AC 2012-3550: REPORT-SMITHING: DEVELOPING EFFECTIVE WRITTEN COMMUNICATION SKILLS

Ms. Jenifer M. Shannon, Pennsylvania State University, Berks

Jenifer M. Shannon is a lecturer of engineering at the Pennsylvania State University, Berks, in Reading, Penn. She earned a B.S.E.E. from the Pennsylvania State University and a M.S.E.E. from Villanova University. She practiced engineering at the Nuclear Regulatory Commission as a Reactor Engineer inspecting electrical systems at U.S. nuclear power plants. She worked in research and development of aircraft power systems at the Naval Air Warfare Center. She also worked at the General Electric Company, Astrospace Division, designing antenna satellite payloads prior to joining academia.

Dr. Rungun Nathan, Pennsylvania State University, Berks

Rungun Nathan is an Assistant Professor in the Division of Engineering at Penn State, Berks, from the fall of 2007. He got his B.S. from University of Mysore, D.I.I.Sc. from Indian Institute of Science, M.S. from Louisiana State University, and Ph.D. from Drexel University. He has worked in the area of electronic packaging in C-DOT (India) and then as a Scientific Assistant in the robotics laboratory at Indian Institute of Science, Bangalore, India. He worked as a postdoc at University of Pennsylvania in the area of haptics and virtual reality. His research interests are in the areas of unmanned vehicles particularly flapping flight, mechatronics, robotics, MEMS, virtual reality and haptics, and teaching with technology. He has active research in the area of lift in porous medium with Dr. Qianhong Wu (Villanova University) and in the area of non-linear control with Dr. Sergey Nersesov (Villanova University). He is an active member of ASEE and ASME and a reviewer for several ASME, IEEE, and ASEE, FIE conferences and journals.

Report-Smithing:
Developing Effective Written Communication Skills

Abstract
Effective communication is one of the key attributes future engineers need in order to be competitive in the global market according to the National Academy of Engineers[1]. Yet surveys from industry employers often indicate that the communication skills of recent engineering graduates are unsatisfactory[2]. This paper describes a strategy to improve student written communication skills and student engagement with the subject matter by developing the use of critical thinking skills during the writing process. The modified pedagogy discussed in this paper provided students with detailed guidance and clear expectations for each writing assignment. A combination of peer review and instructor comments was used as a means of providing feedback for students to incorporate lessons learned into revisions of first drafts. The most student-appreciated aspect of this pedagogy was the division of a full scale formal laboratory report into smaller, more focused writing assignments.

Background
The significance of a student's ability to communicate technical information is manifested by its inclusion as an ABET required student outcome, namely, an ability to apply written, oral, and graphical communication in both technical and non-technical environments [3]. The ABET general criteria has been used by this University's curriculum committees to develop program specific student outcomes. The general criteria and student outcomes are mapped to individual courses in the Associate and Baccalaureate Engineering Technology Programs. In this manner, a student's ability to write effectively is assessed multiple times throughout their educational experience at our University.

In engineering technology programs, a large proportion of the curriculum includes a laboratory component. The intent of laboratory work is twofold. One purpose is to solidify understanding of course concepts through a more in-depth laboratory experience on certain topics. A second purpose is to enable students to gain valuable hands-on experience that will better prepare them for a position in industry upon completion of their studies. As a means of assessment of these laboratory experiences, course instructors often require the submission of detailed laboratory reports.

Our approach has been to initially expose students to the laboratory experience as first semester freshmen in a three credit electrical systems course with a weekly laboratory component. This goal of this course is to introduce a wide variety of electrical components and their application to electrical circuits and systems. Teaching and learning is accomplished through two fifty-minute lecture periods and a one hundred minute laboratory period each week for fifteen weeks. Laboratory exercises complement lecture topics and include the investigation of the behavior of series, parallel, and combination resistive circuits, diodes, solar cells, relays, motors, capacitors, inductors, transformers, and operational amplifiers. Traditionally, students have been asked to write seven to ten formal lab reports throughout the semester without a clear understanding of the instructor's expectations for the quality of the report writing. This method resulted in a wide variation in the quality of submitted reports.

The writing of the formal report has been the primary means of assessment for the laboratory experience. Although the formal report has been a fair gauge of the student's ability to communicate technical information, it may not have accurately portrayed the student's comprehension of the laboratory topic and the student's ability to critically analyze the laboratory experience. In order to avail the opportunity for more students to effectively demonstrate their grasp of the material, the format of the writing assignments was modified for this introductory course. By encouraging a more in-depth attention to detail in the analysis of results and the documentation of this analysis, it was anticipated that student understanding would be enhanced.

During the process of designing a pedagogy with the goals of improving laboratory report writing and encouraging critical thinking, the authors explored the literature. Three key elements in the pedagogy were identified as follows: (1) provide appropriate guidance, (2) define clear expectations, and (3) afford the students the opportunity for review and revision of their writing[4,5]. In addition to these three recommended components, the designed pedagogy also included providing the students with examples of writing containing desirable attributes that they could use as a model for their own writing. This paper describes the strategy used in three sections of the introductory electrical systems course. By targeting a first semester freshman level course to be writing intensive, the instructors hoped to significantly improve the reports that faculty would review in subsequent courses.

Methodology

This course employed a new, innovative method of teaching report writing. Rather than using the traditional approach of assigning a full laboratory report each week following the completion of a laboratory exercise, specialized writing assignments were given pertaining to individual sections of a formal report that is typically required. Assignments were of a smaller, more focused and manageable scale for the student. Each assignment was carefully constructed and incorporated attributes of a writing-across-the-curriculum program[5]. Each assignment included a writing sample that demonstrated the inclusion of key elements for the development of that particular report section. Two instructors implemented this approach in three sections with a total of 36 students. The two instructors have taught this course in the past by assigning full reports for each laboratory exercise.

It is important to point out that the instructors did not want to change the content or number of laboratory exercises in order to incorporate this new pedagogy. Even though students were not writing full reports for each exercise, they were expected to keep detailed notes of their laboratory work in notebooks. These notebooks were periodically collected and graded.

The purpose of the first week's laboratory assignment was to learn how to write an introduction section of a formal report. Students were informed that the introduction should identify the experiment to be undertaken, the objectives and the significance of the experiment, and the overall background for understanding the experiment. Emphasis was placed upon clear and succinct writing of the objectives. The background was to discuss the theory of the exercise, the expected results, and the method used to obtain the experimental results.

The initial assignment included two sections. In the first part, two written introductions from two different experiments were given. Students were asked to critique these two examples keeping in mind the required components of an introduction section. Specific guidelines explaining the audience, tone and length of their critique were provided. The second part of the assignment was for the students to write their own introduction for the laboratory exercise that they were to perform in the following week. Students were told to review the laboratory experiment and research the topic so that they could compose a well-versed background portion of the introduction. This two-part assignment was to be posted to a discussion board with the intent that all students had access to one another's work. The first part of the assignment allowed the instructor to gauge the initial writing style and ability of each student and their understanding of the components of the prescribed introduction section. The second part of the assignment allowed the students to concentrate their efforts and practice writing only the introduction section of a formal report.

Before executing the weekly laboratory exercise in the following week, students performed a response-centered review of their introductions. Students were placed into teams of four and given three review sheets each. Each writer read aloud his/her introduction to the other team members. During the reading, team members were instructed to record notes on the review sheets identifying positives and negatives that came to mind concerning the introduction being read. Students were asked to refrain from giving advice and only give a personal reaction to the draft since this was a response-centered review exercise. At the end of the process each student had three peer reviews for their first draft of an introduction section. Part of the next assignment was to revise their introduction incorporating the feedback they had received from the peer reviews. For motivational purposes, at the conclusion of the reviews, each team was asked to select the best introduction for their group. From this list of favorites, the entire class selected the best overall winner. Peer reviews and revision opportunities allowed for continuous improvement of the writing process. Peer reviews provided student feedback from a variety of readers. These reviews also encouraged students to observe and learn from each other's creative approaches to the assignments. Week by week students were able to gradually build skills and improve their self-confidence in their technical writing abilities.

In subsequent assignments, students were presented with detailed descriptions of the expected content and format for the remaining sections of the formal report. These sections included the procedure, data, expected results, experimental results, summary and conclusion, and abstract. Generally, each week students submitted a revision of a previous assignment and the first draft of the new assignment. Each new assignment included a sample writing of the section under study for the student to emulate. Each first draft submittal was either peer reviewed or graded and annotated with comments from the instructor. The students were always given the opportunity to revise and resubmit the section. In addition to the response-centered review, the students also performed advice-centered reviews. Some reviews were open-ended allowing for a more creative feedback. Others contained specific questions to be answered in the review to provide a more uniform feedback structure. An example of an advice-centered review is shown in figure 1.

Advice-Centered Peer Review of Procedure Section

Directions: As the reviewer, "forget" that you already completed this lab yourself. Try to imagine you have no prior knowledge as to how this lab is to be performed. Perform the checklist as a team. Discuss particular aspects of the procedure that were noteworthy and worked well. Discuss any advice for changes that you would recommend. Write comments from your discussions below.

Name of Person's Work being reviewed: _____

Checklist	YES	NO
Procedure comes across as steps directly copied from lab exercise.		
Procedure is written entirely in first person.		
Procedure is written as a narrative.		
The order of events is clear.		
The set-up of the exercise is easy to visualize.		
If figures are included, are they numbered with a descriptive title centered below the figure?		
Procedure's tone is professional without any personal reflection or comments.		
Depth of procedure is sufficient such that the lab could be easily replicated.		

Discussion Comments:

Figure 1. Example of Advice-Centered Review Worksheet

During the execution of the weekly laboratory exercise, the students were encouraged to think about how they would organize their full written report during their calculations of expected results, while performing the laboratory exercise, and throughout the recording of key measurements. By stimulating this formulation process and encouraging critical thinking, the students not only produced a well-structured written document, but they gained a deeper understanding of the purpose of the laboratory exercise and how it related to the course subject matter.

The course was structured to promote writing as a continuous process. By the eighth assignment, all individual components of the formal report had been covered. The culmination of the previous assignments was the "Putting it all Together Assignment". At this point, the student had been presented with the necessary tools for writing a professional, well-organized laboratory report. The "Putting it all Together Assignment" included a review of all the requirements for the individual sections of the report. In addition, a complete sample report of a different experiment consisting of all sections was provided to demonstrate how each section was interrelated and complemented every other section.

Students were able to write three full formal reports and were provided instructor comments and advice for improvement for each report. A grading rubric, shown in figure 2, was provided to the students in order to establish clear expectations. For each full report, students were given the opportunity to submit revised reports incorporating the instructor's suggestions. The grade for the revised report then replaced the first draft grade. The intent of this practice was to provide sufficient incentive to the student for performing a revision.

	0	1	2	3
INTRODUCTION	Missing	Objective is unclear. Background is not included or lacking in substance.	Objective is clear and succinctly states the purpose of the lab, but background is lacking substance.	Introduction identifies the experiment to be undertaken, the objectives of the experiment, the importance of the experiment, and overall background for understanding the experiment.
PROCEDURE	0 Missing	1 Procedure is not consistently written in the past tense or in first person. Procedure lacks many necessary steps. Figures or diagrams are missing.	2 Procedure is not consistently written in the past tense or in first person. Procedure is lacking some necessary steps. Some figures may be improperly labeled.	3 Procedure is a brief description of steps undertaken. All diagrams and figures are clear and labeled correctly. Procedure is written as a first person narrative in the past tense.
DATA	0 Missing	1 Equipment list is missing pertinent information or recorded data is incomplete. Three significant digits are not given.	2 Data recorded has a small number of units missing or equipment list missing an item. Relevance of every table is not clear.	3 Data accurately reflects proper procedure and careful data acquisition. Data is shown with three significant digits and proper units. All tables are clearly referenced in the body of the report.
EXPECTED RESULTS	0 Missing	1 Expected results are incomplete and do not correlate with experimental results.	2 Most calculations are included. Some minor discrepancies exist in the calculations. The purpose of each calculation is generally described. Multisim analysis is not clearly labeled or is incorrect.	3 Calculations are described and/or explained. Formula and sample calculations are presented when needed. The purpose of each calculation is clearly described. Multisim analysis was performed using proper parameters and is clearly labeled.
EXPERIMENTAL RESULTS	0 Missing	1 Experimental results are incomplete and do not correlate with expected results. Figures, tables, or calculations are incomplete or presented in an unclear manner.	2 All calculations are included. Some minor discrepancies exist in the calculations. Figures or tables may not be properly referenced or labeled.	3 Calculations are described and/or explained. Equations are presented with sample calculations. Figures and tables properly referenced and labeled.
SUMMARY AND CONCLUSIONS	0 Missing	1 Minimal comparison of experimental and expected results. Prose reflects only a superficial understanding of the technical aspects of the lab exercise.	2 Experimental and expected results are not clearly compared. Prose reflects a superficial understanding of the technical aspects of the lab exercise.	3 Conclusion includes a brief discussion of how the experimental and expected results compare. Any abnormalities are discussed. Trends or generalizations in data are presented. A clear indication of how lab objective is met is given. Prose reflects an in-depth understanding of the technical aspects of the lab exercise.
ABSTRACT	0 Missing	1 Abstract is missing one or more of the following: a statement of the objectives, a general description of the experiment, or the outcome of the experiment.	2 Although objective, a general description of the experiment, and the outcome of the experiment are mentioned, a firm grasp of the intent of the exercise is not evident.	3 Writer clearly portrays (1) the objective, (2) a general description of the circuit, control parameters, and measurements, and (3) the outcome of experiment with respect to the objective.

Figure 2. Formal Report Rubric

Instructor feedback was in accordance with the rubric and offered advice concerning sentence structure, format, and clarity of language. Employers often cite conciseness and organization to be the most desirable characteristics in technical writing[6]. Instructor comments emphasized the importance of these characteristics. Instructor comments included both positive reinforcement of successful execution of the assignments and appropriate criticism of missing components with clear directives for correction. Feedback focus differed depending upon the particular section of the given assignment. For example, greater emphasis was placed upon clarity of writing, word choice, and message for assignments involving the abstract, introduction, and summary and conclusions. On the other hand, attention to detail, format, and organization was more important in the procedure, data, and results sections.

Throughout fourteen laboratory exercises, by incorporating short writing assignments, peer reviews, detailed instructor feedback, and the use of laboratory notebooks, the instructors had hoped to design a cohesive laboratory experience for first semester freshman in this course. Figure 3 shows the course schedule used to achieve this objective.

Week	Lab Topic	Due
1	Introduction to Experiments/Lab Safety/Lab Notebook	
2	Response-centered Peer Review Ohm's Law Exercise	*Assignment 1:* Introduction Critique and Introduction Section for Ohm's Law Lab
3	Advice-centered Peer Review Multisim Exercise	*Assignment 2:* Procedure Section and Revised Introduction Section
4	Series Circuit/ Kirchhoff's Voltage Law	*Assignment 3:* Multisim Exercise and Revised Procedure Section
5	Parallel Circuit/ Kirchhoff's Current Law	*Assignment 4:* Data Section for Series Circuit Lab
6	Combination Circuit Lab	*Assignment 5:* Expected Results for Parallel Circuit Lab
7	Superposition Lab	*Assignment 6:* Experimental Results for Combination Circuit Lab
8	Diodes and LEDs Lab Submit Notebook for Review	*Assignment 7:* Revised Expected Results Section and Summary and Conclusion Section for Superposition Lab
9	Advice-centered peer review of Abstracts Solar Cell Lab	*Assignment 8:* Revised Experimental Results Section & Abstract Section for Diodes and LED Lab
10	Op Amps Lab	*Assignment 9:* Putting it all together - Full Formal Report for Solar Cell Lab
11	Relay and Motors Lab	*Assignment 10:* Full Formal Report for Op Amp Lab
12	Oscilloscope Measurements Lab	*Assignment 11:* Revision of Solar Cell Report
13	AC Measurements Lab	*Assignment 12:* Revision of Op Amp Report
14	Mystery Components Lab Submit Notebook for Review	*Assignment 13:* Full Formal Report for AC Measurements Lab
15	Transformers Lab	*Assignment 14:* Revision of AC Measurements Report (Due during Finals week)

Figure 3. Course Schedule

Results

Student surveys and a comparison of the quality of writing to previous course offerings provided the initial data to measure the effectiveness of the approach. Student reports in subsequent laboratory courses will provide a measure of long term effectiveness. The cohort of students in these particular sections will be followed in subsequent courses and their writing abilities will be compared to peers who were not part of the original cohort.

Thirty-four students participated in an anonymous survey following the "Putting it all together" assignment. Thirty-two of the students surveyed reported that their preferred approach to report writing was practicing writing individual sections of the report before writing their first full report. Two students preferred to write full reports for selected experiments with no prior practice with individual sections. Table 1 summarizes the average response for three selected questions that were asked with a scale from one to five with one corresponding to "Not at all helpful" and five corresponding to "Very helpful."

Table 1
Summary of Survey Results

Question	Average Response	Standard Deviation
Was it helpful that you focused on one section at a time?	4.74	0.57
Were peer reviews helpful?	3.47	1.08
Did you see any benefit in revising your write up on individual sections?	4.06	0.95

Most students reported that working on one section at a time and revising these sections was very helpful. Students reported peer reviews only moderately helpful. One student comment concerning the peer reviews was that "…I felt that I did not receive honest feedback. I would prefer instructor review. I felt that this would be more advantageous." Instructors intend to spend more course time in future semesters on peer reviews to refine this process.

Instructors compared student work from current students (group A) that wrote the Summary and Conclusion section alone with students (group B) that wrote the entire report for the same laboratory exercise. Both groups of students were given the following guidelines for writing this section of the report.

> "The summary should address each major part of the experiment. Concluding remarks should be based on the measured results, calculated results and graphical results (when applicable). The conclusions should be clear, logical and technically valid. Conclusions should directly correlate with the objectives and discuss any implications of the results. You must explain if you have enough data to reach a conclusion or if more experimentation is needed to reach a conclusion (and your explanation must be

reasonable). If more experimentation is needed, you must explain what kind of experimentation is needed and why it is needed."

Samples of the summary and conclusion section from both groups were reviewed. A dramatic difference between the two groups of students was observed. Only 10% of the members from group B composed a satisfactory summary and conclusions section containing the prescribed elements. Students from this group seemed to concentrate their efforts on the data and results sections, and then wrote only one or two sentences for the summary and conclusions section. On the other hand, 77% of the members from group A were able to compose a satisfactory summary and conclusions section for a first draft of the same laboratory exercise.

We have concluded that the graduated approach of initially focusing upon a single section at a time in a first semester laboratory course is the most desirable approach for both the student and the instructors. It enabled students to become accustomed to the faculty expectations and to fine tune writing skills for report writing through a combination of peer review, instructor feedback, and opportunity for revisions. Once students were writing full reports, the revision process allowed students to better understand the salient points of the laboratory exercise from instructor comments on first draft reports. For example, one student commented, "I wasn't really sure what to write for the expected and experimental results, but the feedback I got really helped me understand it better." This type of comment provides evidence that students were involved in a thoughtful writing process and made use of critical thinking skills. Another student showed her appreciation of the approach with the following comment, "I love the fact that we only did one section at a time. It made it a lot easier to understand what belonged in each section. After doing each section, the lab report seemed easy."

One difficulty identified by the instructors was the large number of multipart assignments. The number of assignments proved challenging in terms of grading and record keeping. So that students were always aware of assignments, instructors began each laboratory session with a presentation to the students summarizing the expected submittals due that class and the expected deliverables for the following week. A course management system was used for students to electronically post all assignments. This system also enabled instructors to post feedback comments to students for each submittal so that they would have feedback as soon as the instructor review was complete (not having to wait for the following week). On first drafts students also received a marked-up copy of their hard copy submittals. Even though careful attention to detail was given to organizing the assignments, instructors felt that organizational improvements could still be made.

For the next revision of this pedagogy, instructors intend to perform more peer reviews so students can sharpen their ability to supply meaningful feedback. This pedagogy will be implemented again and student surveys will be employed to assess the student-perceived value of the approach on a larger population. To assess the effectiveness of the pedagogy, additional feedback will be sought from other instructors in subsequent semesters about the quality of student report writing executed by students who have been exposed to this approach.

References

[1] NAE (National Academy of Engineering). (2005). Educating the engineer of 2020: Adapting engineering education to the new century. Washington, D.C.: National Academies Press.

[2] Donnell, J., Aller, B., Alley, M., & Kedrowicz, A. (2011). Why industry says that engineering graduates have poor communication skills: What the literature says. 2011 ASEE Annual Conference and Exposition. AC 2011-1503. Vancouver, British Columbia, Canada: American Society of Engineering Education.

[3] Accreditation Board for Engineering and Technology. (October 29, 2011) Criteria for accrediting engineering technology programs, Effective for reviews during the 2012-2013 accreditation cycle. Retrieved from: http://www.abet.org/

[4] Gragson, D.E. (2010). Developing technical writing skills in the physical chemistry laboratory: A progressive approach employing peer review, *Journal of Chemical Education*, vol. 87, pp. 62-65.

[5] Bean, J.C. (2001). *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*. San Francisco, CA: John Wiley & Sons, Inc.

[6] Aller, B.M. (2001). Writing Practices in the Engineering Workplace: Findings and Implications for Teachers of Engineering Communication, Ph D. Dissertation. Houghton, MI: Michigan Technological University.