Evaluating the Impact of Online Delivery of a Process Dynamics and Control Course

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Process Dynamics and Control is a required course in most Chemical Engineering programs. Students typically find the material challenging, and for some, the subject seems divorced from the remainder of the curriculum. In fact, some students claim that it feels as though they are learning another language. To address this and to improve learning, instructors have utilized a variety of pedagogical approaches [1-36]. A recent survey found that a large percentage of Process Dynamics and Control instructors use simulations for instruction and/or assessment [4]. The hypothesis underlying this study is that moving the course to an online delivery method enhances student learning in Process Dynamics and Control. These increases would follow from (a) asynchronous learning and the ability to re-watch lecture material and (b) the ability to conduct simulations alongside lecture effectively. Two cohorts of students are contrasted: a group of students taking the course entirely in-person in a traditional classroom-based course and a group of students taking the course with online delivery but in-person exams. Students in both groups were taught by the same professor and completed identical final exams. This paper examines student perceptions and compares and contrasts the performance of these two cohorts in order to answer whether online delivery of the course is advantageous or detrimental to students.

Cohort #1 – Traditional Delivery

The first cohort includes twenty-two students enrolled in Rowan University's required senior-level Process Dynamics and Control course in Fall 2014. The class met for three 75-minute class periods each week during a 15-week semester. One of the class periods each week was reserved for in-class problem solving with simulations [37] and several class periods were used for exams, leaving approximately 25 class periods (31.25 hours) for traditional instruction. In this case, "traditional instruction" includes lectures, active learning activities, simulation-driven illustrations, and problem solving, not solely podium-style lectures. The classifier "traditional" in this sense is intended to differentiate the classroom-based cohort from the online-based cohort. Through the course management system (Blackboard®), students had access to all SIMULINK® files used for classroom illustrations, as well as electronic versions of all handouts. The students in this cohort completed weekly homework assignments, weekly simulation-based learning assignments, three midterm exams, and a final exam. The second midterm exam was take-home and the remaining exams occurred in person.

Cohort #2 – Online Delivery

The second cohort includes the forty-three students who completed the Fall 2015 offering of Rowan University's Process Dynamics and Control course. In this case, the course was entirely online, except for in-person meetings for exams. A total of 17.6 hours of voiceover lectures were available to the students and assigned for viewing over the course of a 15-week semester. The voiceover lectures were derived directly from the Fall 2014 lecture notes, and included SIMULINK®-based simulations in exactly the same manner as the SIMULINK® examples shown in class. For the majority of the lectures, sparse PowerPoint slides were augmented with live-written notes and narration. Students had access to the sparse PowerPoint® slides and any

SIMULINK® files used for simulations via the course management system (Canvas®). They were encouraged explicitly to conduct and explore the SIMULINK® simulations while watching the lecture videos. Throughout the semester, the students completed weekly homework assignments, weekly simulation-based learning assignments, two midterms, a project, and a final exam. The first midterm, project presentations, and the final exam occurred in-person.

Comparing and Contrasting the Cohorts

Both cohorts had similar course preparation and ultimately achieved statistically indistinguishable final GPA's at graduation, both overall (3.37±0.12 in Cohort #1 and 3.36±0.10 in Cohort #2, where the error represents the 95% confidence interval, $p = 0.54$) and in Chemical Engineering courses (3.26±0.17 in Cohort #1 and 3.19±0.13 in Cohort #2, $p = 0.86$). This suggests that there is no intrinsic bias in student preparation, although it does not account for preparation in math or specific pre-requisite courses.

Every effort was made to make the online instruction mimic in-class delivery. The same instructor taught both cohorts from the same set of lecture notes, and students were required to use the same textbook [38]. Homework assignments were similar, simulation-based learning assignments were identical, and midterm exams were of approximately equivalent difficulty. The project assignment was intended to replace Cohort #1's third midterm, and the content of these assessments is not expected to influence preparedness for the final exam. Importantly, both cohorts completed identical final exams in equivalent testing conditions.

Final Exam Performance

The scores on the final exam are statistically indistinguishable, although the average in Cohort #2 was slightly lower (Figure 1). This suggests that students in both cohorts had similar mastery of the course material, and that online delivery neither enhanced nor diminished students' performance.

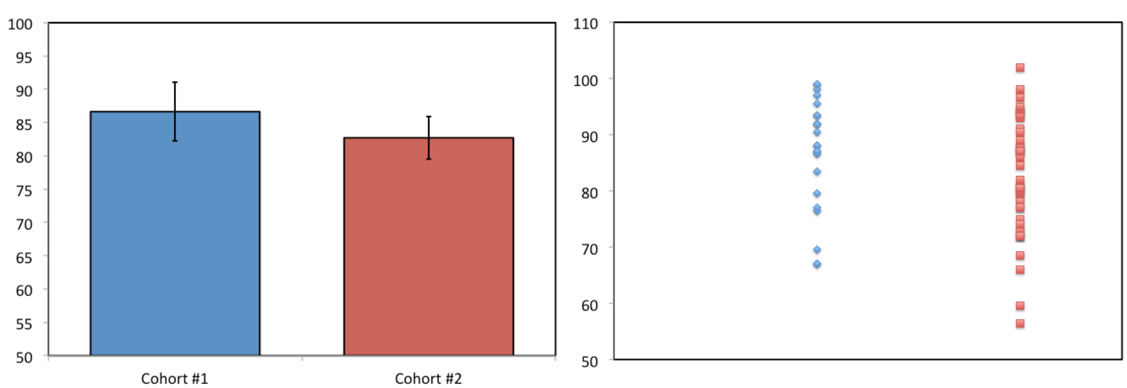

Figure 1: Final Exam Performance. At left, average and 95% CI. At right, scatter plot of exam scores. Cohort #1 is indicated in blue, Cohort #2 in red.

Online Delivery of Process Dynamics and Control

A central tenant of our hypothesis is that asynchronous learning and the ability to re-watch lecture material enhances learning in Process Dynamics and Control. The Canvas® course management system logs the number of videos watched and the total time watching videos for each user's account (Figure 2). Although this is an imperfect metric since students often watch videos together and this is logged only in one student's account, students who benefit from the ability to re-watch lecture material would presumably have a large number of video watches and/or a large cumulative duration of video watching. Figure 2 shows that contrary to our hypothesis, students who spend the most time watching videos do not perform better than students who watch the assigned videos only once (59 videos, 17.6 hours). It is, however, important to note that the number of videos watched probably only reflects video loads, and would not capture multiple watches of the same segment, so there could still be a hidden correlation, but this data does not support the hypothesis.

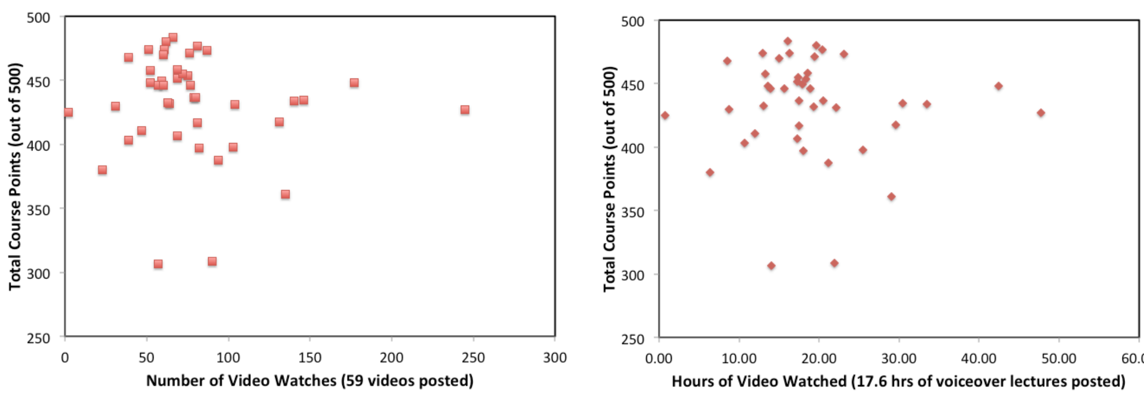

Figure 2: Student Engagement. At left, the number of unique video watches through each student's account is plotted with the total course points earned (of 500). At right, this is translated to hours of video watched compared to total course points.

However, students do recognize the value of asynchronous learning in an online course in Process Dynamics and Control. All students in Cohort #2 were surveyed in an anonymous survey administered through Canvas® prior to accessing any course material and again at the conclusion of the semester. In a pre-semester survey, when asked "What do you think is the biggest benefit to an online course?", the majority of students indicated that they thought the biggest benefit was the ability to watch the lectures at any time, at their own pace, or re-watch lectures. The word cloud in Figure 3 was generated at WordClouds.com to represent student responses to this question.

More importantly, most students felt this to be a benefit at the conclusion of the course as well. Figure 4 shows the responses to the question, "What is the biggest benefit to an online course (in general)?" and Figure 5 shows the responses to the question, "What is the biggest benefit to THIS online course?" The word "lectures" in both word clouds (Figures 4 and 5) was typically accompanied by variations of "re-watch", "pause", or "watch anytime", which indicates that even though this did not lead to increases in student performance on the final exam, asynchronous learning was valued by students in this course. Interestingly,

Figure 3: Word cloud of responses to a pre-semester survey question "What do you think is the biggest benefit to an online course?"

Figure 4: Word cloud of responses to the post-semester survey question "What is the biggest benefit to an online course (in general)?"

when asked specifically about asynchronous learning through a Likert-scale question on the post-semester survey ("Asynchronous learning (learning on my own schedule/at my own pace) was beneficial in this course"), there were mixed responses distributed among students who found asynchronous learning to be beneficial, a large number who were neutral, and many who did not find it beneficial. The latter group likely contains students who struggled with time management and did not dedicate enough time to the course.

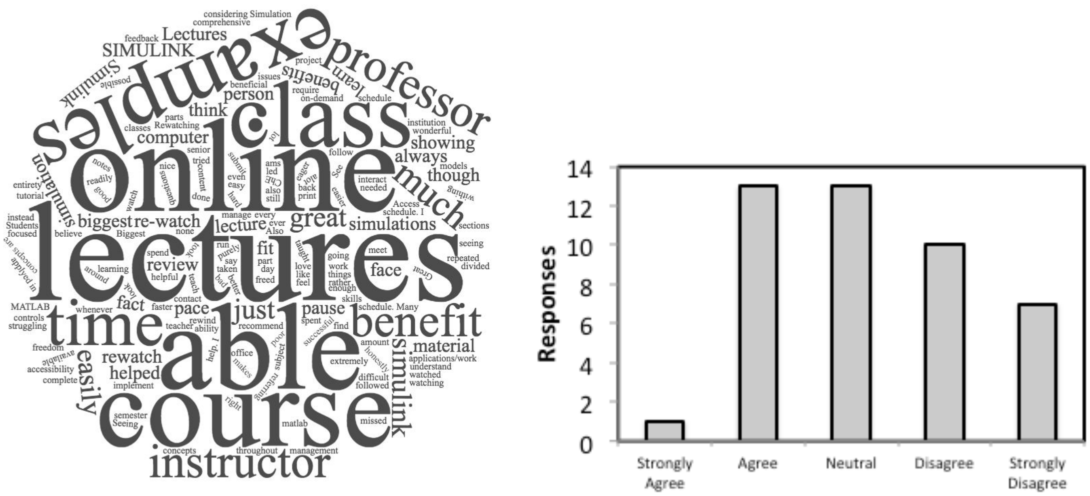

Figure 5: *At left*: Word cloud of responses to the post-semester survey question "What was the biggest benefit to THIS online course?" *At right*: Post-semester survey responses to "Asynchronous learning (learning on my own schedule/at my own pace) was beneficial in this course."

Student Perceptions and Feedback

The transition of the Process Dynamics and Control course at Rowan University to an online format was met with considerable resistance from the students. To acquire a better understanding of their concerns, the pre-semester survey included 4 Likert scale questions:

(1) I am excited about taking this course in an online format. (Figure 6, top left);
(2) The idea of asynchronous (on my own schedule/at my own pace) learning is appealing (Figure 6, top right);
(3) I enjoyed my previous online course(s) (Figure 6, bottom left); and
(4) I am nervous that I will not be able to interact with the instructor efficiently in an online learning environment (Figure 6, bottom right).

Although, in general, the students performed very well in the course (see Figures 1 and 2), the concept of online learning, particularly in a challenging core course, was unwelcome and discouraging to most. In the post-semester survey, we saw modest increases in satisfaction and enjoyment (Figure 7), but general discontent with the appropriateness of this course for online delivery (Figure 8). And while some students indicated that this course has changed their perception of online learning (Figure 9), 41 out of 43 respondents to the post-semester survey indicated that if given the choice, they would elect to take the in-person course rather than the online course.

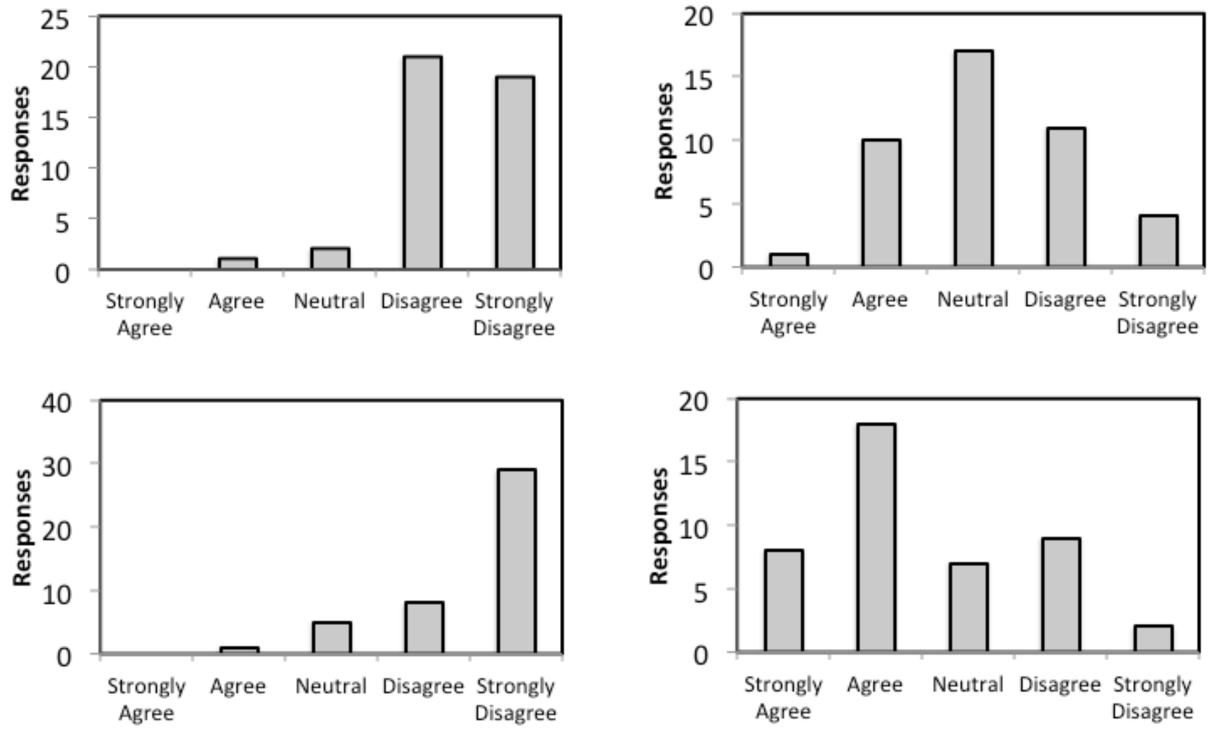

Figure 6: Pre-Semester Survey responses. Specific questions asked are included in the text. Top left: Question 1 - Excitement; Top Right: Question 2 - Asynchronous learning; Bottom Left: Question 3 - Previous online course enjoyment; Bottom Right: Question 4 - Instructor interaction

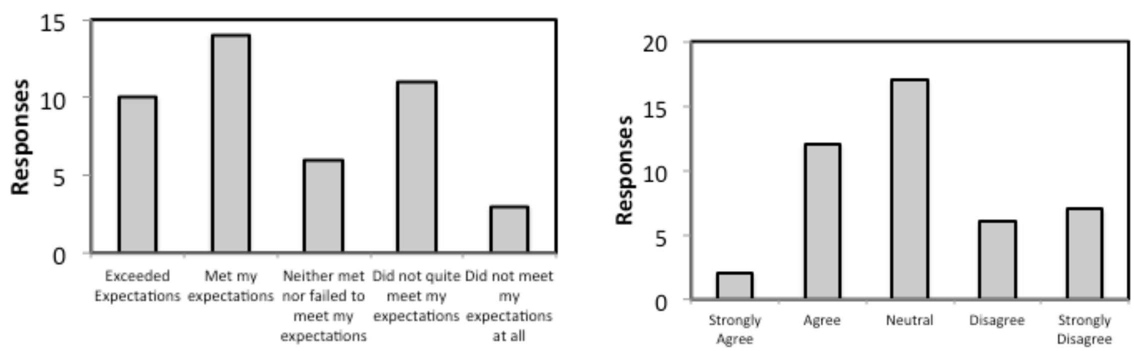

Figure 7: Post-semester survey responses show modest improvements in enthusiasm and satisfaction. At left, responses to "Now that I have completed the Process Dynamics and Control online course, I feel that taking the course online:" and at right "I enjoyed this online course."

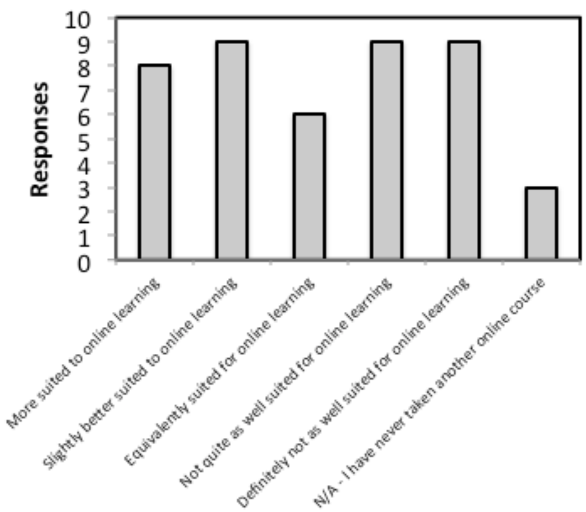

Figure 8: At left: Post-semester survey responses to: "Compared to other online courses that I have taken, I feel that this course was:"

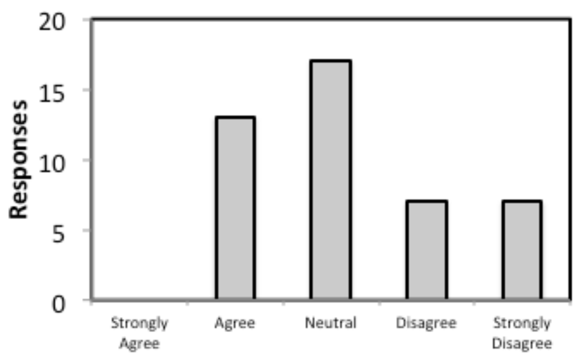

Figure 9: Post-semester survey responses to: "This course has changed my perception of online courses."

Conclusions and Discussion

The hypothesis underlying this study was that moving the Process Dynamics and Control course to an online delivery method would enhance student learning due to asynchronous learning and the ability to conduct and explore simulations alongside lecture effectively. Student performance on an identical final exam was statistically indistinguishable between students in Cohort #1, who took a "traditional delivery" course, and students in Cohort #2, who had online delivery of course material. While there were no observable *increases* in student learning, it is interesting to note that the exam scores did not *decrease* among students who were highly resistant to an online delivery method. This suggests that an online course in Process Dynamics and Control is neither detrimental nor beneficial to student learning, which is promising for institutions struggling to find a suitable instructor for this course.

Asynchronous learning and the ability to review lectures multiple times seems to be an attractive benefit to some students, but most students did not seem to take advantage of this extensively. There are several mentions in the survey comments of MATLAB/SIMULINK® interfacing nicely with the online lectures, and while there is no quantifiable data in this area, it was convenient from the instructor's perspective to guarantee that all lecture "attendees" had access to a computer with MATLAB/SIMULINK® (available through the Rowan University cloud for all students).

In summary, our comparison of two cohorts of Process Dynamics and Control students suggests that online delivery is neither beneficial nor detrimental to student learning (as measured by performance on a common final exam), suggesting that an online course in this area could be utilized effectively by programs struggling to find an instructor for the course, or by instructors seeking to implement a flipped classroom.

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