Learning Technical Writing Skills through Peer Review: Use of Calibrated Peer Review™ in Unit Operation Lab

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Abstract

Calibrated Peer Review™ (CPR™), initially developed by UCLA in the 1990s, is an internet-based educational tool that can be used to improve a student's technical understanding and writing in a large class. CPR™ applies the process of scientific peer review to education. Students perform research (study), write about their key findings, submit it for blind peer review (and act as reviewers themselves), and finally use peer feedback to improve their understanding. All of this can be done without intervention from the instructor using CPR™. This paper reports on an experimental study on the utility of CPR™ in chemical engineering education. CPR™ was introduced into a writing-intensive Unit Operation laboratory course. Students worked in teams and performed a set of experiments, but were required to submit individually-crafted executive summaries using CPR™. Improvements in student writing skills as well as critical reading skills were analyzed.

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1. What is CPR™?

CPR™, originally created under the Molecular Science Project, an NSF-funded systemic reform project by UCLA, is an instructional tool that uses writing and peer review to teach higher-order thinking skills and peer collaboration.[1] In most humanities and social sciences, writing-to-learn is extensively used to enhance reflective thinking.[2] In scientific and engineering writing, peer review is the key process to validate technical contents. Through peer review, students can learn critical thinking skills.[3] However, these essential skills are seldom taught or used in large-enrollment science and engineering classes because the workload involved in these activities is too high. CPR™ enables student writing and peer review without overloading the instructor. It is now being used in more than 1900 courses of various disciplines at over 500 institutions.[4]

The underlying theory is based on the scientific writing process. Students research a topic, write an essay, report, or similar output, and then submit their work for peer review. They also participate as reviewers themselves. The final stage requires the students to review their own work after having seen their peers' writing. This approach to writing assignments makes the

experience more authentic for the student of science and engineering. As the task is more realistic, the students should see the assignment as more than an exercise in writing, increasing their motivation to learn. As "communication skills" is often listed as a desirable attribute for graduates of engineering undergraduate programs, this aspect of CPR™ is very important. The process is illustrated in Figure 1.

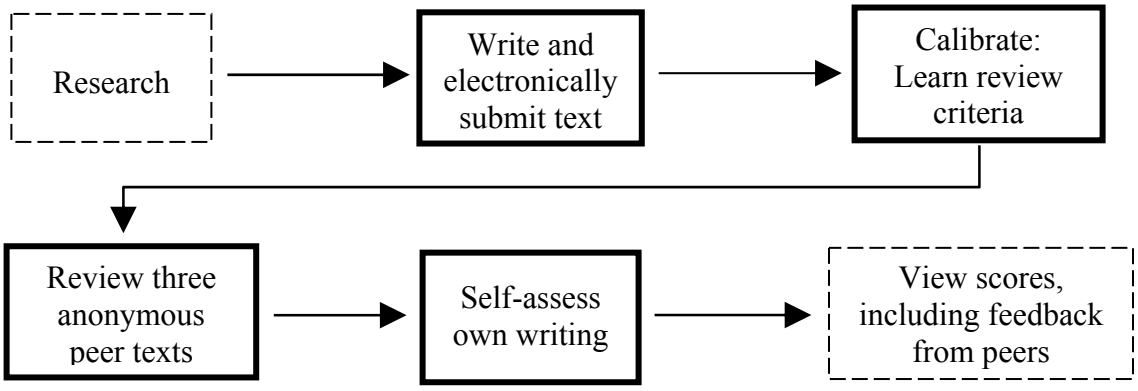

Figure 1. CPR™ Assignment Flowchart

Four main tasks highlighted with bold boxes in Figure 1 reflect modern pedagogical strategies for using writing in the learning process. A separate instructor interface and student interface provide customized reports on performance for individual assignments.

Text Writing – Students are presented with a writing task, with guiding questions to act as scaffolding for the demanding cognitive activities.

Calibration – After a student has completed his or her own writing and prior to being allowed to rate any fellow students, the student is presented with three benchmark samples (prepared by the instructor; one excellent, one average, and one poor) and asked to evaluate them based on a series of evaluative questions (rubric). The similarity between the student and instructor's ratings on the same text determines that student's "Reviewer Competency Index" (RCI). Students are assigned an RCI on a scale of one to six, based on their demonstrated competency in these exercises. The RCI ranges from a low of 1 to a high of 6 and is used to weigh the rating given by any particular student. This mitigates the effect of poor student raters on the performance of other students. The formula for deriving the RCI and other technical information is available at the CPR website.[1] The calibration stage, which determines the accuracy of an individual student compared to the instructor, is the main difference between CPR™ and other web-based peer review tools.[5,6]

Peer Review – After becoming a trained-reader (and being assigned an RCI credibility weighting) students read and provide written feedback on three anonymous peer essays using the same criteria as used in the calibrations. Students also assign each essay a summative score on a scale from one to ten.

Self-Assessment – As a final activity, students evaluate their own essay. As with calibration and peer review, students use the same criteria. Having trained on benchmark samples, and then applied their expertise in evaluating peer texts, students now engage in a reflective, final activity by assessing their own submission. They are encouraged to reflect on whether they have gained a deeper level of understanding for the assignment and its outcomes.

2. Goal of Using CPR in Chemical Engineering Unit Operation Lab

The goal of implementing CPR in the Chemical Engineering Unit Operation Laboratory is to address ABET Engineering Criterion 3(g) − Ability to communicate effectively. Most engineering programs applaud EC3(g)'s emphasis on writing; but they seem a bit vague about how to interpret/implement the criterion and how to measure outcomes. There is no well developed methodology incorporating fundamentals of effective communication in the expectations for writing in most writing-intensive engineering classes.[7] In that sense, CPR™ can be a good instructional tool that can fulfill dual purposes: to both improve and evaluate students' effective communication skills. Although CPR™ has been extensively used in chemistry, biology, and many other science disciplines, it has not been widely utilized in engineering education.[8] This paper reports on the application of CPR™ to a laboratory course in Chemical Engineering. In the chemical engineering undergraduate program at the Pennsylvania State University, this is the designated writing-intensive course. To the best of our knowledge, this is the first application of CPR™ to the large-enrollment Unit Operation laboratory course. In addition to hands-on experiences and experimental data workouts, the course covers effective presentation of technical content in both written and oral forms.

CPR™ was introduced to the Unit Operation lab in order to increase individual writing opportunities, particularly in the writing of the executive summaries that accompany written lab reports. Unlike real-world experiment and research situations, the goal of the undergraduate Unit Operation laboratory is not the generation of a technical report, but learning how the fundamentals of chemical engineering work in small bench-top operation units. Therefore, it is not correct to allow only the best writes to write the report. Without constraints, the best way to accomplish this learning would be for each student to independently conduct the experiment and write his or her own report. Only in this way would each student be exposed to the entire process of unit operation, data collection, data analysis, and technical report preparation. This is, as we know, impractical for classes of any appreciable size with limited experimental resources. It is also important to allow the students to work in teams during their college years to develop effective team working skills. So historically, a certain number of students team up to conduct experiments and then work collaboratively to develop the technical report. In most cases, this collaborative writing results in a division of labor on the final report, with one student writing the introduction, another student the methods, another the results, another the discussion, etc. To ensure that every student has the opportunity to develop his or her writing skills and experiences and benefit from performing reviews, we implemented CPR™ to have each student write executive summaries. The executive summary is different from an abstract or a general summary, and requires a different approach to be effective. In this paper, we will discuss the CPR assignments in the Unit Operation lab and results from assessments taken in two different semesters.

3. Design of CPR Assignment

The objective of the assignment was presented to the students in the following manner:

"*The Nittany Consulting Co. received four projects from various clients. These projects include (a) continuous stirred tank reactor operation of a model saponification reaction, (b) extraction of propionic acid from Leksol, (c) distillation of concentrated ethanol from a dilute ethanol-water mixture, and (d) separation of high purity porcine pepsin (solid product, at least 90% purity, other 10% is buffer salt) from*

a mixture of porcine and mucor pepsins. You were assigned to one of these projects for two weeks to conduct and evaluate the process with a bench-top instrument and write a full report with an executive summary.
Presenting your work to managers and colleagues will be a part of your daily life when you go to industries, and its importance cannot be overemphasized. Without good presentation or report writing, your painstaking work would never be properly acknowledged. The most important part of technical writing is the executive summary that appears on the first page. Very often, the readers (managers, colleagues, or clients) may be perilously close to a final judgment about your manuscript after reading only the executive summary. Through the CPR process, you will be able to improve your executive summary writing skills."

The four experiments described in the goal statement were all the experiments conducted in the lab. Over a given period of time, each student conducted an experiment with his/her team members and then wrote an executive summary independently. Each experiment had specific goals/assignments which were available to everyone in the class for review criteria. The instructions given to students for writing the executive summary were as follows:

"*Write an executive summary that briefly states the problem or purpose of the project, indicates the important theoretical or experimental procedures, accurately summarizes the principal findings, and points out major conclusions. The summary may not exceed 350 words.*
The purposes of the executive summary of a technical paper are to allow the reader to determine the ***nature and scope of the information*** *given in the paper and pinpoint* ***principal findings and conclusions****. They must contain sufficient information to allow the reader to understand what you have achieved and decide whether to read the whole paper for more details.*"

In the peer-review process, the students were asked to put themselves in a manager's position and check to see if the summary included all necessary information needed for decision making and report writing to clients. Since the peer review was assigned randomly, most of students were asked to review the summaries of experiments that they did not perform. This adds complexity, but mimics real world situations.

4. CPR Results

(1) Fall 2003 Semester – First time CPR^{TM} was used in the Unit Operation lab

In this semester, each student had the opportunity to perform three of the four experiments listed above. The course was made up of 36 students, all in their senior year. The CPR^{TM} assignment was implemented each time students finished one set of experiments (three weeks for experiments and one week for report writing). So CPR^{TM} was used three times during the semester. This is unusual, as most CPR assignments are taken only once. It is possible that repeating the same assignment affected the results of this study and this should be kept in mind. After three assignments, the effectiveness of CPR^{TM} was assessed through a survey in the class. Twenty-eight of the thirty-six enrolled students completed a voluntary survey administered by the course instructor.

Students were resistant at the beginning of the semester, but appeared to improve their writing skills through the CPR™ experiences. Initial resistance to CPR™ has been reported by other researchers and should be expected.[9,10] "Substantial discontent" with the use of CPR has also been reported.[11] However, many students showed improvement at the time of the second administration in both reviewing and writing skills, having "mastered" the reviewing process by the third iteration (Figure 2.). It should again be noted that this may be the result of completing the same assignment multiple times, and in fact some students reported that they had simply changed their answers on the third pass based on previous results. Students with high RCIs tended to also have high text scores, indicating that the two skills are related (Figure 3.).

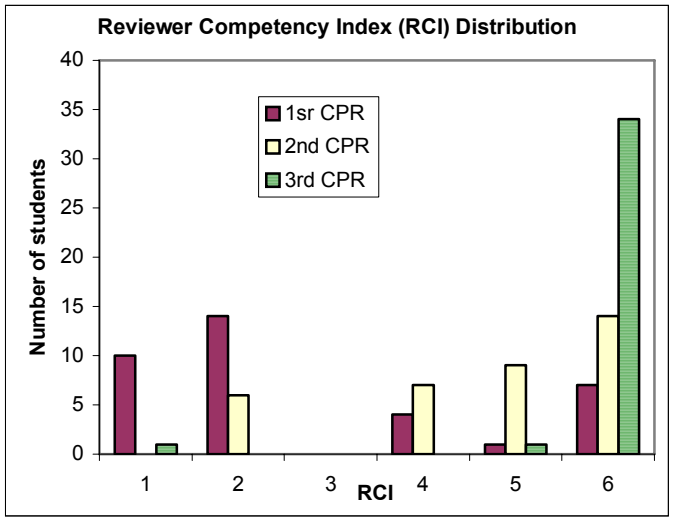

Figure 2. Change in RCI over 3 practices

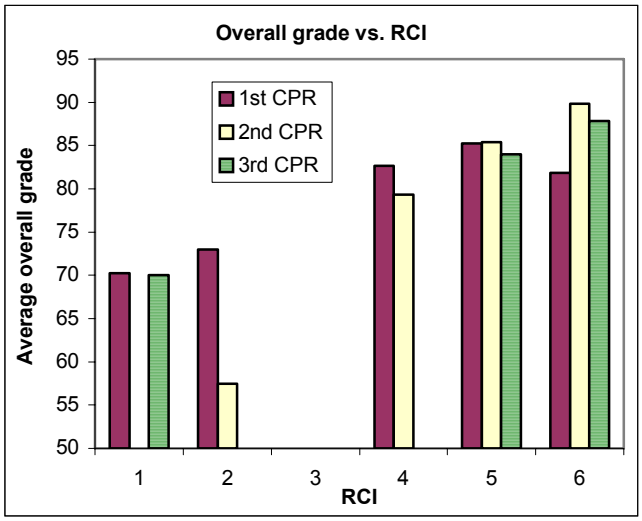

Figure 3. Relation of Overall Grade to RCI

Taken as a whole, most students reported that they thought their writing skill had improved through the use of CPR (Figure 4), but this change was not independently quantified. A rubric will need to be developed in order to adequately measure these differences.

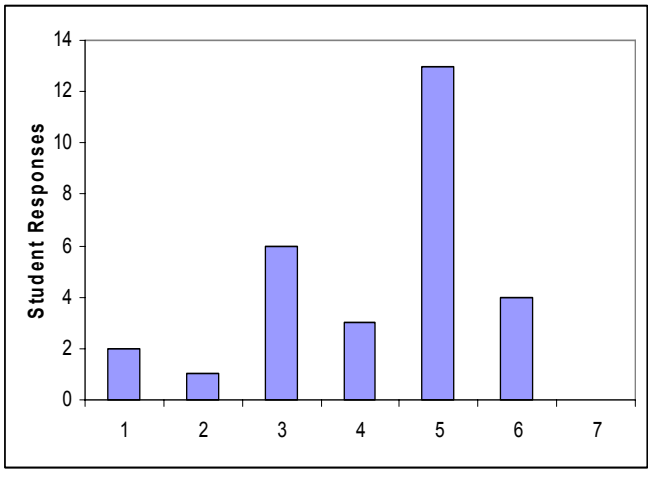

Figure 4. Survey Response from 1 ("Not at all") to 7 ("A lot") for "Did CPR Improve Writing Skill?"

Students were also asked to rate whether or not CPR helped them find the important aspects of the experiment and differentiate them from experimental details. Figure 5 is a histogram indicating the student responses on a scale of 1 ("Not at all") to 7 ("A lot"). Fifty-seven percent (57%) reported CPR as being helpful in this respect. This is a positive finding in keeping with the objectives of this course.

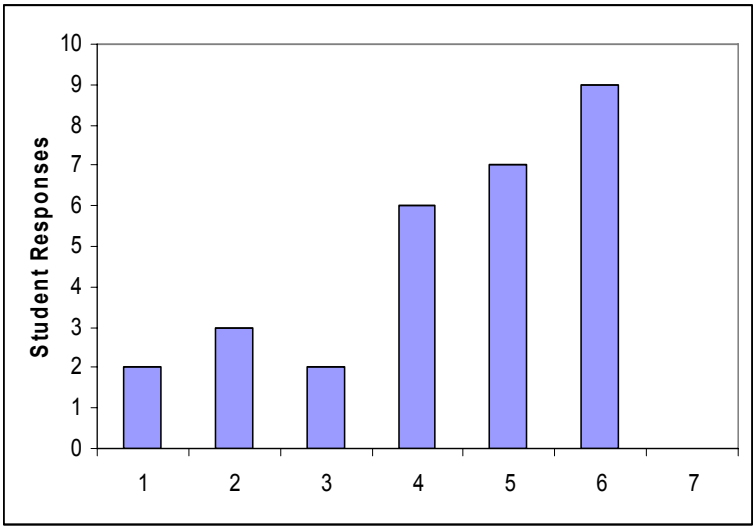

Figure 5. Survey Response from 1 ("Not at all") to 7 ("A lot") for "Did CPR Help Differentiate Important Aspects?"

(2) Fall 2004 Semester – Second time CPR™ was used in the Unit Operation lab

CPR™ was used a second time in the Unit Operation lab course in the Fall 2004 semester. The course was made up of 40 students in two sections (20 in each section), all in their senior year. In this semester, each student had the opportunity to perform all four experiments listed above. The CPR™ assignment was implemented only two times, for the second and fourth experiments. Since we learned from the CPR™ administration in the previous semester that students are able to find a "safe" zone for scoring in peer-review and self-evaluation after the second CPR™ test, we decided to reduce the number of CPR™ assignments to two. Instead, we offered opportunities to get feedback from the instructor for their writings. For example, we asked students to voluntarily write summaries of their first experiment and submit them directly to the instructor. Everyone who turned in their summaries got feedback on their writing styles and weaknesses from the instructor. In the first CPR™, students who practiced executive summary writing did not outperform the overall class ($t=0.471$, $df=38$, $p=0.641$):

Table 1. Comparison of average text rating score of the students who participated in the summary instructor review with the overall class average in the first and second CPR™.

	Group	No. of students	Mean	Standard deviation	t	df	p
1st CPR	WITH summary practice & instructor review	9	6.80	1.53	0.471	38	0.641
	WITHOUT instructor review	31	6.57	1.20			
2nd CPR	WITH summary revision & instructor review	13	6.99	1.39	1.889	38	0.067
	WITHOUT instructor review	27	5.99	1.64			

After the first CPR™ on the second experiment, students were asked once again to voluntarily revise their executive summary based on their learning from the CPR™ experience and submit them directly to the instructor. The students who submitted their revised summaries got feedback from the instructor. In the second CPR™ on the fourth experiment, these students outperformed the overall class by a full point. However, this finding was just short of statistical significance at the 0.05 level (t=1.889, df=38, p=0.067). There was also some migration between groups, as more students chose to participate in the instructor review. The observed effect may be due to four students who switched groups. CPR™ performance appears to improve with the addition of revision (critical reading) of own summaries, but this effect should be further explored.

(3) Fall 2005 Semester

CPR™ is being used again in the Unit Operations Lab in the fall of 2005. The course is currently running with 55 students divided among two sections. All students are in their senior year. Students have the opportunity to run 7 experiments, including the four mentioned before. Students are again being asked to participate in CPR™ two times during the semester, on the second and fifth experiment. Based on the previous results, the students are now required to turn in a revision of their CPR™ reviewed writing after seeing the peer reviews and scores of their original submission. This rewrite report will be submitted directly to the instructor for grading. Based on the previous semester assessment results, it is expected that this rewriting process will tune the student in to their own technical and reporting weaknesses and make them more aware of their own writing in future assignments. To encourage serious and thoughtful reviews with a lot of

written comments within the CPR™ assignment, the rewrite assignment carries slightly more weight than the original CPR™ assignment.

5. Conclusion

This paper reports on a series of applications of CPR™ in an engineering laboratory environment. CPR™ can be used in engineering laboratory courses to give students more experience in technical summary writing in addition to group report preparation. Some resistance can be expected, but students will be able to perform if given adequate support at the beginning of the process. Care should be taken if an assignment will be used more than once, as students will soon determine how to maximize their scores through the ratings they give each other. Revising their own writings after the CPR™ process seems to be a very effective way to improve students' writing skills. Balance needs to be found as well in the weighting given to CPR assignments in the grading scheme. A CPR™ assignment is not a trivial activity, so it should carry some weight; but it should not be such a large part of the grade that students are tempted to concentrate more on the grading than the process of improving their writing.

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