Incorporating Peer Review in the Chemical Engineering Laboratory

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The Unit Operations laboratory represents an important site for the development of technical and non-technical skills in chemical engineering students. Coming in the final year of students' course work, the projects of UO lab give students the opportunity to combine experimental experiences with team work and communication, a combination that chemical engineering educators would agree is crucial to success in the workplace. Unfortunately the UO lab as it is commonly designed in many engineering programs may not provide students with adequate support for developing non-technical skills, particularly communication; as experts in chemical engineering, faculty may feel less comfortable with emphasizing writing to their students and may indeed lack specific pedagogical strategies that can help students become more effective communicators. Our project emerged from this context, recognizing that the lab environment offered particular opportunities and challenges for improving students' communication skills.

Project Background

The Unit Operations lab at Rose-Hulman is organized around the following educational objectives:

- Broad range of equipment & instrumentation
- Designing & planning experiments
- Working in a team
- Analyzing experimental data
- Written & oral communication

The course length is one year, during which students complete 7 different projects with 3 different types of reports. Each student is required to write an individual report for each project. The volume of writing required of students in the course might suggest that students are given adequate opportunities to improve their written communication. The chemical engineering faculty member who worked on this project believed, however, that while students wrote a lot in the course, their writing problems continued. In particular the instructor saw four categories of writing problems as they related to three major sections of the required reports, as well as a fourth problem that emerged in every report section. These writing problems are categorized in Table 1 below.

Introduction Section	Discussion of Results Section	Conclusions Section	Clarity and Conciseness
1. Experiment objectives unclear	1. Data is "what was expected" or "pretty good"	1. Stated conclusions not related to experiment objectives	1. A global problem affecting all sections of the report in general
2. Rambling overview	2. Meaning of data and trends not discussed	2. Conclusions disconnected from results	
		3. Just summaries provided	

Table 1: Four Categories of Writing Problems

The instructor developed several theories in an attempt to locate the source of these writing problems. Students perceived that writing was not as significant as technical content in their reports, and their perception was reinforced by the fact that poor writing had a small effect on their final grade for the project. In addition, students were given inadequate time to write, revise, and review their writing, waiting instead until the last minute before the due date to begin the writing component of the project. The instructor also found that students were not generally offered good models of previous reports on which to base their own work. Students were unable or unwilling, therefore, to identify and correct their own writing problems. Thus, the instructor recognized the importance of communication in the professional lives of his students; he also found further support for this view in Sageev and Romanowski.[1] He began to consult additional sources on the subject to develop an effective set of strategies to address the problem.

Consideration of references on this topic indicated other faculty who were trying to resolve a similar set of root causes.[2, 3] The problem lay in finding sources that provided good models for use in the classroom. Effective models were available from both Ludlow and Newell.[4, 5] Both authors, working in the context of chemical engineering departments, addressed student communication problems through the practice of peer review of student writing. The instructor then set about adapting models for peer review, as well as other writing techniques, from others in a manner appropriate to the unique learning situation of Rose-Hulman.

The instructor determined that the best way to encourage students to work on their communication skills was to show them how important he thought communication was. As a way to demonstrate his emphasis on communication, the instructor developed three new course objectives:

- Devote laboratory time to discuss writing, including evaluating and discussing samples of previous reports that were successful

- Require a formal peer review of documents, including instructor guidance on proper reviewing techniques while also allowing adequate time in the course for making revisions
- Discuss observations from peer review by using additional writing samples from volunteers

These objectives are discussed below. In addition to these changes, the chemical engineering faculty member enlisted the assistance of the campus coordinator of technical communication; together they developed specific writing assignments and pedagogical strategies that could assist students with the development of their communication skills.

Devote laboratory time to discuss writing

Many engineering faculty believe that students should develop good communication skills and use them in their written work. And yet, few faculty are willing to model communication for students by devoting class time to discussions of good writing. In our project, we wished to show, rather than just tell, students that communication is important; to this end, the chemical engineering faculty member devoted class time to discussing the elements of effective communication and illustrated those elements with models of student papers written in previous classes. These examples were collected by the instructor and were used with the permission of previous students. The coordinator of technical communication attended the first discussion session as an observer.

During the in-class discussion, the chemical engineering faculty member offered a limited set of problem areas students should address in their revision process. This ensured that students approached the writing with a sense of what represented higher level problems in areas like organization, clarity, and conciseness, versus what represented lower level problems like comma placement. We believe that students should address both kinds of problems in their writing and revising, but many students believe that all they must do to improve their writing is correct their grammar. In our project, the instructor wished students to focus first on the higher level problems. Using the student examples, the instructor identified strengths of the reports, as well as showing areas that represented opportunities for improvement:

- Wishy-washy language, meaning phrases such as “probably fairly accurate,” “results follow what was expected,” etc.
- Conciseness
- Objectives, meaning a reason for the experiment that goes beyond a class requirement
- Organization of paragraphs with a clear topic sentence and related sentences within
- Prioritization of ideas and information, meaning deciding what represented information that would be important for the reader to know and should be included in a report.

As the category labels indicate, the instructor personalized the problem areas by using his own language to describe what he believed was lacking in the samples. This too showed the instructor's emphasis on good communication and his personal investment in the project.

Require a formal peer review process for documents

The chemical engineering instructor believed that poor student writing was due in part to the brief time students spent on their reports. The key component the instructor wished to change was the timeframe in which students drafted and revised their reports. The peer review component added to the writing assignments meant that each student was required to start his/her report earlier than was normal and to devote time to reviewing and revising the report before handing it in to the instructor.

At the suggestion of the coordinator of technical communication, the instructor also drafted a Peer Review sheet containing instructions to student authors for writing particular sections of the reports, as well as providing specific questions the student reviewers needed to answer to complete Peer Review. In this way, students could use the sheet both to guide their own writing and to conduct an effective review of another student's writing. The Peer Review sheet is included in Figure 1.

The Peer Review procedure was comprised of 4 steps:

Step 1: First, each student author gave a hard copy of his/her report draft to 2 student reviewers. These reviewers were members of different experiment groups, so each reviewer was reading a report on a laboratory in which he/she did not participate. This practice ensured that the report reader did not have firsthand knowledge of the experiment and would be less willing to fill in omitted information or make assumptions not offered by the author.

Step 2: In order to complete the review, student reviewers were required to comment specifically on the three sections that were common to all report types: Introduction, Results and Discussion, Conclusions and Recommendations. The instructor developed specific questions pertinent to each section; for example, the Results and Discussion section on the Peer Review sheet included questions about the kinds of data collected and the format in which the data was presented. While some questions were specific to a particular section, the issue of clarity and conciseness was important for each section, and student reviewers were asked to address them throughout the report drafts. A student reviewer wrote his/her comments directly on a student author's draft, then summarized those comments in a memo to the student author.

Step 3: At the end of the Peer Review period, the commented draft and the summary memo were returned to the student author. After each author read the comments from his/her two student reviewers, the entire class met to discuss and/or clarify the comments. In this session, the instructor was able to reinforce his observations from the first class discussion, illustrating the same principles of good communication, but this time with the students' reports as models.

Step 4: At the end of the process, students were required to submit both their report drafts (marked with student reviewer comments) and the summary memo with the final version of their reports. In addition the student author was required to submit a summary that described how he/she incorporated the student reviewer's comments.

Project Observations

In measuring the impact of the Peer Review Project in the Unit Operations Lab course, we have focused on the way in which the process improved students' communication skills, determining if they have become better writers as a result. At this stage of our project, we rely on the chemical engineering faculty member's sense that the reports have improved in the 4 categories of problems identified in Table 1. Overall the instructor observed improvements in all 4 categories.

In addition to considering students' improvement as authors, we were also interested in students' improvements as reviewers. We find that a student who can identify a problem in another student's draft is more likely to recognize a comparable problem in his/her own work. The technical communication coordinator analyzed the comments provided by student reviewers on the report hard copies. Comments categories are provided in Table 2.

Sentence-level edits	Audience accommodation	Organization	Conciseness	Graphical information
1. Reviewer suggested a different word choice	1. Reviewer identified parts of the report in which the writer had not considered his/her audience, i.e. by omitting key data, etc.	1. Reviewer made concrete suggestions to the author about moving particular paragraphs or reorganizing report sections	1. Reviewer suggested ways to reduce wordiness in a report section	1. Reviewer suggested changes that should be made to the presentation of data and results
2. Reviewer corrected errors in grammar, spelling, and/or punctuation				

Table 2: Categories of Student Reviewer Comments

Our observations are reinforced by comments we collected from the students themselves as part of the course evaluation. In considering themselves as reviewers, students wrote that the Peer Review Project had the following results:

- A student looked at her own writing in order to determine if she had committed the errors she pointed out in the writer's draft
- Another student felt no hesitation in writing comments on drafts

- Several students were willing to share the instructor's suggestions from their own reports, i.e., one student took a suggestion the course instructor made to him and shared it with the student author whose report he was reviewing
- Students used their own reports as models
- Some students cited class discussion as indication of what the writer should do and what the instructor expects
- Many students started their summary memos with a positive comment
- Only two students in the project group offered a minimal review – just a few "you did great" statements
- Most students performed a detailed review of grammar and sentence structure
- Despite their careful review of grammar, etc., all students kept their review focused primarily on technical content

The two sets of summary comments—from the reviewers and from the author—represented an important closing of the loop between reviewer and author. In addition, the instructor also closed the loop between Peer Review and final evaluation by using the same set of evaluation criteria in both (see Figure 2). We believe this helped to prevent some common disconnections that students see in Peer Review processes.

Conclusions

In addition to the analysis performed by the technical communication coordinator, we also collected student responses to Peer Review assignment. We were interested in knowing if students saw value in completing Peer Review and if they saw improvements in their writing as a result. Student comments are listed below:

- Peer evaluations were a lot of extra work, but overall very helpful.
- Peer review of reports good idea, helps to improve writing.
- Grading was pretty rough. I liked the peer evaluation, it cut down on the rush of the project as one could space reworks and rereading down.
- I liked the student eval idea…it took a lot of stress out of lab.

In general student response to the activity was positive. In particular students noted that they had two opportunities for improvement: once based on Peer comments and again based on the documents they reviewed. Students also indicated that reading other students' writing raised their awareness of best practices in the different types of reports, for instance, effective and appropriate discussion of results. Some students also remarked that their ability to discuss and draw conclusions from data improved significantly. As the chemical engineering instructor noted, the average score of the reports improved by nearly a letter grade compared to the initial drafts.

Our initial successes with the Peer Review assignment has led to the general adoption of the practice by all chemical engineering instructors teaching the Unit Operations Lab. It is too early at this point, however, to estimate the success of the assignment applied in different classes. Preliminary evidence indicates that the effectiveness is strongly tied to the degree which the individual faculty member takes class time to discuss the importance of technical communication and the role of the Peer Review. While we

continue to assess the project, we can assert that Peer Review, conducted with an appropriate rubric, is an effective tool that can help students improve their written communication skills**.**

References

1. Sageev, P. and C.J., Romanowski, "A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills," *Journal of Engineering Education* October 2001: 685-93.

2. Miller, R.L. and B.M. Olds, "Performance Assessment of EC-2000 Student Outcomes in the Unit Operations Laboratory," *Proceedings of the American Society for Engineering Education Annual Conference* (electronic), Charlotte, North Carolina, 1999.

3. Dannels, D., C. Anson, L. Bullard and S. Peretti, "Challenges in Learning Communication Skills in Chemical Engineering", *Communication Education*, in press (2002).

4. Ludlow, D.K., "Using Critical Evaluation and Peer-Review Writing Assignments in a Chemical Process Safety Course," *Proceedings of the American Society for Engineering Education Annual Conference* (electronic), Albuquerque, New Mexico, 2001.

5. Newell, J.A., "The Use of Peer-Review in the Undergraduate Laboratory," *Proceedings of the American Society for Engineering Education Annual Conference* (electronic), Milwaukee, Wisconsin, 1997.

Bibliographical information

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Figure 1: Criteria for Peer Review of UO Lab Reports

Although three different types of reports are written for each laboratory experiment, several of the most important criteria are common to all. The major difference among the reports relates to the amount of detail that should be presented. For example, the formal report should have a section detailing the theory and experimental setup. On the other hand, the memo report should concentrate almost exclusively on the important findings, results and conclusions.

As you evaluate one another's reports, comment specifically on the following topics. Make comments directly on the draft, and summarize your comments on a separate page. This page should be turned in along with the original, marked up draft by the writer of the paper. In addition, the writer should briefly describe how the reviewer's comments were incorporated into the final draft.

Introduction

Each type of report should contain an introduction. In the memo report this may just be a few sentences of the opening paragraph. In the formal report, this will likely be an entire section that includes an extensive discussion of the underlying theory. In all cases, the introduction should contain the objectives of the experiment and, hence, this report.

- What is the paper is about?
- What are the objectives (purpose)?
- Are the objectives identified in the opening paragraph?
- Comment on the clarity and conciseness of this section.

Results and Discussion

This section requires that graphical information (tables, graphs, charts) be combined with text. The results should be presented in an easy to understand manner (e.g., tables and graphs), and they should be described in the text so that a reader can readily understand what the data represent. In all cases measured values should be clearly differentiated from calculated values. Units should always be included.

When discussing the results, the writer should direct the reader to interesting trends that the data show. The writer should not assume that the reader can look at a graph and instantly interpret the results. The emphasis should be on what the results mean. If appropriate, comparison with literature values or theoretical values can be made. When making a comparison, be realistic – the writer's credibility suffers when stating that data matches theory when it really does not.

- What data was collected?
- What does the data mean and what general trend does it shows?
- Are visual aids (tables and graphs) clear, easy to read, and properly labeled?
- Is each visual aid adequately discussed in the text?
- Comment on the clarity and conciseness of this section.

Conclusions and Recommendations

This section should follow logically from the discussion of results. No new ideas should be introduced here without being introduced during the discussion of the results. The conclusions should relate to the objectives of the experiment and the purpose of the report. Recommendations may indicate additional work that could be done to test hypotheses that were developed through analyzing the data or may indicate ways in which the experiment can be improved.

- What are the conclusions and do they directly address the objectives?
- Are all the objectives addressed?
- Do all the ideas in this section flow logically from the discussion of results?
- Comment on the clarity and conciseness of this section.

Figure 2: Unit Operations Lab Report Evaluation Sheet

Name:_____ Project:_____

Introduction • What is the paper is about? • What are the objectives (purpose)? • Are the objectives identified in the opening paragraph?	
Clarity & conciseness of section	100-60-25
Results and Discussion • What data was collected? • What does the data mean and what general trend does it shows? • Are visual aids (tables and graphs) clear, easy to read, and properly labeled? • Is each visual aid discussed in the text?	
Clarity & conciseness of section	150-105-40
Conclusions and Recommendations • What are the conclusions and do they directly address the objectives? • Are all the objectives addressed? • Do all the ideas in this section flow logically from the discussion of results?	
Clarity & conciseness of section	60-40-15
Format for specific type of report and summary (progress reports)	30-20-20
Procedures, Equipment & Materials or description	20-20-0
Sample calculations	35-0-0
References	5-5-0
Quality of feedback given on reviews	