students based on their Myers-Briggs temperament (Myers and McCaulley, 1985) or Index of Learning Styles preferences (Felder and Silverman, 1988). Therefore, we evaluated the correlation between the average writing assignment score and the intensity of Myers-Briggs temperament or Index of Learning Styles preference. Most of the students had already taken surveys for Myers-Briggs temperament and Index of Learning Styles preference at the beginning of their freshman year. We used the existing data for the evaluation. Only one dimension of Myers-Briggs, judging/perceiving, seemed like it might have an impact on the explain-a-problem scores. Therefore, we chose not to investigate any correlation to the other Myers-Briggs dimensions. The results of the correlations are provided in Table 5. The number of students with particular temperaments or preferences is also included in the table. The Pearson correlation coefficient is a measure of how well one quantity predicts the other (Hopkins and Antes, 1990). A value of 0.4 is considered a weak correlation; any value below 0.1 is considered no correlation. Therefore, the explain-a-problem type of assignment is not biased toward a particular personality temperament or judging/perceiving learning style preference.

VI. Discussion

The explain-a-problem type of assignment does appear to help students achieve the self-assessment objectives: students discover what they do and do not know, and students recognize the difference between understanding how to solve a problem and blindly plugging numbers into formulas. Achievement of the self-assessment objectives did not appear to improve student learning in this case though.

The assignment also helped students achieve the communication objectives: students communicate the solution process with sufficient detail that another person can reproduce the solution to the problem, and students develop a habit of annotating calculations in all courses. Only limited data was gathered to evaluate whether the writing-to-learn assignments helped students develop a habit of annotating calculations; however, the data did indicate that the assignments helped. The data showed a strong improvement in ability to communicate clearly, but also showed a lack of improvement in communicating appropriate details as the problems became more complex.

The assignment has evolved to the point where the administration objectives have also been met: instructor does not compromise course content, students do not experience a significant time burden to complete the assignments, and instructor does not experience a significant workload to grade the assignments. The syllabus remained unchanged with the addition of the assignments. Students

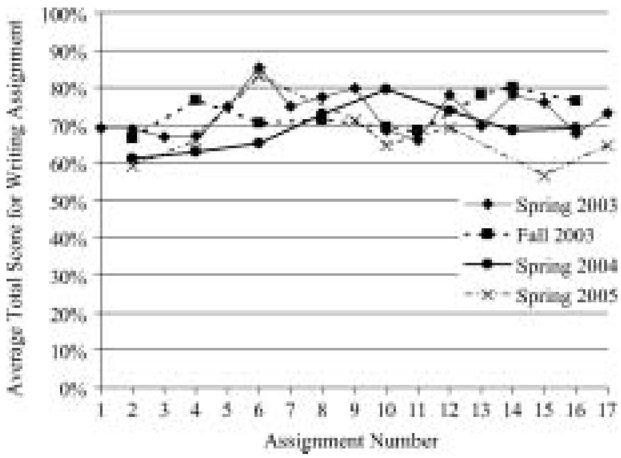

Figure 7. Change in average score for writing assignment over the course of the term for each term.

Term	Weekly Effort
Fall 2002	8 hrs
Spring 2003	7 hrs
Fall 2003	6 hrs
Spring 2004	7 hrs
Spring 2005	7 hrs

Table 3. Average time students reported that they spent on the course outside of class.

did not spend more time outside of class when the assignments were added. The grading rubric can facilitate grading by graders or teaching assistants.

The most common feedback from students was that students felt like they could not grasp what was expected in the assignment. This impression is likely due to the score on Criterion 1: Provides Sufficient Detail. Consistent difficulty with this criterion is probably due to difficulties students have deciding what information to include while staying within the half page limit. Such decisions require high level cognitive processes: Evaluation in Bloom's taxonomy (Bloom et al., 1956). We were not able to address this issue; however, we have several suggestions:

- Students might require explicit training in critical evaluation to improve their decisions on what details to include in the limited space.
- Assign a new writing problem in only odd numbered weeks. Grade and return the assignments right away. In even numbered weeks, do not assign a new writing problem. Instead, have students submit a revised version of the previous week's description. This way, they have time to reflect on the comments provided by the instructor/grader.
- Have students practice describing the solution process orally during class. The instructor uses many example problems worked by student teams during class. Ask a randomly selected team leader to explain the solution process referencing the figure on the board. Allow only 60 seconds. After the student is done, ask the class to critique the description using the rubric. This can be incorporated into the daily routine without sacrificing much class time.
- Provide one-on-one instruction to students. Every student communicates with a different style. Therefore, it might be necessary to provide one-on-one mentoring to each student in order for that student to understand what "acceptable" communication is. The mentoring might come from other students in an upper level communications course. However, this approach will only work if the upper level students have already demonstrated success at preparing the written descriptions.

After four terms of using the explain-a-problem type of assignment, we have found that this type of assignment does meet the stated objectives to some degree. With modifications, however, the assignment might achieve these objectives to a higher degree.

Note that although this study implemented the explain-a-problem type of assignment in an Engineering Statics course, the objectives of the study are not unique to the statics course. The rubric in Figure 1 is general enough to be applicable to other engineering courses. Therefore, the explain-a-problem type of assignment might be an effective tool for achieving the communication and self-assessment objectives in other engineering courses and disciplines.

VII. Future Research Directions

In this pilot study, we used scores on the writing assignments as a measure of the achievement of the self-assessment objectives. In future studies, tools such as a metacognitive questionnaire (Swanson, 1990) or metacognitive interviews (Paris and Jacobs, 1984) might provide more direct assessment of the impact of explain-a-problem assignments in achieving the self-assessment objectives. Although stronger self-assessment skills should lead to improved learning, impact on overall Engineering Statics ability was not the focus of this study. Our focus was on the assimilation of self-assessment skills.

The conclusions of this study must be considered in light of the limited scope of this pilot study. The study was conducted with one instructor in one course with roughly 40 students per term. Follow-on studies should explore the applicability in other courses and effectiveness with various majors. Conducting a larger scale study with a large control group would also allow for stronger conclusions about the impact of the self-assessment skills from the explain-a-problem type of writing assignment on overall learning.

We welcome any requests for assistance from researchers that would like to further this study by implementing the recommended changes for an explain-a-problem assignment in their courses.

Term	Number of Students	Grading Time (per Assignment)
Spring 2003	37	3 hrs
Fall 2003	39	2 hrs
Spring 2004	46	4 hrs*
Spring 2005	40	2 hrs

*First term where used grading rubric.

Table 4. Average time instructor spent grading writing assignments.

	Number of Students	Pearson Correlation Coefficient
Myers-Briggs Temperament		
Judging/Perceiving	70/85	0.07
Index of Learning Styles		
Active/Reflective	111/45	0.02
Sensing/Intuitive	101/55	0.04
Visual/Verbal	132/24	0.07
Sequential/Global	97/59	0.04

Table 5. Correlation between intensity of Myers-Briggs temperament or Index of Learning Styles preference and average writing assignment score considering students from all four terms.

ACKNOWLEDGMENTS

We would like to thank Mr. Timothy Chow from the Office of Institutional Research, Planning & Assessment at Rose-Hulman for performing the correlation analyses for this study.

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Appendix A: Assignment Instructions

Assignment:

For the specified problem, describe the steps followed in order to set up and solve the problem. Use no more than half of a page. It may be typed or hand written. Use the template provided on the course website.

Objectives:

The goal of this course is to understand the material, not just to plug numbers into equations. An effective way to demonstrate understanding of the material is to describe how you use it.

Another motivation for these assignments is to develop the ability to articulate your thought process in an efficient and comprehensible manner. On real projects, engineers' calculations are archived for many years. If there is ever a problem, the calculations are reviewed. Brief notes on the calculations can make the difference when a review board is determining liability. In addition, it is a distinct advantage to be able to articulate your thought process clearly and concisely when working with other engineers.

Grading Criteria:

1. Has the student provided sufficient detail that I could reproduce the approach to the solution?
2. Has the student demonstrated an understanding of what is being done in the solution process?
3. Is the description written such that I can understand what the student means?
4. Is the description focused on the approach to the solution of this problem, not the specific numbers of the solution?

Examples:

The following paragraphs are examples of descriptions of the solution shown on the attached pages.

Good:

The objective is to determine the moment of *F* about the *OA* axis. First, calculate the position vector, *r*, from the origin to the point where *F* acts. This is done by subtracting the Cartesian coordinates of the origin from the coordinates of the point where *F* acts.

Find the moment of *F* about the origin by crossing r into *F*. Use the matrix approach to find the cross product. Add products obtained by multiplying diagonals down to the right. Subtract products obtained by multiplying diagonals down to the left. The result is a moment vector in Cartesian coordinates.

To obtain the moment about the *OA* axis, take the dot product of the unit vector along *OA* and the moment vector. To obtain the unit vector along *OA*, calculate a position vector, r_{OA}, from the origin to point A. Calculate the length of r_{OA} by taking the square root of the sum of each Cartesian coordinate of r_{OA} squared. The resulting length is a scalar, not a vector. The unit vector is obtained by dividing each coordinate of r_{OA} by the length of r_{OA}. The dot product is obtained by multiplying *x*-coordinates of the unit vector and the moment vector and summing that product with the products of the *y*-coordinates and *z*-coordinates. The resulting moment value is a scalar. To convert the value to a Cartesian vector, multiply the unit vector by the scalar moment value. The result is the moment of *F* about the *OA* axis in Cartesian coordinates.

Minimally Adequate:

The objective is to determine the moment of *F* about the *OA* axis. First, calculate the position vector, *r*, from the origin to the point where *F* acts. ***[How is this done?]***

Find the moment of *F* about the origin by crossing *r* into *F*. Use the matrix approach to find the cross product. ***[How is this done?]***

To obtain the moment about the *OA* axis, take the dot product of the unit vector along *OA* and the moment vector. Calculate a unit vector between two points along *OA*. Calculate the dot product, which is a scalar. Multiply the unit vector by the scalar moment value to obtain the moment of *F* about the *OA* axis.

Poor:

First, calculate the position vector, *r*, from the origin to the point where *F* acts. ***[What is the objective?]***

Find the moment of *F* about the origin by crossing that into it. ***[I can't understand what this is saying.]*** Use the formula on page 122 to calculate the moment. ***[Does not demonstrate understanding of what is being done in the solution process.]***

To obtain the moment about the *OA* axis, take the dot product of the unit vector along *OA* and the moment vector. Calculate a unit vector between two points along *OA*. Calculate the dot product, which is a scalar. Multiply $0.7071\hat{\imath}$ by 56.6 N*m to obtain 40.0 N*m $\hat{\imath}$ for the *x*-component of the moment about the aa axis. Similarly multiply 0.7071 $\hat{\jmath}$ by 56.6 N*m to obtain 40.0 N*m $\hat{\jmath}$ for the *y*-component of the moment. ***[Too specific. Description should be focused on the process, not the specific numbers.]***

Appendix B: Example Student Submission and Use of Scoring Rubric

Student Submission:

Note: The brackets have been inserted by the authors to indicate how the submission was scored using the rubric.

> The objective of this problem was to find the maximum theta [what is this?] so that the clockwise moment about A does not exceed the clockwise moment [is this a typo?] equal to the moment the man can exert on the pole. Using couple moments, you know that the moment of the girl must be equal and opposite of the moment that the man is exerting. Given the moment of the man and the force of the girl times the height [should be length] of the pole times the cosine of theta. Add the resulting number to the produce of the force of the girl times the height of the pole times the sine of theta [no, these to quantities do not add]. Next solve for theta, giving two answers [no, there will be only one]. Because the maximum theta is wanted, the larger of the numbers is the correct theta so that the moment about A exceeds the given moment.

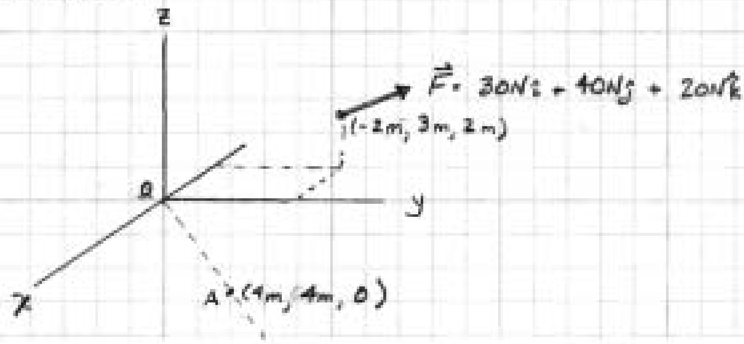
GIVEN: Force F applied as shown below.

FIND: Determine the moment of F about the OA axis.

ASSUMPTIONS:

None.

FIGURE:



FBD's / CALCULATIONS:

Find position vector from a point on the OA axis to the point where $\vec{F}$ acts. Use the origin for simplicity.

$$\vec{r} = (-2m - 0)\hat{i} + (3m - 0)\hat{j} + (2m - 0)\hat{k} = -2m\hat{i} + 3m\hat{j} + 2m\hat{k}$$

Find the moment of $\vec{F}$ about a point along the OA axis, the origin.

$$\vec{M}_O = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -2m & 3m & 2m \\ 30N & 40N & 20N \end{vmatrix} \begin{matrix} \hat{i} & \hat{j} \\ -2m & 3m \\ 30N & 40N \end{matrix} = 60N{\cdot}m\hat{i} + 60N{\cdot}m\hat{j} - 80N{\cdot}m\hat{k} - 90N{\cdot}m\hat{k} - 80N{\cdot}m\hat{i} + 40N{\cdot}m\hat{j}$$

$$= -20N{\cdot}m\hat{i} + 100N{\cdot}m\hat{j} - 170N{\cdot}m\hat{k}$$

Find the unit vector along axis OA.

Calculate the position vector from the origin to point A

$$\vec{r}_{OA} = (4m - 0)\hat{i} + (4m - 0)\hat{j} = 4m\hat{i} + 4m\hat{j}$$

Calculate the length of that vector

$$|\vec{r}_{OA}| = \sqrt{(4m)^2 + (4m)^2} = \sqrt{32m^2} = 5.657m$$

Unit vector.

$$\vec{u}_{OA} = \frac{\vec{r}_{OA}}{|\vec{r}_{OA}|} = \frac{4m}{5.657m}\hat{i} + \frac{4m}{5.657m}\hat{j} = 0.7071\hat{i} + 0.7071\hat{j}$$

Find the moment of $\vec{F}$ about the OA axis.

$$M_{OA} = \vec{u}_{OA} \times \vec{M}_O = 0.7071(-20N{\cdot}m) + 0.7071(100N{\cdot}m) + 0(-170N{\cdot}m)$$

$$= 56.6 N{\cdot}m$$

$$\vec{M}_{OA} = M_{OA}\vec{u}_{OA} = 56.6N{\cdot}m(0.7071)\hat{i} + 56.6N{\cdot}m(0.7071)\hat{j}$$

$$\boxed{\vec{M}_{OA} = 40.0N{\cdot}m\hat{i} + 40.0N{\cdot}m\hat{j}}$$

Rubric:

Criteria	Full Credit (4 pts)	Partial Credit (2 pts)	No Credit (0 pts)
Has the student provided sufficient detail that I could reproduce the approach to the solution?	• **Identify sequence by which unknowns are being found.** • **Terms used in each equation are identified (e.g., forces that contribute moment in moment equilibrium).** • **Body or particle for FBD is identified.**	• One necessary equation is not identified. • Terms used are not identified for one equation. • Body or particle for FBD not clearly identified.	• Several necessary equations are not identified. • Terms used are not identified for multiple equations.
Has the student demonstrated an understanding of what is being done in the solution process?	• Approach described is fundamentally sound. • **Each equation used is described in words, not with algebra.**	• One error in the approach. • One equation described algebraically.	• **Multiple errors in approach.** • Multiple equations described algebraically.
Is the description written such that I can understand what the student means?	• **Description begins with the objective of the problem.** • **Description no longer than one-half page (if typed, single spaced lines).** • Handwriting is legible. • Pronouns have clear meanings (i.e., "that", "it" are easily interpreted).	• Description does not begin with objective of the problem. • Description more than one-half page, but less than full page (if typed, single spaced lines). • **One or two sentences do not make sense because of handwriting, ambiguous pronouns, and/or undefined variable names.**	• Description more than one full page (if typed, single spaced lines). • More than two sentences do not make sense because of handwriting, ambiguous pronouns, and/or undefined variable names.
Is the description focused on the approach to the solution of this problem, not the specific numbers of the solution?	• **All variable names used in the description are defined.** • **No quantities (e.g., 100 lb, 20°, 3 m) are used in the description.** • **Details are provided about solving this particular problem.**	• One variable used in the description not defined. • One quantity is provided in the description. • Description is about how to solve this type of problem in general.	• Multiple variables used in the description not defined. • Several quantities are provided in the description.

Final Score:

The score for each criterion is the lowest scoring bullet. Therefore, this example submission received 4 points for Criterion 1, 0 points for Criterion 2, 2 points for Criterion 3, and 4 points for Criterion 4 for a total score of 10 points.