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A Multi-Year Case Study in Blended Design: Student Experiences in a Blended, Synchronous, Distance Controls Course

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A Multi-Year Case Study in Blended Design:

Student Experiences in a Blended, Synchronous, Distance Controls Course

Motivation for Blended Design

Instructors at higher education institutions select to implement a blended course design for a variety of reasons. The reasons may include a lack of classroom space, a desire to incorporate active learning strategies, or a need to provide access to instruction where otherwise not feasible. The motivation for adopting a blended course model in this study came out of the instructor's desire to discover a more efficient and learner-centered method for distance learning as well as a more active method for teaching linear control systems.

An elective course in Linear Control Systems is taught at a distance across two campuses in the electrical and computer engineering department at our Midwestern, research-intensive university. Traditionally, courses of this type are taught by an instructor who teaches at one site in person with another cohort at a distance the entire time, or the instructor alternates travel to each location (once per week in a course that meets two times a week). This model of distance learning inherently presents challenges to teaching and learning. First, there is an inefficiency of instructor time, when time is lost while traveling (the instructor devotes three hours to teach a one hour class at the distant location). A dedicated distance room is required twice per week, and such rooms are in heavy demand and often difficult to schedule at our university. Finally, there is a potential for loss of engagement in the far cohort who views class through a screen, most often in lecture format, with limited interaction with peers or the instructor. However, the most compelling reason to adopt a blended course model by the instructor in this study was the opportunity it would allow to implement research-based instructional practices in a distance learning setting. The instructor previously taught this course in a lecture format and believed that incorporating active learning and group collaboration would greatly improve students' ability to grasp and apply concepts in this first course in linear controls, a traditionally difficult, theoretical course, but with exciting applications. In addition to anticipated student learning gains from active and collaborative learning, the blended design would allow the instructor to use instructional time more strategically. This was an entirely new approach for distance engineering courses at our university.

This study thus combines two primary areas of literature, blended learning and synchronous distance instruction. The literature provides various interpretations and definitions of blended learning [1], [2]. In our study, we define blended learning as a classroom learning model that integrates synchronous in-person meetings with asynchronous online instruction resulting in reduced class seat time. In addition, the synchronous in-person teaching component incorporates evidence-based instructional strategies. We define synchronous distance instruction as a form of instruction where the faculty member is physically located with one set of students and other students are connected into the class remotely. In this case, students are located in two classrooms on two campuses that are sixty miles apart. The instructor is facilitating the instruction from either of the campuses. With these two definitions in mind for blended learning and synchronous distance instruction, student experiences in a blended, synchronous classroom are now presented.

The Blended Course Experience

Blended learning could be viewed as a subset or variation of the Flipped classroom. Similar to the flipped classroom, students in a blended classroom will prepare for a class session by engaging with a set of learning materials before class. Often, these materials include readings, videos and study notes among others followed by an assessment. As Figure 1 depicts, in blended learning, students learn the basic concepts out of class. The classroom time that follows is spent focusing on advanced topics and application. The primary difference between a blended and flipped classroom is that blended classrooms offer reduced class seat time. For example, for a 75 minute 2 sessions per week class offered on Mondays and Wednesdays, students would only physically attend a class session on Wednesdays.

Figure 1

Students engage with pre-class online content hosted on a learning management system in preparation for the in-class session. Completion of online content is required before class. Students should come to class prepared and ready to move onto a more in-depth treatment of the week's learning outcomes or more complex topics. A week in the linear control systems course consists of a unit of study called a module. A module contains a week's worth of online activities. The activities include reading assigned text sections, watching short narrated videos, and doing activities that include automatically graded short quizzes for each video. The module's in-class activities consist of a number of practice problems, group problems to turn in, and occasional simulations and mini lectures to further support the learning outcomes. An individual quiz on each module is given the week after the module is completed in class to provide formative feedback to students.

Blended classrooms offer the opportunity to create a highly engaged in-class experience that relies on active learning strategies. While there is a decrease in class seat time, there is more opportunity to focus on complex problems in the classroom. In our study, we are intentional in offsetting 50% of class seat time with a rich online learning experience that focuses on the components defined in the Community of Inquiry instructional approach [2] (Szeto, E., 2015).

Figure 2 illustrates the pedagogy of backwards design and evidence-based instructional strategies that were employed in designing the course. The implementation of backwards course design included the following steps. First, approximately 50 learning outcomes were defined for the course. Next, short videos were created for each outcome as narrated, animated, PowerPoints. Finally, short automatically graded online quizzes were created for each learning video. Other online activities were created to support each learning outcome, including practice problems and MATLAB code to explore.

Figure 3 shows a partial view of the course outcomes, the module structure and the blooms level for each outcome. Each week, a subset of the 3 to 5 outcomes were covered. Every video was designed specifically around one or two learning outcomes. The in-class learning activities were designed to build upon pre-class work and align to specific learning outcomes. In-class activities each week included the following:

- A Check for Understanding quiz (interactive, individual or group, non-credit) over the week's learning outcomes
- Group activity problems, for practice (not graded)
- Group activity problems, to turn in (for credit, group grade)
- Quiz (individual grade) over the previous week's learning outcomes
- Mini lecture/ instructor-led discussion, simulations, or supplemental PowerPoints

A key aspect of the course design was a commitment to provide students with timely feedback. To accomplish this, solutions to practice activities were shown in class immediately after students worked the problems, quiz solutions were shown immediately after the quiz, and solutions to group problems were posted less than a week after the turn in date. While the online and in-class work formed the body of opportunities for practice and lower-stakes formative assessments, the summative assessments for the course consisted of 3 exams, taken outside of the class time, and an individual design project using MATLAB.

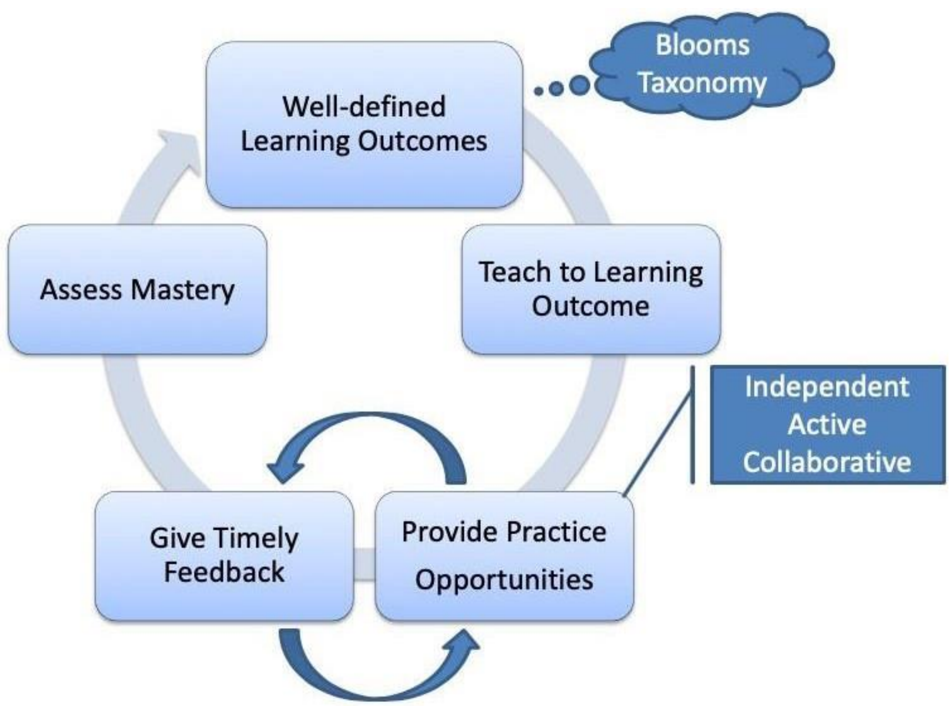

Figure 2

Backwards Course Design Employed

ELEC 4440/8446 Fall 2016						Linear Control Systems										
						By the end of this module you will be able to:	Bloom's Taxonomy									
						Student Learning Outcomes	Cognitive Dimension						Knowlege Dimension			
Week #	START DATE (Monday)	Module #	Topics	Outside Class Work DUE DATE	Outcome #	Begins Friday online, Ends Friday in class	Remember	Understand	Apply	Analyze	Evaluate	Create	Factual	Conceptual	Procedural	Metacognitive
1	8/22/2016	M0	Orientation to Blended & Course		0	Understand expectations of the struture, weekly responsibiliies, activities and assessments in the course. Motivation for controls.		x							x	
2	8/29/2016	M1	Introduction to Control Systems & Mathematical Modeling	Thursday 9/1 Noon	1	Describe the basic features and configurations of control systems.	x						x			
					2	Describe a control system's analysis and design objectives and understand the steps of the design process in a practical example.	x						x			
						" (This outcome is covered by two videos)	x						x			
					3	Understand the three ways to create a mathematical model of a physical system - d.e, transfer function, state space equations.		x						x		
					4	Become familiar with the computer aided design resources and download software.		x							x	
					5	Use the Laplace transform to find the transfer function from a LTI d.e. or electrical network. Solve using the transfer function.			x						x	
3	9/6/2016	M2	Modeling	Thursday 9/8 Noon	6	Find the transfer function for linear, time-invariant electrical networks			x						x	
					7	Understand how to transform a mechanical circuit into an analogous electrical circuit.	x							x		
					8	Linearize a nonlinear system in order to find the transfer function.		x							x	

Figure 3 – Sample of Student Learning Outcomes and Course Schedule

Technology

A key factor in this design was the selection of tools that would bring the vision of this class to life. The vision of engaging two cohorts of students separated by distance, in group and active learning, led simultaneously by an instructor in one location had not been done in any engineering classroom at our University. Figure 4 shows a photo of the course environment with the in-person cohort, the instructor, and the distance cohort shown in the upper right corner on screen. Both groups of students could see the projected content and the instructor, and both groups of students could work electronically on the same digital whiteboard to do problems that the instructor could then project to the entire class and comment upon. In addition, TAs were secured during class at both locations to help with passing out and grading quizzes. The result was a highly interactive in-class experience that involved moving quickly from activity to activity, discussing solutions to problems, and students working problems, discussing questions and collaborating in groups.

A comprehensive list of technologies that were used to create and deliver this course during the three years of the study is shown in Table 1. In several cases, the technologies that were used in year 1 are different from those in years 2 and 3. This is due first, to a University-wide change in learning management systems which moved all courses from Blackboard™ to Canvas ™ in 2018, and a corresponding move from the video capture system TechSmith Relay to VidGrid. The free online whiteboard, Stoodle, that was used for group collaboration in 2016 was eliminated and left an essential gap in the course design. To fill this gap, in 2018 and 2019, Microsoft One Note was used because it was free on campus and mimicked much of the same functionality, albeit with intermittent lags in performance.

Figure 4

Weekly Synchronous In-person Class Meeting with Both Cohorts

Significance of the Study

While previous studies have shown the benefits and drawbacks of both blended learning and synchronous instruction independently, it is important to investigate the combination of both modes of instruction. This is particularly true due to the lack of significant literature on the topic.

The primary significance of our study is threefold; the first is that the literature discussing methods of incorporating evidence-based instructional strategies in a blended synchronous classroom is sparse. Second, while the literature discussing instructors' and students' perceptions on synchronous instruction [4] and blended learning [5], [6] is rich, within the context of undergraduate engineering education offered as a combination of synchronous instruction and blended learning, minimal literature exists. Finally, contrary to the majority of research on blended synchronous learning (BSL), our students are given reduced class seat time and are restricted to two distant locations on two campuses 60 miles apart. Most of the literature on BSL discusses students at remote locations connecting individually to a classroom, such as [7], [8], [9]. Our design has unique implications as it discusses two classrooms with no remote individual connections, rather two classrooms connected synchronously.

Table 1. Technologies Used for Course Design and Delivery

Technology	Functionality	2016	2018	2019
 Microsoft Surface Pro/Book	Create and record narrated PowerPoints. Writing and presentation teaching platform.	X	X	X
TechSmith Relay ™ 	Screen-recording and video storage	X		
VidGrid	Screen-recording and video storage		X	X
Bb Blackboard	Learning management system	X		
canvas BY INSTRUCTURE	Learning management system		X	X
Google Forms	In-class group discussion questions	X	X	X
? ??/ ? ?? N	Course notebook for weekly in-class group assignments and groups' turn-in problems.		X	X

Technology, cont.	Functionality	2016	2018	2019
Stoodle	Online digital whiteboard for in-class group activities	X		
	Students personal cell phones & laptop computers	X	X	X
Kahoot! 	In-class polling system	X	X	X
MATLAB The Language of Technical Computing	Software tool for analysis and design of control systems	X	X	X

Analysis of Student Data

Students enrolled in the course during the fall 2016, 2018, and 2019 semesters were asked to complete a survey at the end of the semester (a different instructor taught the course during the fall of 2017). The survey covered a range of topics related to students' experiences in the course, including what they did and did not like, challenges they faced, and the extent to which they completed the out-of-class activities. All students were asked to complete the survey, but they were able to decide whether they wanted their responses to be used for research purposes. A total of 57 students who completed the survey consented to have their data used for research, including 25 from the fall 2016 course, 12 from the fall 2018 course and 20 from the fall 2019 course. This represents approximately 86%, 46% and 59% of the students enrolled in each course, respectively. Most of the students (n = 49) attended class on the Lincoln campus, and most (n = 49) were undergraduate students. Other demographic data (e.g., gender, ethnicity) were not collected.

The survey contained four different types of items: estimated frequencies of out-of-class behaviors (0 to 100 scale), ratings of experiences in the course (1 to 5 scale), votes for favorite and least favorite components of the course, and open-ended questions. Within these categories, there were some changes made to the survey from semester to semester, but the overall structure of the survey was the same each term.

Table 2. Student Reported Frequency of Outside-of-Class Behaviors (0-100%)

Fall Semester Year	**2016**		**2018**		**2019**		**Overall**
Survey Questions	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Multi-Year Average**
Completed pre-class online activities	85.96	22.1	89.83	17.06	91.35	18.48	89.05
Viewed pre-class videos	88.72	17.05	98.17	4.06	85.55	22.85	90.81
Viewed pre-class slides	*Video Slides Added in 2018*		74.18	35.71	88	20.09	81.09
Took notes on pre-class slides			66.36	39.45	71.55	39.26	68.955
Viewed pre-class slides with videos			72.1	36.06	59.83	34.45	65.965
Used slides during quizzes			47	45.81	64.68	35.04	55.84
Used slides during in-class problem solving			63.2	44.35	63.32	36.41	63.26
Used slides to study for exams			63.18	43.93	79.58	30.96	71.38
View in-class problems before class	*In-class Problems Shown Before Class in 2019*				50.94	37.54	*N.A.*
Begin work on in-class problems before class					52	39.5	
Review solutions to in class quizzes outside of class					67.65	26.64	
Review your graded group problems and/or the posted solutions to the graded problems					53.94	35.06	
Review solutions to in-class example problems (not turned in for a grade) outside of class					56.81	34.59	
2016 *Note.* N = 25. 2018 *Note.* N ranged from 10 to 12, depending on the item. 2019 *Note.* N ranged from 18 to 20, depending on the item.							

Participants were asked to indicate on a 0 to 100 scale how many of the pre-class online activities they were completing and the pre-class videos they were watching. In 2016, 2018, and 2019, students reported rather high rates of both completing pre-class online activities and watching pre-class videos. In 2018, participants were additionally asked about how they used the pre-class slides and about how often they engaged with in-class materials and activities before and after class. Students reported lower and more variable rates for viewing pre-class slides, taking notes on the slides, and viewing the slides with the videos, with their involvement being over 60% in most cases, with the exception of using slides during quizzes. Students were also highly variable in the extent to which they used the pre-class slides to complete quizzes, during in-class problem solving activities, and as a study aide. In 2019, when asked the same questions, students also reported relatively lower and more variable rates for viewing pre-class slides with or without the videos, taking notes on the slides, and using the slides during other parts of their work for the course. That year, participants were also asked five additional questions about in-class problems and quizzes. These participants reported viewing and working on in-class problems before class and reviewing in-class problems about half the time, on average, and reported reviewing quiz solutions at a higher rate. See Table 2 for item means and standard deviations each year, and item multi-year average.

In the study, participants were also asked to rate their agreement with seven statements related to their experience in the course. The statements were the same for each year. In 2016, participants were somewhat positive about the worthwhileness of assigned activities and were in the middle on whether activities were “busy work.” They were quite positive about the usefulness and number and length of the PowerPoints. On average, participants were neutral as to whether having the instructor at their location supported their engagement in class, and they were slightly negative about class discussions as opposed to lecturing. Participants also reported that they mostly were not experiencing technical difficulties when completing the weekly activities. In 2018, students believed assigned activities to be quite worthwhile and mostly did not perceive them as busywork. They also were very favorable about the content and number and length of the PowerPoints. This cohort reported engagement was mostly not affected by the instructor’s location and that they slightly preferred discussion as opposed to lecture. Finally, this group reported few technical difficulties related to completing the course activities. In 2019, students were also quite positive about the worthwhileness of assigned activities, the usefulness of the PowerPoints, and the number and length of the PowerPoints. They were, on average, neutral about the influence of instructor location on engagement and perceiving assigned activities as “busywork.” This group showed a slight preference for discussions over lecture, and reported a low instance of technical difficulties. Means and standard deviations for these items are shown in Table 3.

Table 3. Student Reported Agreement with Course Experience Statements

Statements (1 = strongly disagree to 5 =strongly agree)	**2016**		**2018**		**2019**		**Overall**
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	3-year Average
I believe that most of the activities assigned in each module are pertinent and worth completing.	3.76	1.39	4.42	0.67	4.10	1.17	4.09
I believe many of the activities assigned in each module are just busy work and are not helping me better understand the course topics.	2.84	1.60	2.17	1.12	2.80	1.36	2.60
I believe the Narrated PowerPoints posted on Blackboard are beneficial.	3.96	1.10	4.83	0.39	4.00	1.41	4.26
The length of the narrated PowerPoints and the number of narrated PowerPoints per module is on average reasonable, not too long or too short.	4.08	1.08	4.33	0.65	4.40	0.94	4.27
Being at a distance, I feel that I am as engaged with the instructor and class as if the instructor was present in the classroom	3.16	1.34	3.67	1.37	2.90	1.59	3.24
I prefer having the professor include me in the class discussions instead of lecturing to me.	2.72	1.31	3.83	1.03	3.30	1.08	3.28
After four weeks I am having technical difficulties completing the activities each week.	2.36	1.35	1.58	1.24	1.80	0.89	1.91

Response scale: 1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree.

2016 Note. N = 25
2018 Note. N = 12
2019 Note: N = 20

Favorites and Least Favorites

In 2016 (N=25), the course elements most commonly identified as "favorite" components were meeting once per week (11 votes), group problem solving in class (10 votes), the narrated PowerPoints (6 votes), and quizzes on Blackboard (6 votes). In 2018 (N=12), the course elements most commonly identified as "favorite" components were the narrated PowerPoints (10 votes), meeting once per week (9 votes), group problem solving in class (8 votes), Kahoot! Quizzes (7 votes), and interactions in class (7 votes). In 2016, the course element that was overwhelmingly identified as the "least favorite" was the online discussion boards (11 votes), followed to a lesser degree by group problem solving in class (5 votes), quizzes on Blackboard (4 votes), and the mini lectures (4 votes). In 2018, the course elements that were identified as "least favorite" were having exams out of class (5 votes), group problem solving in class (3 votes), and the online discussion boards (2 votes). No other components received more than 1 vote. It was later discovered that one of the outside of class exams in 2018 occurred the day before homecoming, which may have impacted the high negative votes. It is also clear that while many students listed in-class group work as a favorite aspect, there were some each year who did not prefer it. The narrated PowerPoints were consistently considered a favorite aspect.

Open-Ended Questions

In 2016 (N=25), participants were asked two open-ended questions: "Can you identify one challenge or barrier to learning?" and "Do you have any comments about the course that you would like to share?" In 2018 (N=12), participants were asked five open-ended questions: the same two questions used in 2016 as well as "What worked well with your group work in this class?", "Do you think this type of blended course design should be adopted in other classes? Why or why not?", and "What advice would you give to future students about how to succeed in this class?" The 2019 cohort (N=20) were asked the same five open-ended questions as the 2018 cohort.

Not all participants provided substantive responses to these questions. In 2016, the most common challenge that was mentioned was the pacing and time allotted to the in-class activities (7 participants). These participants felt that they were rushed and not given enough time to do all they were instructed to do while in class. Three others indicated they felt they were not able to learn the material in the videos as fully as was expected of them, and a three commented there was not "enough teaching of the material" during class time. Finally, a small number of students identified assorted technology-related challenges, either related to technical difficulties experienced in the classroom or to the specific software used as part of the coursework. For the group of participants in 2018, the most commonly mentioned challenge or barrier was problems around the classroom technology that was used to support the distance learning set up (3 participants). Two students mentioned problems using OneNote for the various activities and assignments. No other challenges or barriers were mentioned by more than one student. The group in 2019 identified several challenges related to the narrated PowerPoint videos, ranging from "Learning through videos instead of a lecture was a challenge," to "Hard to ask questions during outside class lectures," and "...the videos were too vague." There were also multiple comments about the in-class group activities that echoed comments from the Fall 2016 semester, specifically that the groups often did not have enough time to complete the activities in class. Three participants indicated that it was difficult to ask questions when the professor was in the opposite location, and one student said they felt a "disconnect from the professor due to the blended learning style."

In 2016, the other open-ended question returned a wide variety of responses. The topic of the in-class activities being rushed was again raised by several students, and three said there should have been more in-class lecturing. This group provided fewer specific comments in response to the question about general comments on the course, but one participant suggested students be given more time on the Kahoot! Quizzes and another suggested the in-class activities be more structured with more concrete directions. In 2018, for the question about "other comments," four participants commented positively about the course including: "I felt like the videos explained the concepts very clearly and were well organized.', "Generally good course and structure of distance learning. Some concepts were glossed over more than I would have liked." and "Great class! Super practical course, thanks very much for a positive learning experience!". Other comments expressed a desire to have more structure in in-class activities, increasing the audio volume in some videos, and longer time on Kahoots. In 2019 responses once again touched on numerous topics. Five participants commented positively about the blended format, including "I feel this class gave all the tools to be successful in the class. You have to be willing to invest in the time." Four participants commented negatively about it, including mixed comments about the narrated PowerPoints, with some students finding them helpful and others not liking them or finding them helpful. There were also several individual comments about specific activities or tools used in the course such as the Kahoot! Quizzes not being worth the time, a desire for the instructor to spend more time lecturing, and one student felt that group work activities were not always explained well enough. There were again two students who mentioned having problems with OneNote, one stated that the TA in the location that was more often opposite the instructor was not knowledgeable enough about the content to be fully helpful.

With regard to group work, participants in 2018 reported that their groups functioned well because everyone contributed (3 participants), they were able to start working on the in-class problems before class (3 participants), and they were able to give and receive help from peers as they worked through the problems (3 participants). There were also comments about group members being motivated and well-organized (2 participants) and getting along well (1 participant). Notably, one participant said not everyone contributed to their group's work, and another indicated that the frequent switching of activities made it hard to keep the group focused. In 2019, participants showed considerable agreement as to what went well with the in-class group work. Common responses were that everyone looked at or attempted the problems before class (8 participants), group discussions allowed them to help each other understand the problems and topics (7 participants), everyone contributed to the groups' work (5 participants), they like being able to do the work together in class (4 participants), and group members got along well (3 participants).

As a whole, the participants in 2018 were slightly in favor of using a blended design in more courses (5 "yes," 3 "no," 1 "it depends on the instructor"). This was also the case in 2019, when eight participants said yes to more blended courses, four said no, and five were not definitive one way or the other, saying things like "I wouldn't want all my classes like this," or that the combination of blended design and a distance course created too many challenges. Several of the participants who were not in favor of more blended courses seemed to feel that "learning from videos" resulted in a lower quality educational experience. In contrast, the participants who were in favor of more blended courses seemed to like the independence afforded by the out-of-class work and the ability to refer back to the videos whenever necessary. It seems likely that some students did not know exactly what was meant by "blended course design." For example, one respondent in 2019 commented, "maybe if the other lecture on thurday [sic] would be added. There was not enough time to talk about questions and also more difficult tasks." This comment suggests the student did not understand that a key element of blended course design is reducing time in class.

The 2018 participants were rather single-minded on their advice for future students: eight participants indicated it is important to do the pre-class work, especially watching the narrated PowerPoints and attempting the example problems. The advice given in 2019 to help future students be successful was again mostly about doing the out-of-class work before class (15 participants). Multiple students also mentioned that keeping up with the work is important (3 participants) and taking notes on the narrated PowerPoints (3 participants).

Each year strategic changes were implemented in the course in response to student survey feedback and instructor observations. The changes made after 2016 are detailed in Table 4. The changes made after 2018 are detailed in Table 5. These tables represent an application of iterative course design based on student feedback that has been shown to be successful for improving student learning outcomes [10]. The impact of some of these changes can also be seen from the survey data. For example, in 2019, showing in-class activities in advance resulted in students reviewing or attempting activities ahead of time at least half of the time on average (Table 2). As reported in the open-ended responses for group work that year, doing these problems ahead of time led to greater preparation for in-class group work. It can also be seen from Table 2 that adding video slides resulted in students using them a majority of the time, while watching videos or to take notes during videos and to a slightly lesser extent during quizzes, while solving group problems, and to study for the exam. In 2019, although the number of in-class problems was reduced, and students were given additional time outside of class, some students still reported that they felt rushed to complete the group problems.

Table 4. Course Changes after the First Offering

Changes after 2016	Why and Expected Impact
Posted pdfs of all online video slides.	This enables students to have a copy of the slides to take notes while watching videos, and as a study aid. This also gives an opportunity for students to engage deeper while watching videos.
Changed online formative quizzes to have unlimited attempts.	The goal is to create a low stakes environment and encourage learning. This change was well-received students and resulted in near 100% scores on these quizzes.
Added a short mid-semester check	Respond to pressing student concerns before the end of the semester survey.
Offered online office hours to students	Offer office hours while present on a remote campus. This was used by only one student.
One Note Notebooks were integrated (to replace Stoodle, the free online whiteboard used in Fall 2016 which was discontinued) as the platform for group problems to be posted, and for groups to turn in work electronically.	In Fall 2016, while some practice problems were done in Stoodle during class, most group problems were turned in on paper. In 2018, One Note was used as the electronic notebook for students to turn in all group work submitted each week for a grade. One Note was free, but at times buggy, occasionally preventing students from entering work. The pros for the instructor included having electronic access to all students work from both locations and the ability to grade and save the work for each group in Canvas.
Groups given more time to turn in work, one day or two after the end of class.	This was due to feedback that groups had trouble completing the number of problems that were to be worked by the end of class.
Added more structure into the design project assignment and a design project rubric that was published to students. .	This was done to spell out specific questions students should answer at each phase of the project and to provide a rubric to guide their work. The instructor observed noticable improvement of students projects year over year

Table 5. Course Changes after the Second Offering

Changes after 2018	Why and Expected Impact
Made in-class activities/problems visible ahead of time	This was done as an experiment when several students expressed interest in seeing problems before class to determine if this would help students complete group assignemnts with individual exposure and the opportunity to work on them before class.
Reduced the number of problems worked in class, per class.	Since the in-class practice activities were posted ahead of time, instead of allowing students time to work ALL problems in groups, the instructor gave a smaller amount of time for groups to review practice problems together and then went over the solutions to the practice problems and gave more time to work on the problems that were to be turned in.
Structured formative points to a formula that is clearly articulated in Canvas to allow students to track their progress.	Due to feedback from mid-term survey in 2018, students expressed that they were anxious about their grades on the formative assignments, which were in fact a small portion of their grade. Showing this in Canvas for each formative category seemed to help students put formative assignments in perspective and eliminated this anxiety. (I overhead students discussing a low module quiz grade and saying well, it only counts for x%, and it helps to know it before the exam).
Hosted posted office hours in person in Lincoln in addition to in person office hours in Omaha. Kept the option for online office hours for both cohorts.	Provide extended opportunities for students to talk to the instructor, build rapor and seek help. Students spoke to the instructor more often before or after class. One student came to office hours in Lincoln.
Virtually eliminated writing out problem solutions real time during class compared to earlier semesters. Instead, stepped through solution steps as the solutions were already prepared.	This was done to save class time and allow more time for group problem work and due to using a different browser that did not allow editing of pdfs but was faster to log in. In part, this was a work-around to sigiificant WiFi connectivity issues that were experienced in the classrooms this semester.
Empasized student reflection on considering the practical performance of their individual design projects by devoting one class period to a jigsaw approach related to the design project so that each group had an "expert" in each aspect of the project and could discuss and help one another.	The instructor observed that in 2018, students did not understand the realistic operation of the systems they were asked to design in the project. To address this, the jigsaw exercise on project goals was added to the class in 2019. As a result, the instructor observed that more students demonstrated thoughtfulness about their system's realistic operation and were able to achieve realistic design project outcomes. The projects also improved in quality year over year.

Discussion of Study and Results

Commonalities during the three years shows that students reported a high level of engagement in the pre-class assignments online. In particular, PowerPoint videos and online content was overwhelmingly rated helpful to students during all three years of the study. Other tools were reported to be engaged over half of the time by students. Overall the data shows that this study was a success. It is believed that most of the benefits resulted from the successful design of course elements using backwards design. While no formal measure of engagement was used, one can estimate engagement based on the high levels of participation reported in outside of class activities, and with observations of in-class instructor and student behaviors (the latter is a future direction).

For the instructor, the students' performance on individual design projects demonstrated the depth at which the student learning outcomes were realized. The design project involved a cumulative design of a unique control system in MATLAB. The same project was used each year, with slight modifications in 2018 and a rubric was used in 2018 and 2019 for grading. While not a formal part of this study, performance on this cumulative project each year provided proof that the course achieved the instructor's goal of producing students who demonstrate an ability to analyze and design a system like a control systems engineer, which required mastery of a number of outcomes. The blended format was ideally suited for this higher level course in linear control theory.

It was noted that a consistent amount of feedback over the years was associated with the distance learning rooms themselves (connectivity, communication issues) and technology failures (e.g. WiFi, OneNote). It was learned that rooms set up to deliver lecture-style distance instruction do not necessarily have all of the functionality needed to support a high level of interaction in active, blended courses. While students were initially hesitant to work in groups on the first day of class, as this was a break in culture for the department, the culture of interaction quickly grew and students became accustomed to interacting with one other and the professor. With this culture established, when students attempted to ask questions but were unable to due to the rooms open mic set up, varying volumes from week to week, and the instructor could not hear questions from the remote location, students resorted to standing up and moving closer to mics in the ceiling and yelling the questions. This was a frustrating scenario to a class that was accustomed to a high level of interaction with the instructor. In a traditional lecture-based distance course, the culture is that students remain quiet and listen a majority of the time, so this would not pose the same types of problems.

Lessons Learned

Much was learned over the three years and modifications were made each year to address the nuances of facilitating student learning in this blended environment. Other significate lessons learned included the following:

- Backwards design provides an excellent means for instructors to create blended course materials and to establish a successful roadmap to tie pre-class/online materials to in-class material.

  With the recent global events that have forced many universities to rapidly adopt remote learning strategies, more and more instructors will be considering how to transition to remote or blended modes of course delivery. This course was the instructor's first experience with blended course. With support from the University's instructional design staff, the time invested by the instructor to build the course ultimately paid dividends in engaging students with the online work.

- Technology can make or break a distance student learning experience where active learning is the norm.

  The distance classrooms at our University were designed for lecture based courses, while the blended course design relies on an active learning paradigm. Key to the course design was the use of collaborative and interactive computer tools via a network, which when worked well helped facilitated the design, but when the technology had disruptions, it halted progress. Rooms designed to support blended distance learning need to be designed to better support this mode of learning.

- Coordination of and securing TA support in both locations each week was essential for the facilitation and success of delivering immediate feedback and support for student activities.

- There is still an important place for some lecture and working limited example problems in real time to increase students' comfort level before diving into group problems. This instructor focused most time on engaging students in the later. While this approach was effective overall in achieving learning outcomes, working at least one or two problems for students step by step may provide students with increased confidence before they dive into group problems.

Future Research Considerations

The following steps would further strengthen this study:

- Include a comparison of student levels of participation (% of videos watched, time spent doing online activities, etc.) to investigate any correlation with student performance on the individual design projects.
- Incorporate a controls concept inventory pre and post test. Compare pre-results for each cohort to determine the start baseline for each group, and observe the change for each group.
- Incorporate intentional group structuring vs. ad hoc groups, and incorporate lessons for students about group dynamics and teamwork skills. Use CATME to assign static groups and allow group members to evaluate one other measure group effectiveness and preparedness.
- Use the COPUS protocol to characterize student and instructor behavior over a larger subset of course meetings to formerly characterize the active learning taking place, and to provide a formal measure of student engagement. In fall 2019, the two class meetings that were observed were characterized as "student centered" and "interactive lecture".

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