

Board 14: Using Active Learning and Group Design Activities to Increase Student Perceptions of a Course's Educational Value

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Introduction

In the chemical engineering curriculum, courses in process economics and preliminary process design aim to introduce students to topics that will be crucial to their success in their senior capstone projects as well as in their future careers. At the study institution, this course, entitled Process Economics and Green Design, has traditionally been offered in a lecture-only format and has at times suffered from poor attendance and low participation in class discussions. The students' perception of the educational value of the course has been lower than expected (average score = 3.5/5 over past three offerings) which was believed to be a function of students not adequately engaging with the course material and appreciating its relevance.

It is widely accepted that active learning approaches, including project-based learning, can improve student engagement and achievement of course-level student outcomes [1-2]. Project-based learning works to emulate professional behavior, in this case of the engineer, allowing for students to apply knowledge in a manner that could be transferred to a professional setting [3]. Project based learning has been shown to bring about increased motivation and positive attitudes from students as well as a perception that course objectives are being met [3-4]. Incorporating contextual learning activities into a course can result in an increase in student perceptions of course relevance which can then positively impact student motivation and willingness to put time and effort into a course [5]. In a previous effort at the study institution, a project-based approach to assessment was successfully implemented in this course, where students were tasked with proposing their own senior design project idea for potential use in the capstone design course [6-7]. This project was used to assess students' ability to communicate effectively, describe a preliminary process concept that met a societal need with realistic constraints, understand ethical responsibilities and safety issues, understand the impact of the proposed project in a global, environmental, and societal context, and to engage in life-long learning by immersing themselves in the literature.

In Fall 2018, this course (Process Economics and Green Design) was further redesigned to include a laboratory-component with a group-project focus. The new course format was similar to the studio model used at Oregon State University [8]. In order to allow students additional opportunities to actively engage with the course material, the four hours previously allotted as lecture time were reallocated to include three hours of lecture/discussion with the class as a whole, and one hour of laboratory, or small group activities with no more than twenty-four students at a time. The lecture period was redesigned to focus on topical case studies illustrating key concepts related to chemical engineering plant design as well as to include active learning exercises. Case studies included the conceptual design of a biomass gasification process, modeling a chlorobenzene plant using Aspen Plus™, and the 2005 Texas City refinery explosion. Active learning strategies that were used included think-pair-share, role playing, and solving short problems in small groups.

The heart of the redesign was realized in the new laboratory component. These laboratory sessions emulated a work environment, where students worked in groups of nominally two students (maximum of three students) on pieces of a larger design project and rotated through the roles of lead engineer and engineer. The small-scale projects were designed to prepare students to take on larger plant design projects such as the capstone projects that they were required to complete later in their senior year. These projects are summarized in Table 1. The projects started during the laboratory session were then completed during the following week outside of laboratory, and submitted prior to the next session. Specific outcomes of the course redesign that were anticipated included:

1. students would have a greater appreciation of the relevance of the course with the addition of the active and contextual learning experiences in both the lecture and laboratory sessions, and
2. students would demonstrate enhanced achievement of course outcomes with respect to previous offerings of the course due to a potential increase in motivation and willingness to put time and effort into the course.

Data Collection and Analysis

The goals of the course redesign were assessed using end-of-term student evaluations of teaching and performance on common assignments completed by the cohort taking the redesigned course vs. students who took the course during the previous offering. Specifically, to evaluate the first goal (students would have a greater appreciation of the relevance of the course), student responses to two survey questions, as well as free-form feedback, on the end-of-term student evaluations of teaching were collected and compared to responses collected after previous offerings of the course. Student responses to the prompt “*Please indicate the overall educational value of the course*” (as well as free-form feedback) were used to evaluate student perceptions on the relevance of the course material. Students responded to this prompt by selecting a rating between 1 (poor) and 5 (excellent). Data from the previous three course offerings was available for comparison. The statistical significance of performance by different cohorts was determined using chi-squared tests with $\alpha = 0.05$. Responses to the prompt “*What percentage of lectures did you attend*” (as well as free-form feedback) were used to evaluate the extent to which students were taking advantage of the lecture time to engage with the course material. Students were required to attend the laboratory sessions. Students responded to this prompt by selecting from the following options: 80% or more, 60% or more, 40% or more, 20% or more, less than 20%. Data from the previous course offering was available for comparison (this question has only appeared on the survey for the '17 and '18 offering of the course).

Table 1: Laboratory assignments incorporated into the redesigned course.

<i>Discussion Topic</i>	<i>Highlight of Learning Activity</i>
Introduction to Preliminary Process Design	Students developed a qualitative I/O diagram, BFD, and PFD for a familiar process (making coffee), gaining insight into how to go from a general everyday process and abstract the process into steps.
Hierarchical Method of Process Design	Students developed a qualitative I/O diagram, BFD, and PFD for a biodiesel production process requiring them to do research into the necessary steps to include in their diagrams as well as alternative processing routes.
Aspen Lab 1 – Building a Flowsheet (Guided)	Students were provided step by step instructions to build a chlorobenzene plant model in Aspen Plus. They were also introduced to the sensitivity analysis and design specification tools as well as calculator blocks and allowed to experiment with these features.
Aspen Lab 2 – Building a Flowsheet (Unguided, Upstream)	Students were tasked with designing the upstream section of a methyl acetate process in Aspen Plus, leveraging experience gained in the previous Aspen Lab to approach a new problem.
Aspen Lab 3 – Building a Flowsheet (Unguided, Downstream) and Flowsheet Optimization	Students were tasked with designing the downstream section of a methyl acetate process in Aspen Plus and building in the recycle structure of the process. Students worked to meet a target product flowrate and purity while minimizing the amount of reactants used.
Process Safety	Students were given information on the T2 Laboratories process that resulted in a runaway chemical reaction (without being told about the explosion) and were asked to do a hazards analysis on the process.
Chemical Plant Profitability Analysis (2-week project)	Students completed an economic analysis of the methyl acetate project, reporting the total capital investment, yearly cash flows over the life of the project, return on investment, net present value, and modified internal rate of return.

Performance on common assignments was compared between the students taking the redesigned course and the students who took the previous offering of the course. These results were used to gauge if there were indications that the second goal (enhanced achievement of course outcomes with respect to previous offerings of the course) was being realized. However, year-to-year inconsistencies were considered in the interpretation of these results. The common assignments were a major midterm project (design project proposal) where students proposed potential capstone design projects [6-7] and the final course examination (primarily process economics). These assignments were both created and evaluated by the same instructor, but with the help of different teaching assistants. The same rubric used to evaluate the midterm projects in each offering, and grades were assigned with oversight from the same instructor. Due to the open-ended nature of these projects, precise consistency in grading could not be assured. In regards to

the course final, while an effort was made to allocate points consistently by topic, specific questions (and corresponding grading rubrics) were modified each year in order to ensure the integrity of the exam.

The cohort taking the redesigned course was assumed to be comparable to previous cohorts taking this senior-level course for chemical and biochemical engineering majors. Each cohort consisted of > 100 senior-level chemical and biochemical engineering students at the study institution with the required preparation of successfully completing the junior-level transport series. There were no significant differences in the cumulative GPAs of each cohort ('15: Average GPA = 3.07 ± 0.45 , '16 Average GPA = 2.97 ± 0.41 , '17 Average GPA = 3.07 ± 0.41 , and '18 Average GPA = 3.05 ± 0.50).

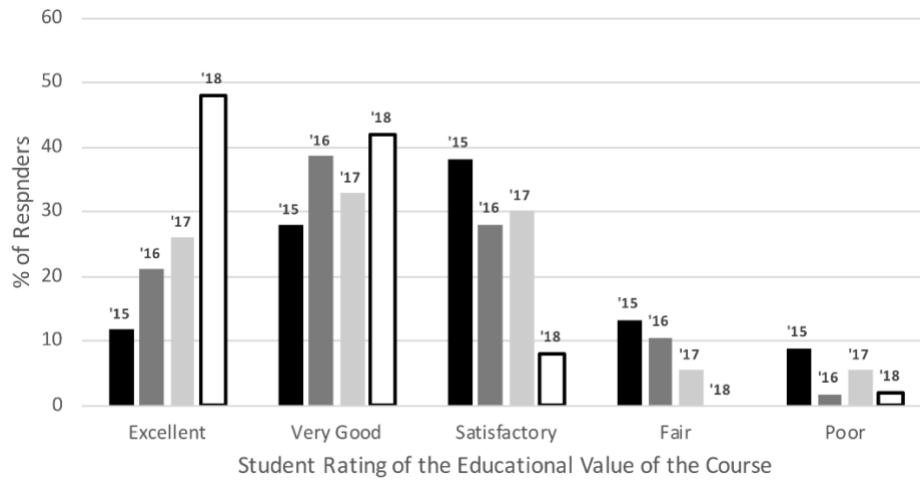
Student design project proposal submissions were rated as “Excellent”, “Good”, “Fair”, or “Poor” based on performance across a number of project-specific criteria [6-7]. Submissions for students taking the redesigned course were compared to submissions from the previous two cohorts covering the period of time over which this particular project has been required. The statistical significance of performance by different cohorts was determined using chi-squared tests with $\alpha = 0.05$. Final exam scores were compared across the past four offerings of the course. The statistical significance of performance by different cohorts was determined using t-tests with $\alpha = 0.05$.

Results

Evaluation of the impact of the course redesign on student perceptions on the relevance of the course material is presented in Figure 1A. The student rating of the educational value of the course increased for the redesigned course to an average of 4.3 ($\sigma = 0.8$) from an average of 3.7 ($\sigma = 1.1$) in the most recent previous offering of the course. The differences in students' categorical ratings of the educational value of the course when compared between the redesigned offering and each of the three previous offerings were all found to be statistically significant as determined using chi-squared tests ($p < 0.05$).

Of the students responding to the end-of-quarter student evaluations of teaching, the number of students reporting that they attended 80% or more of the lectures increased from about 74% in the '17 offering of the course to about 85% in the redesigned '18 offering of the course, as shown in Figure 1B. Further, none of the students responding to the evaluation after the redesigned course reported attending less than 60% of the lectures. It must be noted that since attendance was self-reported and data was only available from the students completing the survey, these results may not reflect the actual attendance in lecture. Anecdotally, lecture attendance was observed to be better throughout the quarter in the redesigned course. It should also be noted that in the redesigned course, students were required to attend the once a week one-hour laboratory section in order to work with their design group. The students honored this requirement and only rare absences due to illness or conference participation were noted.

A



B

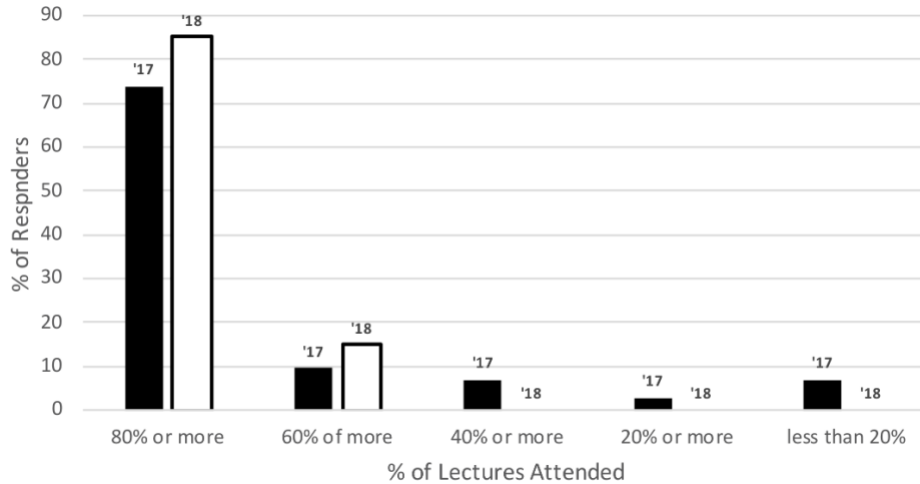


Figure 1. Evaluation of Student Engagement and Perceptions on the Relevance of the Course Material. (A) Students responded to the prompt “Please indicate the overall educational value of the course” on an end-of-term student evaluation of teaching using a Likert-type scale (1 = Poor to 5 = Excellent). The percentage of responses for each category is presented for the ‘15 (black, n = 68/122), ‘16 (dark grey, n = 57/145), ‘17 (light grey, n = 73/164), and ‘18 (white, n = 50/118) course offerings. (B) Students responded to the prompt “What percentage of lectures did you attend” on an end-of-term student evaluation of teaching. The percentage of responses for each category is presented for the ‘17 (black, n = 73/164) and ‘18 (white, n = 47/118) course offerings.

Student performance on major course assignments common to the redesigned course and previous offerings of the course is presented in Figure 2. While student performance on the major midterm project (design project proposal) by the cohort taking the redesigned course appears to be significantly better ($p < 0.05$) than the 2016 cohort, it was not significantly better

than the 2017 cohort. Interestingly, the 2017 cohort was allowed to work on this assignment in pairs (same as the 2018 cohort in the redesigned course), while the 2016 cohort was required to work on this assignment individually. This difference in performance further motivates the move to incorporate more collaborative assignments into this course.

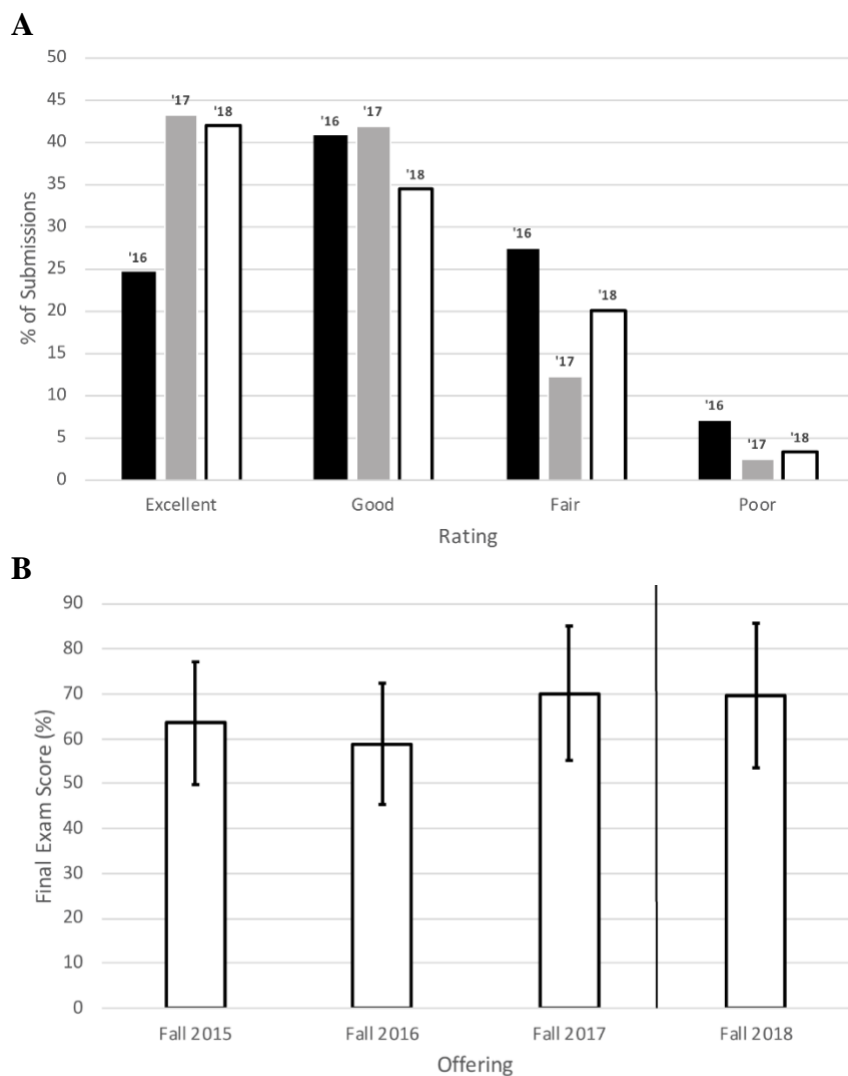


Figure 2. Assessment of Student Achievement on Major Course Assignments. (A) Students' performance on a major midterm project (as rated on a four-point scale) is presented as the percentage of students who achieved a grade in each category for the '16 (black), '17 (grey), and '18 (white) offerings of the course. (B) Students' performance on the final course examination is presented as the raw average score for the cohort (error bars = standard deviation) for the '15 – '18 cohorts (line on chart separates pre-redesign offerings from post-redesign).

Student performance on the final course examination by the cohort taking the redesigned course was observed to be significantly better ($p < 0.05$) than the 2015 and 2016 cohorts, but not significantly better than the 2017 cohort. In fact, the exam statistics for the 2017 and 2018 cohorts were nearly identical (2017: 70.16 ± 14.96 and 2018: 69.63 ± 16.09). Outside of the previously mentioned year-to-year inconsistencies, it is also important to note that during the redesign year (2018) the campus unexpectedly shut down for seven days approximately two weeks before final exams, requiring that the presentation of topics in the process economics unit of the course be abridged. Since the majority of the final exam for this course is an assessment of the students' knowledge of process economics, this loss of class time could have deflated the students' performance on the exam in the redesign year.

Discussion and Future Directions

Responses to the end-of-term student evaluations of teaching shows that the students' rating of the educational value of the course significantly increased for the redesigned offering of the course. Students were given many opportunities to actively engage with the course material via contextual learning experiences as a part of the course redesign, and students appeared to respond in a positive way to these opportunities based on the percentage of lectures that students self-reported on attending and adherence to the attendance requirement in the laboratory sections. When prompted to describe what aspects of the redesigned course positively impacted their learning experience, one student noted:

“Interactive activities, as well as real life applications and practices...the discussion assignments helped a lot in training my critical thinking and analytical thinking abilities. I learned a lot about what chemical engineers do in industries, and what factors to consider when designing and operating a real project.”

Performance on major assignments common to the redesigned course and previous offering of the course were observed to be not significantly impacted. Future efforts will focus on better connecting the weekly design laboratories to the content presented in lecture and to the project proposal assignment so that any improvement in student comprehension of the course material achieved via the design labs will have a greater probability of being transferred to these other applications. Students commented that they did not always appreciate the connection between what they were working on in lab and what was being presented on in lecture. This was partly due to the fact that process simulation using Aspen Plus™ was addressed for three weeks in lab and only for one week in lecture. This led to future labs being off-sequence with the lecture material. In the future, a short review will be incorporated into the lab sessions where students will be reminded of the relevant lecture material and the aspects of their project proposal assignment that pertain to the current assignment.

One other aspect of the course that many students noted as needing improvement was the course workload. In addition to the weekly design labs, outside of class students also completed three individual homework assignments, four peer/self-evaluations of group work, and the design project proposal project. A number of students commented that the frequency of the design labs

was too high, and that overlapping assignments did not allow them adequate time to spend on any one of the assignments. In the future, the individual homework assignments may be eliminated in favor of expanded design labs and occasional quizzes in order to keep individuals accountable.

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