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BOARD # 40: A Comparison of Three Teaching Methods in Junior Chemical Engineering Required Courses

Dr. Laura P Ford, The University of Tulsa

Laura P. Ford is an Associate Professor of Chemical Engineering at the University of Tulsa. She teaches engineering science thermodynamics and fluid mechanics, separations/mass transfer, process control, and chemical engineering senior labs. She is an advisor for TU's student chapter of Engineers Without Borders - USA.

Dr. Hema Ramsurn, The University of Tulsa

Hema Ramsurn is the A. Buthod Associate Professor of Chemical Engineering at the University of Tulsa. Her teaching repertoire consists of the following courses: health and safety in chemical processes, mass transfer, advanced chemical reactor design, fluid mechanics, thermodynamics and senior lab. Her research revolves around bio-based materials (graphene, activated carbon, biochar), catalytic methane conversion, carbon-carbon composites and their anti-oxidative coatings for high temperature applications.

Prof. Javen Scott Weston, The University of Tulsa

Javen Weston is an Associate Professor in the Russel School of Chemical Engineering at the University of Tulsa. He teaches Principles of Chemical Engineering (Material and Energy Balances), Chemical Reactor Design, Fluid Mechanics, and Heat Transfer courses. His education research efforts focus on pedagogical assessment and science fair participation by students in grades 6-12.

A Comparison of Three Teaching Methods in Junior Chemical Engineering Required Courses

Abstract

Juniors in chemical engineering at a small, private, South Plains institution (The University of Tulsa) take three required chemical engineering courses in the spring semester: mass transfer & separations, reactor design, and process control. The faculty structured their courses in different ways:

- Mass Transfer was taught traditionally with in-class lectures and in-class problem solving by the professor before students solved a graded activity.
- Reactor Design was taught with video lectures before class, and class time was used for instructor-led example problems along with occasional, multiple-choice conceptual questions.
- Process Control was taught with video lectures before class, and the professor worked an example in class before the students worked a graded problem in groups during class.

All three courses had traditional homework, exams, and design projects. We surveyed the entire Spring 2024 class of 17 students in Fall 2024 to assess two items: 1) the student preferences for the various teaching methods, and 2) the differences between faculty *intentions* and student *perceptions* regarding the teaching methods used in each class. Since all three courses included an identical cohort of students, this survey offered a unique opportunity to compare cross-course preferences among a consistent student cohort, eliminating the need to assume that all cohorts have identical preferred teaching methods. To observe cross-cohort preferences, the same survey may be given to the junior cohort taking the same courses in Spring 2025, if possible.

The first part of the survey asked the students to describe the three courses, with questions based on the Student Response to Instructional Practices (StRIP) Survey. Students perceived that 'faculty lectures' and 'individually-solved problems' were used as teaching methods more frequently than the faculty intended them to be. The faculty and students also had different perceptions on what counted as an individual grade versus a group grade for group work submitted during class time. Finally, the faculty thought that the students answered questions during class on material not previously covered in class more than the students thought they did.

The survey's second part aimed to discover which methods the students thought helped them learn the best and if they liked non-traditional methods more than traditional lectures. Although at least half of the students said that the video lectures aided their understanding, three-quarters preferred live lectures when compared to video lectures. A majority agreed or strongly agreed that the following methods aided their understanding: 1) on-line quizzes, 2) in-class discussion questions, 3) instructor-led practice exercises, and 4) small-group practice exercises. About two-thirds of respondents also expressed a preference for in-class practice exercises rather than a traditional lecture. A cross-course difference was that 70% of respondents thought the teaching methods used in Mass Transfer and Reactor Design helped them gain a deep understanding of the material, while only 33% felt the same about Process Control. Additionally, responses

indicated that the students were more engaged with the material in Mass Transfer than in Reactor Design, which in turn was more engaging than Process Control. The students saw Mass Transfer as the easiest course and Process Control as the most difficult course. All respondents agreed or strongly agreed that they could ask questions whenever needed in all three courses.

Introduction

The faculty teaching the three junior spring courses at The University of Tulsa realized that we had an opportunity to survey a single student cohort taking a trio of courses in the same semester where three different course design frameworks were used. Two faculty recorded video lectures for the students to watch before class, and one used a traditional in-person lecture style. All three worked examples in class. Two faculty had the students work problems in class, but these were not the same two faculty who recorded video lectures, resulting in three different combinations of teaching methods. Our interest was in assessing two things: 1) whether the students and faculty perceived the teaching methods of the courses to be the same, and 2) which method(s) the students preferred in each course and across all courses.

Surveys to compare teaching methods have been widely published, but this study compared the same cohort subjected to three different methods in the same semester. For an example of the literature, in a survey of students and faculty of science courses, the faculty averaged across the college thought they used active learning more than the students did [1]. When the data were broken down by department, the students and faculty agreed about the amount of active learning included except for geology courses. Students in that study listed problem-solving as their most preferred teaching method, followed by lecture. The remaining four methods were tied for last place: videos, reading, group learning, and educational games.

Another study compared a traditional course to flipped courses, including one with video lectures [2]. The students preferred live lectures to the video lectures, which they thought did not help them understand the material. They agreed that small group problem solving helped them understand the course material, but they wanted the instructor to guide them as they solved the problems. They were neutral when asked if they preferred the problem solving to traditional lecture. The questions from this study were modified for use in our project.

Methods

The spring semester of the junior year gave us an opportunity to compare different teaching methods in three courses with the same cohort of students. The required courses that semester are a 4-credit-hour Mass Transfer (and separations) course, ChE 3084; a 3-credit-hour Reactor Design course, ChE 4063; and a 3-credit-hour Process Control course, ChE 4113. The faculty teaching them will be referred to as Dr. MT, Dr. RD, and Dr. PC generally, but their real identities are Hema Ramsurn, Javen Weston, and Laura Ford, respectively. The faculty and course designs are described in the next several paragraphs.

The faculty teaching these courses had 5 – 25 years of experience. All had attended Summer School for Chemical Engineering Faculty and worked to include active learning in their courses. By the end of the semester, all three had received the department's teaching award selected by the seniors and the college teaching award selected by a faculty committee. Dr. MT has also received the university teaching award. The Mass Transfer and Process Control courses were new courses to their faculty that semester, but Dr. MT had the benefit of Dr. PC's materials from previous years. Dr. RD had taught the Reactor Design course four times before. It had originally been taught in a traditional lecture style but was flipped as part of the transition to virtual teaching associated with the COVID-19 pandemic and has remained flipped since Spring 2021.

Dr. MT taught the Mass Transfer course traditionally with in-class lectures and a lab (see Figure 1). The class met three times a week (MWF) for 50 mins for classes and 1 hour per week on Wednesdays for ASPEN HYSYS labs. The lab was usually based on the topic covered that week in lectures. A TA supported the lab to troubleshoot the HYSYS activities. The TA also held office hours to help with the lab assignments but did not attend or deliver lectures. Class materials (PDF of lecture notes and links to useful websites) were posted ahead of time to the university's learning management software (LMS). During class, the instructor went over the material and explained all the concepts related to the topic of the day. Often, the instructor would ask questions during class to keep the students engaged. The instructor would then solve a related problem in class and would usually ask questions while doing so to encourage student participation. Dr. MT would then give the class a related assignment to solve in class. Students were allowed to discuss among themselves and ask the instructor questions as well. Most of the time, these assignments were collected for grades to ensure that all students completed their work. In the next class, the instructor would often give them an individual activity to complete on their own for grades. This course had an exam every two weeks and a comprehensive final. Quizzes were also posted each week online and were due within 2 days. They tested the students on the material covered that week and were usually simple multiple choices. During exam weeks, quizzes would be open on Wednesdays and closed on Fridays while for non-exam weeks, quizzes would be open on Fridays and closed on Sundays. All labs and homework were due each week on Wednesdays for consistency. The design project was based on separation processes not covered in class and included a graded group presentation at the end of the semester. The solutions to all assignments were posted online after the due date.

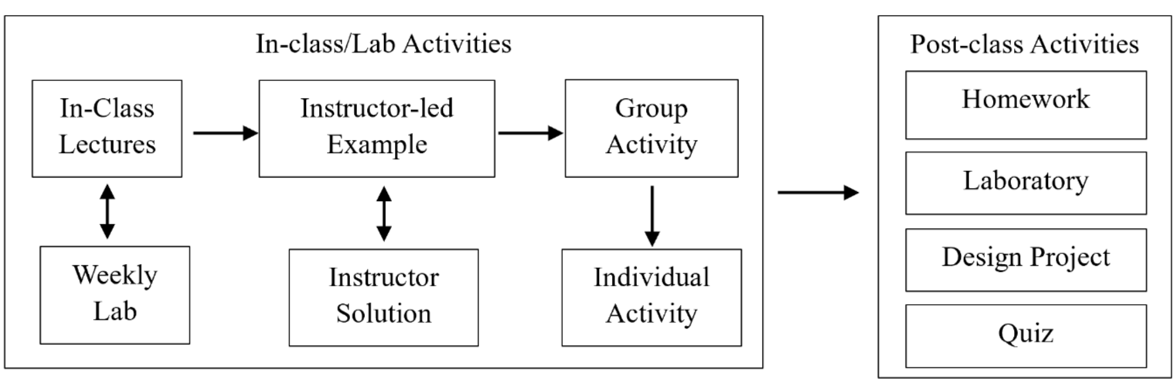

Figure 1. Mass Transfer course design: traditional classroom.

Dr. RD taught the reactor design course with a flipped classroom, as detailed in Figure 2. The course was split into seven two-week long content ‘blocks’ that covered two ‘topic areas’ of course material. The course met twice a week for 75 minutes (150 minutes total per week), traditional lecture material (theory, definitions, and solution strategies) was disseminated as recorded videos posted to the course website using the university’s LMS. Lecture videos ranged from 18 to 51 minutes with an average length of 29 minutes. The students were tasked with watching one lecture video each week before class time on Monday. Each RD class period began with a brief re-cap of the content of the lecture video followed by a collection of instructor-led example problems covering the corresponding material. The instructor solved these example problems using a tablet and stylus which was screencast onto the main screen of the classroom. All example problem sessions were recorded by and automatically posted to the course website using the university’s LMS, where students were able to access and review the example problems, as needed. During class time, students were also asked to respond to 1-2, multiple-choice In-Class Discussion Question. These questions were usually pulled from the AIChE Education Division’s Concept Warehouse [3]. Students were encouraged to discuss the answers to these questions in informal groups. Between the first and second example session for each topic area, the students had to submit a ‘Clarifying Question’ (CQ) online. CQ’s are free-form, short-answer response to the question, “What concepts or equations related to [the current topic area] do you feel the least confident about, in terms of your own mastery?” These requests for clarification were reviewed by the instructor prior to the next example session, and responses to the questions were given at the start of the next class period. These CQ’s are meant to provide the students with an opportunity to ask questions outside of the time-constrained and peer-pressure-filled environment of the classroom. Responses were graded purely on completion, and answers along the lines of “I do not have any questions at this time,” were given full credit. After classes, the students worked on homework assignments, which were graded on an individual basis. Homework assignments were due every week. In-class quizzes were given every other week during the second half of the second class period of each week. The overall structure of the course was built using 2-week-long ‘blocks’ consisting of 2 recorded lecture videos, 4 instructor-led example sessions, 4 In-Class Discussion Questions, 2 individually-graded Clarifying Questions, and 2 individually-graded homework assignments culminating in an individually-graded, in-class quiz, as illustrated in Figure 2. There were seven of these two-week blocks over the course of the semester. Beyond these individual student-based blocks, the students worked on a two-part group design project during the second half of the semester. The first part of the project related to fitting real world data to a simplified mathematical model, and the second part of the project required them to use the predictions of that model to design and maximize the profitability of a chemical reactor. Each group was responsible for submitting two memos along with a final oral presentation summarizing the results of their group’s project. Finally, at the end of the semester each student was given a comprehensive final exam, which was graded on an individual basis.

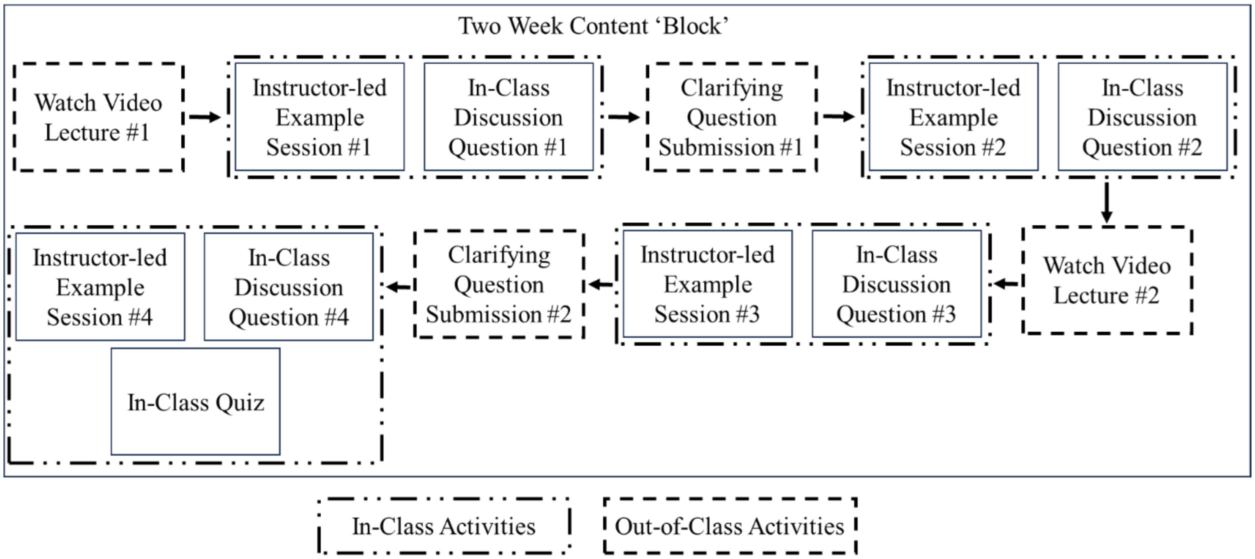

Figure 2. Reactor Design course framework diagram: flipped classroom with two-week content 'blocks'.

Dr. PC taught the process control course as a flipped course, as described in Figure 3. This course met twice a week for 75 minutes with two team labs scheduled at the students' convenience. The typical lecture material for theory, definitions, and equations was recorded in videos, with one 10 – 15-minute-long video per class meeting. The videos were made with PowerPoint slides in Panopto with an image of the professor presenting and captions edited by a workstudy student who had already passed process control. The students took a 2 – 4 question quiz over each video. The quizzes were graded such that the students received 60-70% of the points just for taking the quiz. Dr. PC went over the answers to the video quiz questions at the very beginning of each lecture period. During class, the students tried an example problem, with the instructor revealing the answer in stages as the students worked with their neighbors. After the example problem, the students worked a problem to submit for individual class activity credit. They were allowed to discuss the problem with their classmates. The class activities were graded such that the students received 60-70% of the credit just for working the problem. Solutions to example problems, class activities, and individual homework were posted in the LMS. The students also had a group design project, two group laboratories with memos, three individual exams, and a comprehensive, individual final exam.

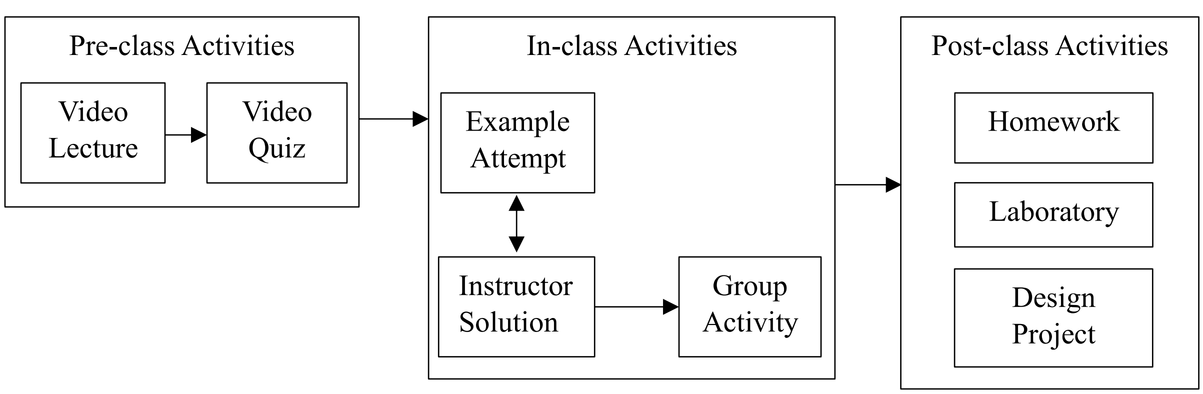

Figure 3. Process control course design: flipped classroom.

The technology available in the three classrooms was similar: computers connected to projectors and document cameras. The classroom for PC had movable tables with movable chairs, but the classroom for RD had flip-top desks while that for MT had a sloped floor with fixed tables but movable chairs.

Over the summer following the completion of the three courses described above, the faculty created a Google form to survey the students who had taken all three junior courses during the spring of 2024. There were two students in process control who were not in the other two courses – a graduate student and a senior repeating the course - and they were excluded from the survey. Dr. MT was teaching this cohort again in a required fall course and recruited the students to take the survey by following a survey link posted in the LMS. Reminders were sent through the LMS email system. The Office of Compliance determined that this survey was not human subjects research. We were focused on a teaching assessment instead of a generalizable study, so the project did not meet the definition of research.

The complete survey is provided in Appendix A. Questions 1 – 14 were those in the Student Response to Instructional Practices Survey (StRIP) [4]. The StRIP Survey asks how often the students did a variety of traditional (listen to an instructor lecture) and non-traditional (discuss concepts with classmates during class) activities on a scale of never to very often (more than once/week). The faculty also took this identical survey responding with how they *desired* students to perceive the implemented instructional practices for their respective course. These results were then used to see if the students' views of how the courses were taught match the faculty views of how the same courses were taught. Other studies have looked only at the students' views of how the courses were taught, so our contribution is a comparison of the faculty versus student viewpoints.

Questions 15 – 27 of the survey were based on the "Student Perceptions of Active Learning Formats" questions of Turner and Webster [2]. We elaborated on some of the questions (such as #17 regarding online quizzes) to attempt to communicate clearly to the students what we were asking about. Some of Turner and Webster's questions were eliminated because they did not apply to our courses (such as their #5 and #6). In Questions 22 and 23, we added instructor-led and small group to distinguish the two types of practice exercises in our courses. Question 27 was a variation of Turner and Webster's questions about other course materials that were changed to better fit the instructional practices described previously.

Questions 28 – 30 were based on the assessment questions for the double-pipe heat exchanger desktop learning module [5]. These questions asked if particular instructional practices helped the students gain a deep understanding of the material and if the way the course was taught kept them engaged with the material during class time. For Question 31, we wanted to see if the students still felt comfortable asking questions during class. Questions 32 – 36 were about gender identity, course difficulty, course grade, and an overall question of the best way to teach each course.

Limitations and Advantage

Our course descriptions show that we have many confounding variables in comparing our courses. These include the teaching experience, number of times the faculty member had taught the specific course, length of class periods, the TA in Mass Transfer lab, course material, course difficulty, and grade distribution. Classroom technology was the same across all courses. Perceived difficulty and grade distributions are discussed in the Results and Discussion section.

This study involves only one course size, course level, and student population. We cannot generalize from this study to other course sizes, levels, or student populations.

Our advantage is that we have exactly the same cohort of students in the three courses. We are not concerned as other studies must be about whether the algorithm to sort students into different courses provided cohorts who matched in prerequisite skills, abilities, and personal characteristics. The students are the same students for each course and the responses are thus directly comparable.

Results and Discussion

We have 18 responses for the 17 students in the junior course cohort, so it appears that one student took the survey twice. Responses were anonymous, so we cannot eliminate one (or more) as a duplicate response. All 18 students responded to all questions with two exceptions. One student did not respond to the question about the grades received, and three students did not respond to the open-ended question about the best way to teach each course.

Questions 1 – 14 asked the students how often they did a variety of activities. The three faculty answered the same questions for their courses. In the graphs that follow, the responses were coded (Never = 1, Very Often = 5), and the student responses were averaged. Some questions had a large difference between faculty and students in more than one course, and those are marked with an * and discussed after the graphs. The results for Mass Transfer are given in Figure 4. The Mass Transfer students and faculty agreed fairly well about how the course was taught, as the sum of the differences between the faculty response and the student average for the 14 questions was 18. The five questions with larger differences (marked with *) are discussed after the results for all three courses are presented.

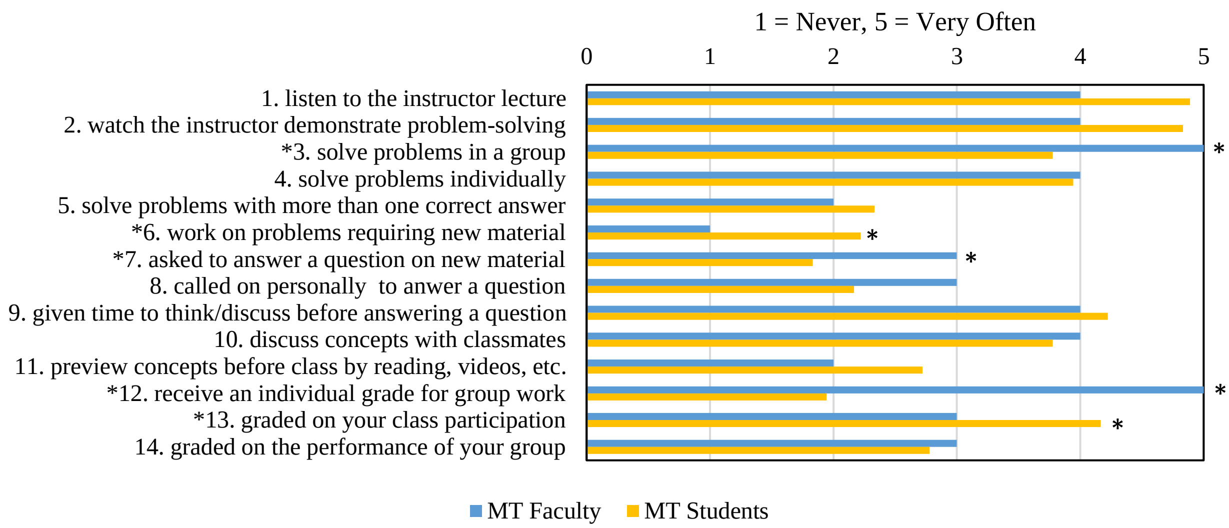

Figure 4. StRIP responses for faculty and student average in Mass Transfer: How often did you…with 1 = Never and 5 = Very Often (almost every class). An * marks disagreement between faculty and students.

Similar responses from faculty and students to the StRIP survey for Reactor Design are given in Figure 5, where the sum of the differences for the 14 questions was larger at 29 than the 18 for Mass Transfer. Most of the large differences (marked with *) are discussed after the Process Control graph. Two large differences unique to Reactor Design were in questions 10 and 11. The students responded that they discussed concepts with their classmates in class much more often than Dr. RD said they did, but Dr. RD responded that the students previewed concepts before class by reading or watching videos much more often than the students said they did. Perhaps the students did not do the assigned pre-class activities.

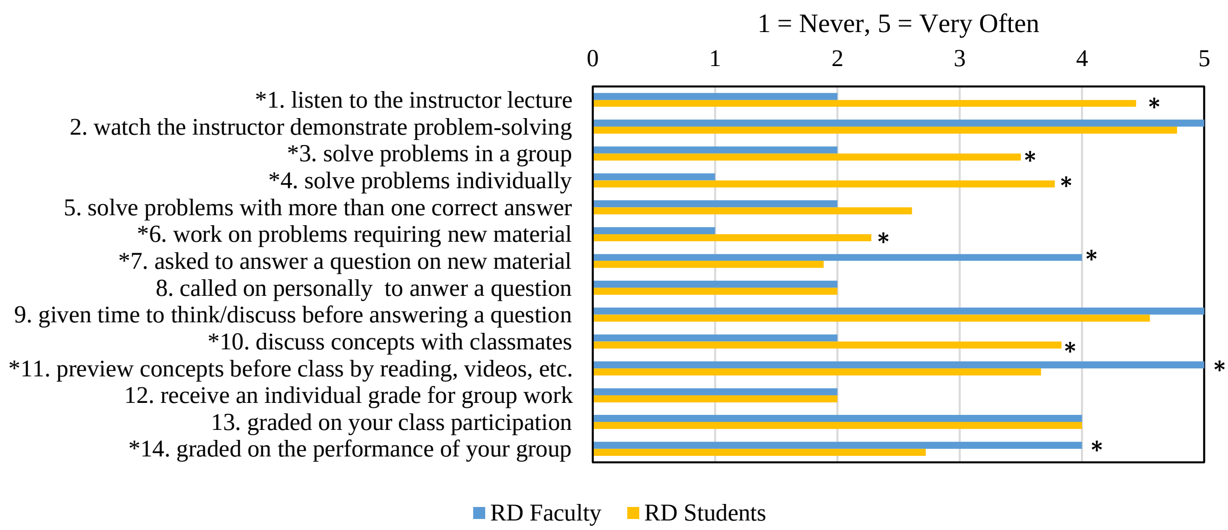

Figure 5. StRIP responses for faculty and student average in Reactor Design: How often did you… with 1 = Never and 5 = Very Often (almost every class). An * marks differences between faculty and students.

The sum of the differences for Process Control (Figure 6) at 31 for the 14 questions was similar to that of Reactor Design. All large differences between students and faculty are discussed as common differences with Mass Transfer and Reactor Design next.

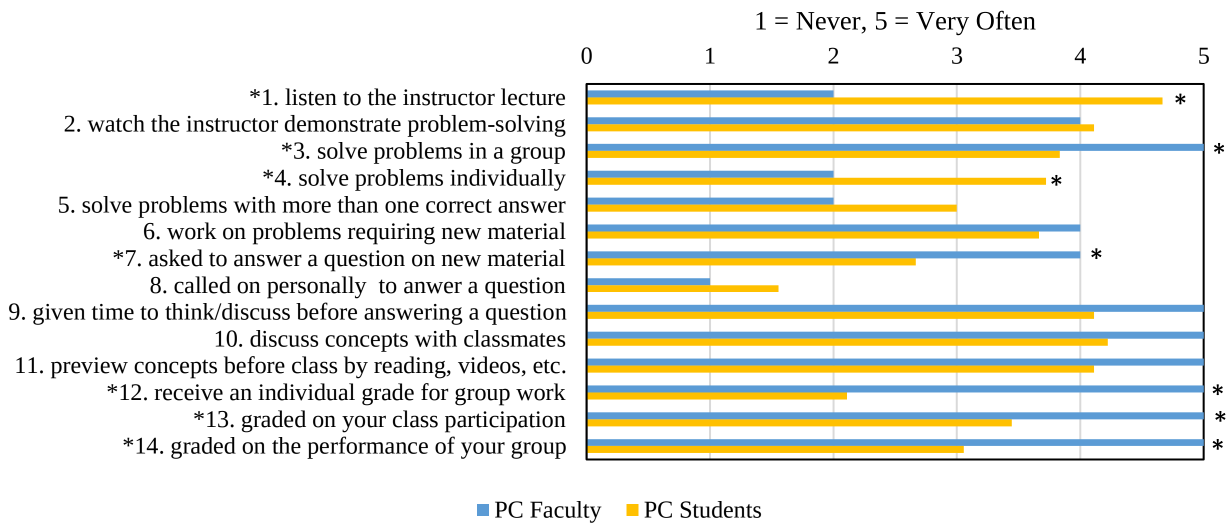

Figure 6. StRIP responses for faculty and student average for Process Control: How often did you…with 1 = Never and 5 = Very Often (almost every class). An * marks differences between faculty and students.

Two questions had large differences between faculty and students for all three courses: 3. solving problems in a group in class and 7. asked to answer a question in class on material not covered previously. Although there were large differences regarding solving problems in class (#3), the direction of disagreement depended on the course. Faculty in Mass Transfer and Process Control thought that the students solved problems in class in a group much more often than the students themselves thought they did, but it was the other way around in Reactor Design. The questions in Reactor Design were multiple-choice questions, but the questions in the other courses were generally show-your-work questions, which may have influenced the students' perceptions. The faculty in all three courses thought that the students had to answer a question during class on material not previously covered in class (#7) more often than the students did, by one to two categories. A possible explanation is that the students may have a more expansive view of "in class" than the faculty did, in that the faculty considered material presented in readings or videos to not be "in class", but the students considered it to be part of the course and therefore "in class".

Large differences in three questions were common to Reactor Design and Process Control. The students thought that they listened to lecture more frequently (#1) than the faculty thought they lectured, by one to two categories. This difference is likely due to differences in the definition of 'lecturing'; perhaps students think that anytime the professor is talking is lecturing, whereas faculty view time spent explaining a solution to an example problem as not lecturing. The students also thought they solved problems individually in class (#4) more often than the faculty thought that they did. Similarly, the faculty thought that the students were graded on group performance much more often than the students thought they were (#14). The students were allowed to discuss work together before submitting individual papers. The faculty viewed this as groupwork, but the students seem to view this as individual work. The discrepancy between the faculty and student perceptions of what was individual work and what was group work indicates that instructors should likely be very explicit about demarcating between the two, since perceptions seem to differ substantially, regardless of the specific course or instructional style.

Mass Transfer and Reactor Design had one question in common with large differences between students and faculty: 6. work on problems during class that required seeking out new information not previously covered in class. Students responded that this happened more often than faculty did, perhaps forgetting that something had been covered in class previously or that the faculty expected them to know from previous classes.

Mass Transfer and Process Control had two questions in common with large differences between faculty and students. The faculty for both courses replied that the students received an individual grade for group work (#12) more often that the students said they did. This is related to the students discussing the problems but submitting an individual paper, which the faculty view as individual grade for group work but the students may not. Regarding being graded on class participation (#13), Dr. PC's response was more often than the students' response, but the situation was reverse for Mass Transfer. In Process Control, the students receive 70% on the activity for participating in it, and the remaining 30% is based on performance. The students and faculty have different takes on this policy.

Overall, there are disconnects between the students and faculty about work done in preparation for class and remembering material already covered in class, with faculty expectations higher than student performance. There are differences in understanding grading of group work, with faculty focused on group contributions and students focused on individual contributions. Also, faculty thought that they lectured less often than the students thought they did.

The next set of questions asked if the students thought particular instructional practices aided their understanding, if they recommended the instructional practice, if they preferred the instructional practice, etc. These responses were coded with strongly disagree = 1 and strongly agree = 5 and averaged over the responses that were not "Not Applicable" to get an average score for each course. The averaged responses are presented in Table 1. The questions have been reordered from the order in which they were presented to the students to group them into effectiveness, preference, recommendations, and two miscellaneous questions. The original question order is given in the first column of the table, starting with 15 as the first 14 questions were the StRIP questions.

The questions about aiding the student's understanding of the material will be considered first. Half of the responses are at or above 4.0, indicating that the students on average "Agree" that the particular instructional practice aided their understanding of the material. The effectiveness of any given instructional practice generally declines as one moves from Mass Transfer to Reactor

Table 1. Average score for each course for questions 15 - 30 about effectiveness of, preference for, recommendation for various instructional practices, and miscellaneous. 1 = Strongly Disagree and 5 = Strongly Agree

#	Question	MT	RD	PC
15	A.) The video lectures aided in my understanding of the course material	3.1	3.7	3.5
17	C.) The online quizzes aided my understanding of the course material.	3.6	3.4	3.3
18	D.) The in-class discussion questions aided my understanding of the course material.	4.5	4.1	3.6
19	G.) Talking about the in-class discussion questions with other students helped me to better understand the course material.	4.5	4.1	4.4
22	J.) The instructor-led practice exercises aided my understanding of the course material.	4.3	4.2	3.5
23	K.) The small group practice exercises aided my understanding of the course material.	4.4	4.2	4.1
27	L.) Having the notes and other materials available in advance of class helped me to better use the class-time.	3.9	3.9	3.9
28	Q.) The way this course was taught helped me gain a deep understanding of the material.	4.1	4.0	3.2
16	B.) I preferred the video lectures as compared to live lectures.	1.7	1.9	2.0
20	H.) I preferred the use of the in-class discussion questions as a supplement to a lecture when compared to a lecture without formal discussion questions.	4.0	3.9	3.8
24	N.) I preferred the use of the practice exercises as compared to a traditional lecture.	3.7	3.6	3.5
21	I.) I would recommend that this course continue to use the in-class discussion questions as an instructional tool.	4.2	4.2	3.7
25	O.) I would recommend that this course use instructor-led practice exercises as an instructional tool.	4.2	4.1	4.1
26	P.) I would recommend that this course use small group practice exercises as an instructional tool.	4.3	4.2	4.3
29	S.) The way this course was taught kept me engaged with the material during class time.	4.1	3.8	3.2
30	T.) I was able to ask questions during class whenever needed.	4.6	4.5	4.4

Design to Process Control, which will be discussed more later. Video lectures and video quizzes were rated the lowest in aiding understanding, with the students on average "Uncertain" that the instructional practice aided their understanding. Note that Mass Transfer did not have any video lectures, yet the students rated their effectiveness regardless. Dr. PC used the video quizzes to verify that the students had watched the videos and did not expect them to help student understanding significantly. Having the notes or other materials available before class was also rated with a lower effectiveness than other instructional practices. In Process Control, no notes or materials were provided except the video lecture, which the students were supposed to take notes on for taking the video quiz. The students frequently pulled up the Process Control videos to help them work the exercises during class.

The next section of Table 1 is questions about student preferences for various instructional practices. The students were less agreeable in this section than they were about the effectiveness of the instructional practices. Although they were split between “Agree” and “Strongly Agree” for Mass Transfer on the effectiveness of the discussion questions, they merely “Agreed” with preferring them. Trends with Reactor Design and Process Control were the same. Similarly, they “Agreed” about the effectiveness of the practice exercises but were more uncertain about preferring them. In contrast, they did not prefer the use of video lectures to live lectures, which matches their uncertainty about their effectiveness compared with other instructional practices.

The third section of Table 1 is about recommendations to use the various instructional practices. Except for discussion questions in Process Control, the students recommend the discussion questions and practice exercises in all courses. It is interesting that they were more likely to recommend an instructional practice than to prefer it to traditional practices. We inadvertently left out a question about recommendations for video lectures, as did Turner and Webster.

The results here are similar to those found by Turner and Webster [2]. Both sets of students indicated dissatisfaction with the effectiveness of the video lectures and were uncertain about the online quizzes. Both cohorts thought discussion questions and small group problems were effective, which agrees with the findings that students valued non-lecture activities during class [6]. Our students were more likely than those of Turner and Webster to prefer in-class discussion questions to traditional lecture, but both groups were neutral about the small-group practice exercises. Similar to [1], our students preferred live lectures rather than videos and problem solving rather than lecture.

The fourth section of Table 1 gives the responses for engagement and the ability to ask questions. The students “Agreed” that the way Mass Transfer was taught kept them engaged with the material, but agreement dropped to “Uncertain” for Process Control. This trend matches common responses about effectiveness, preference, and recommendation for the instructional practices across the courses. The students “Agreed” to “Strongly Agreed” across all classes that they could ask questions during class whenever needed.

This next section attempted to see whether the results in Table 1 were somehow related to the perceived difficulty of the courses, the grades the students received, or how they felt about the course [7]. The students perceived Mass Transfer to be the easiest course and Process Control to be the most difficult course, as seen in Figure 7. This trend correlates well with the self-reported final grades in the courses (Figure 8), as Mass Transfer grades were the highest and Process Control grades were the lowest. The self-reported grades are fairly accurate, with three grades over-reported in Mass Transfer, two grades over-reported in Reactor Design and one over-report and one under-report in Process Control. In particular, no one failed Process Control. The easier the students found the course, the more likely they were to over-state their grades in the course. Although the trends between easiness and grade match, none of the courses was an easy A. It is surprising that 60% of the students found Mass Transfer difficult, yet 82% thought they received an A or a B when only 70% actually did. Even in Process Control, which 60% of the students found very difficult, 60% received an A or a B. Dr. PC has the reputation of being the most difficult grader in the department, and this dataset reinforces that assessment.

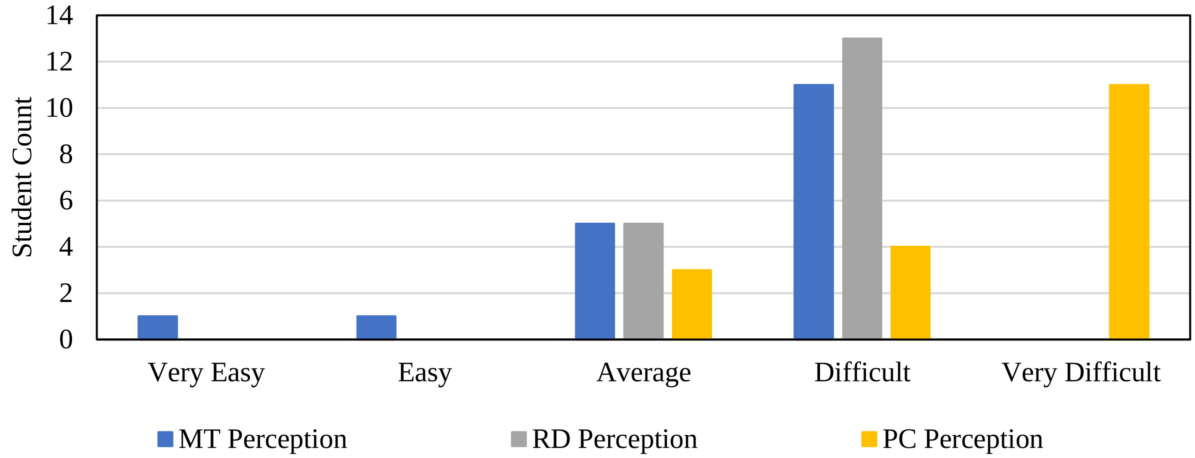

Figure 7. Student survey results regarding perceived course difficulty of spring junior courses.

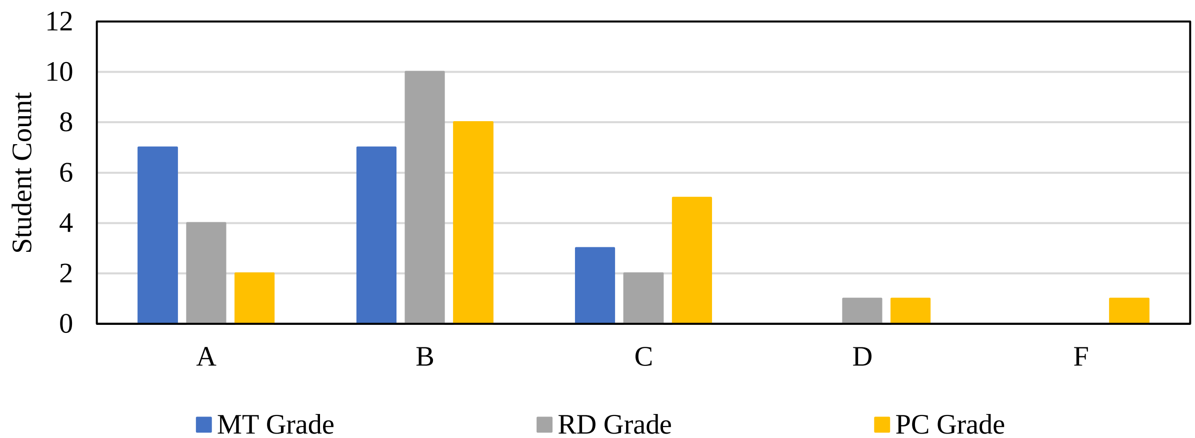

Figure 8. Self-reported final grades in the spring junior courses.

In the discussion about Table 1 above, it was mentioned that the effectiveness of any given instructional practice declined as one moves from Mass Transfer to Reactor Design to Process Control. That may be because the grades declined in that same pattern – the faculty were telling students through their grading that the students understood the material better in Mass Transfer than in Reactor Design, which in turn had more understanding than Process Control. Student understanding may have been equal in the three courses, yet the faculty assigned different grades to those same levels of understanding, which then may have affected the students' perceptions of effectiveness of particular instructional practices. Other studies have also shown that student assessment of teaching scores correlate with grades more than performance in subsequent courses (a measure of effectiveness) [8] or that they negatively correlate with effectiveness [9]. Student assessments of teaching are different from the survey here, but we do expect similarities between them.

Figure 9 is another way of looking at data from Figure 7 and Figure 8. Here, we present the averaged self-reported course grade and averaged perceived difficulty for the three courses and the individual responses for each course. The averaged course grade decreases as the averaged perceived difficulty increases, as discussed earlier. For the individual courses, the size of the dot in the individual courses represents the number of students with that particular combination of responses. In these subsets of data, the students agreed about the course difficulty broadly, but the correlation with their grade was much weaker than that observed in the intra-course results.

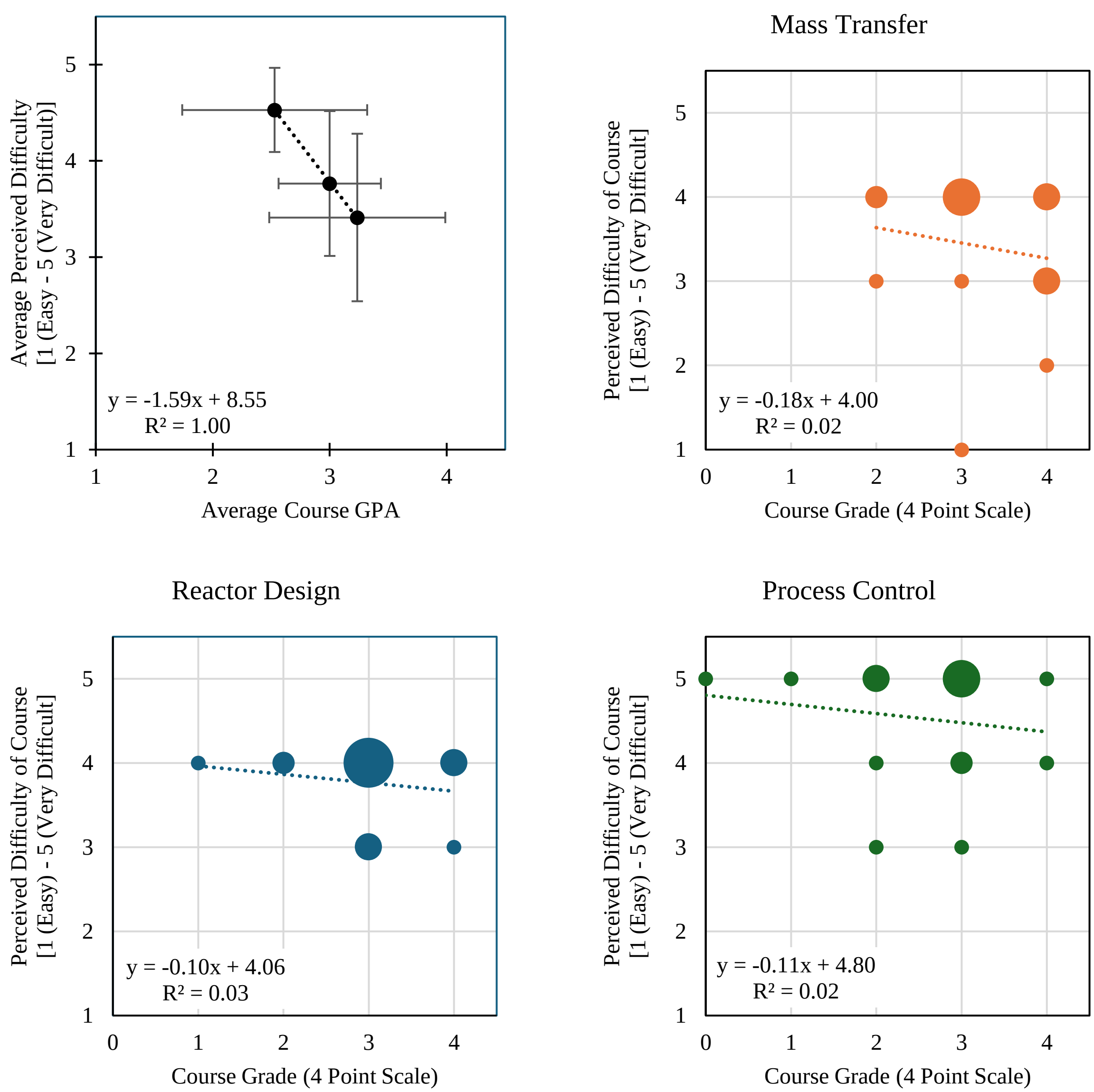

Figure 9. Averaged perceived course difficulty versus course GPA based on self-reported grades for all three courses (upper left) and the individual correlations within each of the three courses can be found in the remaining three graphs. On the course-specific graphs, the radius of the circle is proportional to the number of students that replied with each combination of difficulty and self-reported grade.

The students were given the opportunity to provide short answer responses regarding the best overall teaching method for each course, and fifteen out of the eighteen surveyed students provided responses. Most of the students preferred the same method across all three courses, which is interesting considering the differences in course material. Two simply said that the way

Reactor Design was taught was the best, and three said the same thing for Mass Transfer. Four students mentioned in-class example/practice problems or small group work as the best method. Three students wanted live lectures added to the example/practice problems. Note that Figure 4 to Figure 6 show that the students said they already listened to the faculty member lecture either "Often" or "Very often", so there is a disconnect between the response to this question and the responses to the StRIP survey. Only three students gave best methods specific to the three courses, which is interesting considering the topics are quite different. One said that Mass Transfer was best, Reactor Design needed online quizzes, and Process Control needed live lecture. Another mentioned lecture and slide show notes for Mass Transfer, examples in Reactor Design, and in-class activities for Process Control. The third student gave student-worked examples as best for Mass Transfer and Reactor Design but instructor-led examples for Process Control. Most of these responses say that the best way to teach the junior courses is to include in-class activities.

Future Work

Spring 2025 brings us another semester with these same three courses. Drs. MT and PC are teaching the same courses. Dr. RD2 has stepped into Reactor Design but is teaching it much the same way as Dr. RD. We plan to administer the same survey again to the junior cohort of Spring 2025. With this additional confounding factor, data may not be easily comparable except for Drs. MT and PC, but we are still interested in the results. We do not plan to have all three faculty rotate through to teach all three courses within a semester due to practical reasons.

We will add two questions to the survey. Similar to Questions 21, 25, and 26, we will add a question to ask if the students recommend using the video lectures. We will also ask the students to rate the video quality, as that is known to affect effectiveness. Based on the students' responses and in an effort to generate a less contradictory and more realistic response, we may also add a question to probe the desired balance between live lecture and in-class practice exercises.

Conclusions

We compared teaching methods, as seen by both students and faculty, in three required junior spring courses using the same student cohort for consistency of sample set. The faculty for these courses used different combinations of in-class lecture, video lecture, and in-class problem solving by the faculty and by the students. There are disconnects between the students and faculty about work done in preparation for class and remembering material already covered in class, with faculty expectations higher than student performance. There are differences in understanding grading of group work, with faculty focused on group contributions and students focused on individual contributions. Faculty thought that they lectured less often than the students thought they did.

The second part of the survey looked at the effectiveness of and student preference for different teaching methods. Although the students thought that the video lectures were effective, they preferred live lectures when compared to video lectures. A majority agreed that the following methods were effective: 1) on-line quizzes, 2) in-class discussion questions, 3) instructor-led practice exercises, and 4) small-group practice exercises. About two-thirds of respondents also expressed a preference for in-class practice exercises rather than a traditional lecture. The faculty view these as contradictory opinions. With a finite amount of class time available, the faculty can provide additional lectures or additional example problems, but not both at the same time. Future surveys may include an additional question to help discern whether these answers are truly contradictory (students desire more of both) or if their preference is a different balance between the two options. Positive answers for effectiveness were more common for Mass Transfer than Reactor Design, which in turn were more positive than for process control. These responses align with Mass Transfer being seen by the students as the easiest course and Process Control as the most difficult course.

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Appendix A: Survey

Course Methodology Survey

In this first section, you will be asked to describe the three courses in terms of their teaching methods.

1. 1.) How often did you... Listen to the instructor lecture during class?

Mark only one oval per row.

	Never	Seldom (1-5 times per semester)	Sometimes (5-10 times per semester)	Often (Once per week)	Very often (almost every class)
Mass Transfer	◯	◯	◯	◯	◯
Reactor Design	◯	◯	◯	◯	◯
Process Controls	◯	◯	◯	◯	◯

Similar grids were used for questions 2 – 14.

2. 2 .) How often did you... Watch the instructor demonstrate how to solve problems during class.
3. 3 .) How often did you... Solve problems in a group during class.
4. 4 .) How often did you... Solve problems individually during class.
5. 5 .) How often did you... Solve problems during class that have more than one correct answer.
6. 6 .) How often did you... Work on problems during class that required you to seek out new information not previously covered in class.
7. 7 .) How often were you... Asked to answer a question during class on material not previously covered in class.
8. 8 .) How often were you... Called on personally by the instructor to answer a question during class.
9. 9 .) How often were you... Given time to think or discuss before answering a question posed by the instructor during class.
10. 10 .) How often did you... Discuss concepts with classmates during class.
11. 11 .) How often did you... Preview concepts before class by reading, watching videos, etc.
12. 12 .) How often did you... Receive an individual grade for group work.

13. 13 .) How often were you... Graded on your class participation.
14. 14 .) How often were you... Graded based on the performance of your group.

Now you will be asked to provide information about how the different teaching methodologies affected your learning.

Instructional Practice Evaluation

15. A.) The video lectures aided in my understanding of the course material

Mark only one oval per row.

	Not Applicable	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Mass Transfer	⬭	⬭	⬭	⬭	⬭	⬭
Reactor Design	⬭	⬭	⬭	⬭	⬭	⬭
Process Controls	⬭	⬭	⬭	⬭	⬭	⬭

Similar grids were used for questions 16 – 31.

16. B.) I preferred the video lectures as compared to live lectures.

In the following question, the term "Online Quizzes" refers to: In Mass Transfer, online quizzes were basic questions on course material covered in the previous class. In Reactor Design, the online quizzes were the Clarifying Questions submitted prior to class. In Process Control, the online quizzes were the quizzes over the video lectures.

17. C.) The online quizzes aided my understanding of the course material.

In the following questions, the term "In-Class Discussion Questions" refers to: In Reactor Design, the in-class discussion questions were the in-Class questions/polls submitted using the PollEverywhere application. In Process Control and Mass Transfer, the in-class discussion questions were the problems that you discussed before turning them in as your Class Activity.

18. D.) The in-class discussion questions aided my understanding of the course material.
19. G.) Talking about the in-class discussion questions with other students helped me to better understand the course material.
20. H.) I preferred the use of the in-class discussion questions as a supplement to a lecture when compared to a lecture without formal discussion questions.
21. I.) I would recommend that this course continue to use the in-class discussion questions as an instructional tool.

In the following question(s), the terms "Instructor-led" and "Group" are used to distinguish between activities that were done by the instructor at the front of the classroom vs as a group of students. In Mass transfer, Reactor Design and Process Control, all example problems, solved in class, can be treated as "instructor-led." The term "practice exercises" refers to different activities in different courses: In Mass Transfer, exercises were given to students who were allowed to discuss with others while solving the ungraded problems. In Reactor Design, Exercises refer to the example problems solved during class time that required calculation. In Process Control, Exercises were the problems that Dr. PC worked for the class.

22. J.) The instructor-led practice exercises aided my understanding of the course material.
23. K.) The small group practice exercises aided my understanding of the course material.
24. N.) I preferred the use of the practice exercises as compared to a traditional lecture.
25. O.) I would recommend that this course use instructor-led practice exercises as an instructional tool.
26. P.) I would recommend that this course use small group practice exercises as an instructional tool.
27. L.) Having the notes and other materials available in advance of class helped me to better use the class-time.
28. Q.) The way this course was taught helped me gain a deep understanding of the material.
29. R.) The out-of-class assignments and projects for this course helped me gain a deep understanding of the material.
30. S.) The way this course was taught kept me engaged with the material during class time.
31. T.) I was able to ask questions during class whenever needed.

Personal Information

32. What was your perceived difficulty for each course?
Mark only one oval per row.

	1 - Very Easy	2 - Easy	3 - Average	4 - Difficult	5 - Very Difficult
Mass Transfer					
Reactor Design					
Process Controls					

33. In your opinion, what was the best overall teaching method for each course? ___________
34. What is your gender identity?
Mark only one oval.

- Female
- Male
- Prefer Not to Answer
- Other: _____________

35. What was your final letter grade for each course?
Mark only one oval per row.

	A	B	C	D	F
Mass Transfer					
Reactor Design					
Process Controls					