PEER EVALUATION IN CHEMICAL ENGINEERING CAPSTONE DESIGN VIA WIKIS

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Chemical engineering design is the capstone course of the curriculum that requires the student to integrate the knowledge gained in the previous years of study into one overarching project. The successful student is expected to be able to perform the duties of a chemical engineer in an industrial setting. The student is given an open-ended problem and must work within a group to compile and analyze complex data. There is, however, a missing component in this scenario. The students have been critiqued by their instructors, but they have not had the opportunity to critically evaluate another group's work and to determine the quality of the information presented. This critical peer evaluation skill is essential for entry-level engineers to assess data provided to them, as well as for students who continue on to graduate studies. Peer evaluation in engineering education is often used to assess the individual contributions of a team member[1] and has been used to rank group oral presentations and written deliverables for engineering projects.[2] It has been shown, however, that peer evaluation also improves writing in subjects ranging from teacher education[3] to biology.[4] This use of peer evaluation outside of discrete team evaluation and to specifically enhance writing and critical thinking skills is not widely documented within engineering education.

Engineering students receive a thorough education in technical subjects, but communication skills often receive secondary emphasis. It has been noted that special training enhances engineering communication skills.[5] Recent scores received by chemical engineers on the GRE exam, with an average of 487 ±119 on the verbal section (out of a total of 800) and 729 ± 79 on the quantitative section, confirm that many of our students have significantly stronger quantitative skills compared to their verbal skills.[6] Online activities have been developed to enhance chemical engineering writing skills.[7] Purely online, multiple-choice exercises to enhance writing skills, however, cannot duplicate the benefit gained by personal evaluation and specific review.

Wikis are showing great use in education as a method for collaborative learning and peer evaluation. A wiki is defined by Leuf and Cunningham[8] as a "freely expandable collection of interlinked Web pages, a hypertext system for storing and modifying information..., a database where each Web page is easily edited by any user with a forms-capable Web browser client." The advantages to this system include the ability to freely edit and create content with little hierarchical structure and the need for minimal programming knowledge and little specialized software.[9] The implementation requirements

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TABLE 1 ABET Outcomes for Capstone Senior Design Course		
Graduates will have:		
	ABET Outcomes	**Activity to Promote Accomplishment of Outcome**
b*	an ability to design and conduct experiments as well as to analyze and interpret data	Critical evaluation of other projects allowed students to analyze and interpret data presented by others utilizing wikis.
c	an ability to design a system, component, or process to meet desired needs	The student groups were given open-ended design projects to strengthen their ability to design a process.
e	an ability to identify, formulate, and solve engineering problems	Unit operations were required to be designed and sized using engineering principles.
f*	an understanding of professional and ethical responsibility	Students were expected to be professional and ethical when commenting on others' reports.
g*	an ability to communicate effectively	The students presented their design reports both orally and in writing. They also evaluated other student reports in writing utilizing wikis.
* *the wiki peer evaluation was designed to enhance outcomes b, f, and g*		

of this type of software are minimal on the instructor and the students, as compared to many other technology-based learning tools.

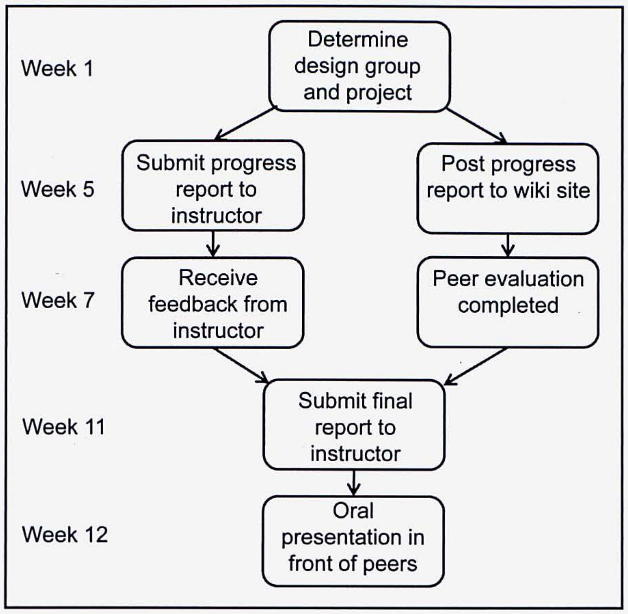
Web 2.0 technologies, including wikis, allow students to actively participate in their learning, as compared to passively reading a Web page to gain information.[9] Many uses of Web 2.0 technology take advantage of multiple-choice tutorials that allow the students to obtain instant feedback on their ability to answer questions.[7] This is a good tool when there exists a right and wrong answer to the questions being asked. Writing skills, however, are more difficult to assess in such a concrete manner. The use of collaborative media and wikis has been shown to enhance student engagement and provide a method for enhanced discussions.[10] The requirement to write about science and also to discuss science among peers leads to greater retention of skills.[4] Collaborative learning benefits all levels of students, as documented by Felder and many others.[11] The weaker students have a chance to be instructed by stronger students, which in turn strengthens the stronger students who learn by teaching. It also lets students who may be behind in the current material be aware of at what level the rest of the class is currently performing. These are many of the same attributes that Felder promotes for active learning in the classroom.[12] While the focus of this project was on peer evaluation and not collaborative learning, collaborative learning also occurred during the preparation of the design reports. This demonstrates that wikis are a structure that can be used to enhance many different forms of student communication and learning.

Here, we provide the students with an online forum to enhance their communication skills through peer evaluation. Peer evaluation enhances communication skills by allowing students to participate as both the assessor and the assessee, the former being a role not often adopted by students.[3] This ability to assess data and other students' communication skills is a valuable skill for undergraduate students to acquire.

COURSE OBJECTIVES AND WIKI LEARNING OBJECTIVES

Chemical engineering capstone design courses at Michigan Technological University involve two required semesters, each consisting of two credits of lecture and one credit of laboratory. Total enrollment for this cohort was 59 students. The first semester laboratory experience introduces the students to a full plant evaluation. Students are provided with an existing plant, and they must evaluate the plant to determine if it is profitable and what possible optimizations will increase profits. The students are asked to write three reports, which include two progress reports and one final report on their conclusions and recommendations. The learning objectives of this course are to apply process and project engineering skills to realistic industrial problems, to become familiar with the profit motivation in industry and analyze how decisions are made, and to complete an open-ended project assignment that requires the student to define the scope and cost of a project.

The second semester involves two design projects. The first is an open-ended project where the students are asked to perform a level one scoping study design and economically evaluate (± 30%) a chemical plant to make a product of their choosing given a list of about 30 projects. There were a total of 15 groups (14 four-person groups and one three-person group) across three sections of the class and every group was required to select a different project. The mid-semester progress report required for this open-ended project was integrated with wikis to allow students to peer-evaluate the progress reports. This is described in more detail in the next section. The last project was the 30-day AIChE design competition problem that could be done either in groups or individually, depending on a student's preference. The objectives of the second semester are similar to those of the first semester, but the projects are larger and even less defined for the students.



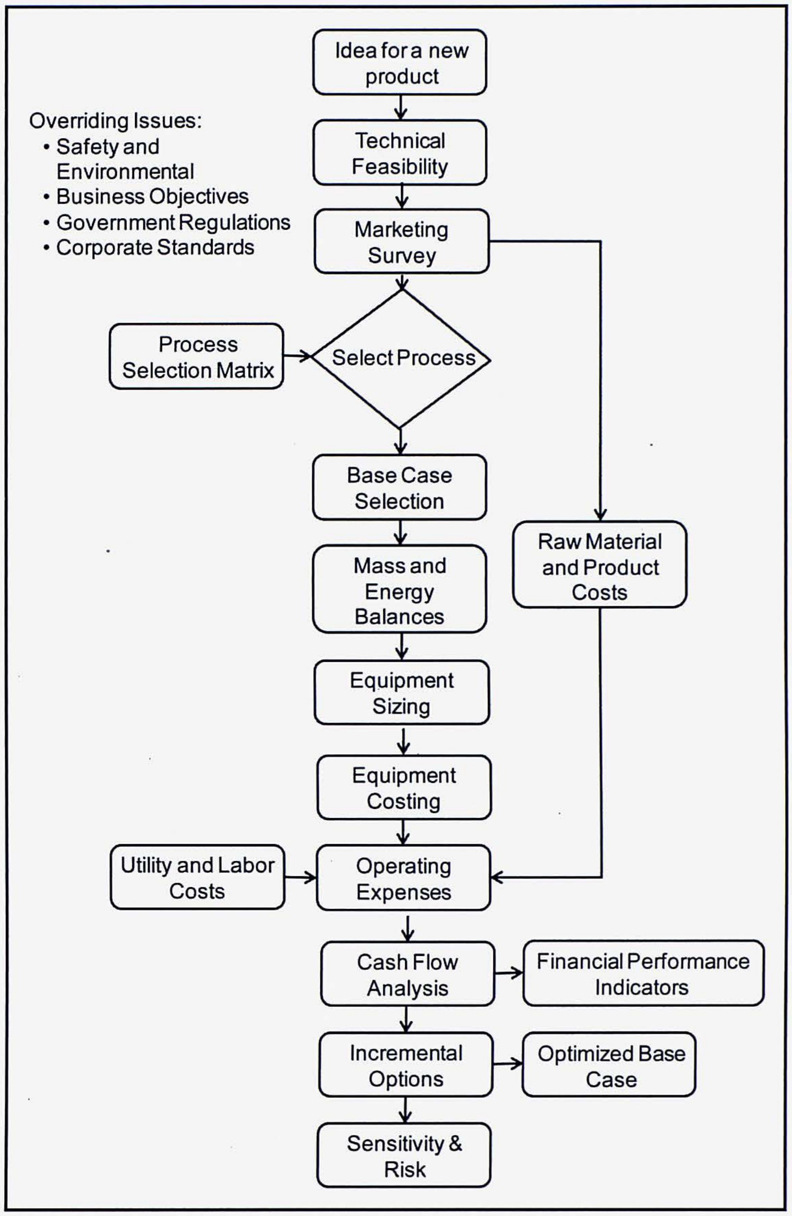


Figure 1 (above). *Flow chart for assignment requirements for second-semester capstone design laboratory.*

Figure 2 (right). *Flow chart for completion of the open-ended design project. Students were asked to focus on the economical feasibility of the process while reducing environmental impact and keeping the process inherently safe.*

The ABET objectives of the design courses are found in Table 1.[13] The Wiki portion of the course was designed to enhance objectives b, f, and g, which include analysis and interpretation of data, professional and ethical conduct, and effective communication, respectively. The students were asked to analyze and interpret data, not only for their own project, but also for the projects they were evaluating. Students were graded on their written progress reports, final reports, oral presentation, and completion of the wiki analysis. The peer evaluation with wikis was reviewed by the instructors, with 60% of the grade assigned to the timely completion of the wiki portion of the assignment and 40% of the grade to the assessment of the comments provided. Special emphasis was placed on the comments for improving the final report. This was a first iteration of this project, and the instructors were unsure of the quality and the engagement the students would have with the wiki project. Therefore, the quality of the comments was a smaller part of the grade than timely participation. It is projected that increased emphasis will be placed on the content of the students' comments in the future as we improve the presentation and formatting of the wiki using student and instructor input.

PRESENTATION OF WIKI MATERIAL

We chose to use the interactive wiki platform (using the free, open source MediaWiki software) to allow students to critically evaluate other students' progress reports for their capstone design project. The students were placed into self-selected groups of three to four students. They were given about 15 minutes to chose a design topic from a list, and it was determined that no project could be duplicated across different sections of the class. At the beginning of week 5 of the semester, groups were required to submit a progress report on their design project, with the final design being due on week 11. This timeline can be seen in Figure 1. The students were also given the flow diagram in Figure 2 to guide their assessment of the feasibility of their design project to be profitable within a 10-year project life.

The peer-evaluation process was introduced in the first class period. The students were given a memo containing the wiki site Internet address and instructions on how to sign onto the wiki. This wiki was access controlled so that only students and instructors in the class could access the wiki. The memo also contained some qualitative suggestions for how to assess other groups' work. The suggestions were:

Technical

- *Does the process appear to be feasible within the limits set by management?*
- *Are environmental and safety issues being addressed?*
- *Does the market survey seem complete?*
- *Is the base case selection technically feasible?*

Communication

- *How can the report be written in a more clear and concise manner?*
- *Are there missing elements in the report?*

At week 3, the students were given a 15-minute tutorial on how to use the wiki site. It was pre-loaded with each of the design project names and a link to a new page. The students were encouraged to make additional pages for collaborative work, but none of the groups took advantage of this opportunity. Pre-formatted wikis have been successfully used for collaborative work with students[14]; the instructors may use these in the future to encourage the use of the wiki during the development of the design reports and foster increased collaboration between group members.

On the same day as the progress report was due, the students were required to upload their progress report, including figures, to the wiki site. Most groups designated one student to be in charge of uploading the files. Some students had difficulty with the formatting, especially the requirement that figures could only be in .png, .gif, or .jpg. Most groups uploaded the file with little trouble.

The students were assigned to qualitatively evaluate different groups. Each group was assigned two other groups to evaluate. The assignments were based on the relative strengths of each group, as judged by faculty from the previous semester design course. The faculty rated each group as strong, average, or weak. We then used the following criteria to pair groups for evaluation:

- *Pair weak groups with strong group reviewers. Also, weak groups evaluated at least one strong group so that they could see in which areas they were below expectations.*
- *Mix the groups among class sections. There were three sections being taught, so each group was assigned one group in their class and one group outside their class.*
- *Mix project subject areas* (i.e., *biotechnology, petroleum, organic synthesis) to expose the students to different areas of chemical engineering.*
- *Do not allow groups to evaluate their assessors.*

Students were given two weeks to make their comments. In this time, the instructors also evaluated the projects, but did not post their comments on the wiki site, as this could be viewed as an invasion of FERPA regulations.[15]

This mixing of student ability was intended to engage and enlighten students at all levels. The higher-level student was given the challenge of assisting a lower-level group in improving its project. The lower-level students were exposed to higher-level thinking and allowed to discern if their performance was adequate for senior-level students.[12] The students were also mixed across sections, giving them exposure to additional projects that they would not have seen otherwise. This appeared to benefit the students, since several responses on the post-project survey expressed that they enjoyed learning what other groups were doing and seeing the levels other groups were attaining. Future iterations of this project will include similar methods to distribute evaluating groups. One student suggested that they could have given better technical feedback if the subject areas were not mixed. At this level in their education, however, the instructors feel that exposing the student to different technical areas may benefit the students more than allowing them to specialize in one area.

STUDENT RESPONSE

The quality of the student feedback varied with the level of the student. The lower-level students often found a statement that was unclear or a grammatical error. This was the extent of their peer review. The higher-level students took time to reflect and understand what they were reading and gave technical advice. For example, one student commented that there were some missing considerations when comparing two catalytic reactions, including the requirement of a PFR vs. a CSTR. This student also noticed fluctuations in the marketing data that were not explained by the authors. The peer reviewer stated that the trends during the past few years for crude and purified product were different and understanding these trends could impact future decisions. In the future, the students will be given more guidance on how to conduct their peer review to help the lower-level students achieve deeper understanding and evaluation.

The student opinion of the use of wikis in senior design was evaluated by pre- and post-project surveys and the results can be found in Table 2. The open-ended questions were not included in the table. Between 56-59 responses were tallied in the pre-project survey for each question and 53-56 responses for the post-project survey questions. The students were asked a series of questions about their use of online media, their method of communication, and how important publicly engaging in technical discussions will be in their future. The students' method of communication outside the classroom was not affected by this project, with students preferring face-to-face meetings, e-mail, and text messaging. The students did, however, change their communication during the semester for in-class projects. The preference of face-to-face meetings (47% pre-project vs. 33% post-project) was replaced with e-mail (16% pre-project vs. 33% post-project). This can either have a negative or a positive contribution to the students' education. It is more difficult to effectively communicate by e-mail than face-to-face meetings. The negative contribution of the shift from oral (face-to-face meetings) to written (e-mail) communication between project team members may result in the students communicating poorly with their teammates. Lack of communication within a team can lead to lower grades or one person taking responsibility for the project. The positive aspect of this shift to written communication is that the students may have enhanced their written communication skills through e-mail. It is not clear if the wiki project caused the shift from face-to-face meeting to e-mail or if the heavy load that most students were experiencing in their final semester as an undergraduate chemical engineering student was contributing to this shift.

The students were asked about their overall reading and contribution to the public Wikipedia project. Over the course of the semester, the students' daily reading of Wikipedia increased from 25% to 32%, and the students who had contributed to Wikipedia increased from 12% to 37%, which was statistically significant, as shown in Table 2, Question 2. The contribution to Wikipedia should be viewed as a positive outcome. We believe that the students now feel empowered and confident enough to share their knowledge with others. This could be promoted as a method of lifelong learning and sharing that should be encouraged in our student population. A recent survey of Wikipedia users showed that 65% of responders had not contributed to the resource, and the most common reason for not contributing was the lack of information to contribute.[16] The same survey also demonstrated that contributors had a small, but significant, increase in education level as compared to people who only were readers of Wikipedia. Chemical engineering graduates have significant knowledge in areas that could use increased input on Wikipedia, including areas of energy and biotechnology.

There was a minor, but not statistically significant shift from neutral to somewhat confident when the students were asked how they felt about publicly engaging in scientific or technical discussions either oral or written (Table 2, Question 6). Now 46% of students were either confident or very confident in contributing to online wikis in the future (Question 10). This confidence is important in chemical engineering students as they enter industry and academia.

At the end of the post-project survey, the students were asked what they liked the most, the least, and what they would change about this project. They liked reading others' reports, which gave them a new perspective on their own work. They also liked having additional feedback than only from the instructor. Other positive remarks included getting instant feedback and the ability to refer back to the wiki as they progressed with their project. The negative responses included: the project felt forced and the timelines were too strict, the text-only formatting was difficult, and the feedback was not

TABLE 2
Survey Responses of the Available Quantitative Data

	Question	Pre-results	Post-results	p-value^
1*	How often do you read Wikipedia	2.2 ± 1.1	2.1 ± 1.0	0.40
2*	How often do you contribute content to Wikipedia	4.9 ± 0.4	4.6 ± 0.6	<0.005
3*	How often do you contribute content to social networking sites (Facebook, MySpace, Twitter)	2.2 ± 1.1	2.2 ± 1.0	
4+	How do you feel about posting content online for other students to read	3.3 ± 0.9	3.3 ± 0.9	
5+	How do you feel about posting content online for anyone to read	3.1 ± 1.1	3.0 ± 1.1	
6+	How do you feel about publicly engaging in scientific/professional dialog either oral or written	3.2 ± 1.1	3.3 ± 1.0	0.38
7#	How important do you think publicly engaging in scientific/professional dialog will be in your career	4.3 ± 0.9	4.4 ± 0.9	
8+	How do you feel about your ability to publicly engage in oral scientific/professional dialog	3.5 ± 1.0	3.5 ± 1.2	
9+	How do you feel about your ability to publicly engage in written scientific/professional dialog	3.7 ± 0.9	3.7 ± 0.8	
10+	After completing this project, how do you feel about contributing to public wikis		3.4 ± 0.9	
11**	After completing this project, how likely are you to contribute to Wikipedia or other public wikis		2.4 ± 1.0	

*1 - Daily, 2 - Weekly, 3 - Monthly, 4 - Less than monthly, 5 - Never

+1 - Nervous, 2 - Somewhat nervous, 3 - Neutral, 4 - Somewhat confident, 5 - Confident

#1 - Not important, 2 - Somewhat not important, 3 - Neutral, 4 - Somewhat important, 5 - Important

**1- Unlikely, 2 - Somewhat unlikely, 3 - Neutral, 4 - Somewhat likely, 5 - Likely

^ The p-value was calculated using the Student t-test for unpaired events useful or repetitive. Some students suggested not doing it again, whereas others suggested an additional progress report so that they could improve, having more formatting options, or conducting the peer-review through paper copies and not the wiki. A few students suggested that the comments remain private to each group so that others could not copy responses.

In general, the students were positive about the wiki experience and the feedback they received from their colleagues. Over half of the students said they received helpful suggestions on their project, and 26% of the students reported that they spent more time writing their progress report knowing that other students would be reading it. This extra time spent writing and improving communication helps students learn to evaluate their own ability to relay technical information. The students that used the wiki comments also had additional time to reflect on their work. Quiet time to reflect on events has been shown to improve the performance of rats in a maze,[17] and can often improve learning. With additional encouragement from the faculty on the use of the student comments, we hope to increase the number of students who not only carefully craft their reports but also the number of students who provide thoughtful peer feedback and who view peer feedback positively.

SUMMARY AND SUGGESTIONS

In the capstone design course at Michigan Tech, we have implemented wikis as a method of peer-evaluation of mid-semester progress reports. This project was designed to engage students in the analysis and interpretation of data, as well as enhance communication skills. The students were required to analyze and interpret data for their particular project in previous iterations of this class, but now they were also asked to apply the same skills to other students' projects. They were also asked to effectively communicate their own progress as well as their evaluation of others' projects. The students enthusiastically engaged the project and gave helpful suggestions to their peers with minimal instructor input. Based on surveys given to the students, their confidence in their ability to effectively communicate technical information improved over the semester, leading us to believe that the wiki project was worthwhile.

We plan to continue to use wikis in the capstone design class, with modifications to address specific opportunities for improvement. As mentioned earlier, we will likely place more emphasis on the quality of the comments when grading the peer-evaluation of the students. It was not known how much the students would be engaged in this project, so we conservatively only distributed 40% of the grade to the quality of the comments. A second improvement will be to add pre-formatted wikis pages for the students to use as templates. The pre-formatted pages will be designed to encourage collaborative work in the wiki environment, along with giving more structure to the peer-evaluation portion of the wiki. A third improvement will be to add anonymous quantitative evaluation of the progress reports, along with the currently performed qualitative evaluation. Anonymous quantitative evaluation has been found to correlate well with instructor scores, and students were most satisfied when they received both qualitative and quantitative feedback.[3] This additional information will give the students a clear picture of the level at which they are performing, not just in their instructor's opinion, but also in the opinion of their peers. Finally, we would like to add industrial advisors who will also evaluate the students' progress reports, in addition to review from peers and the instructor. The industrial advisors would give qualitative evaluation of the technical and communication skills of the progress reports, similar to the evaluation given by peer-review detailed in this manuscript. They would also give a quantitative score so the students can see where they rate compared to other entry-level engineers. This should increase the value that the students place on the wiki evaluation, as they will be visible to potential employers.

This use of wikis in the classroom engages a generation of students who are technology savvy at a level that they normally use for communication. It is important for instructors to embrace Web 2.0 technology and other up-and-coming methods to engage students who are willing to embrace innovative educational approaches.

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