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

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RESEARCH

Abstract
This case study combines two primary areas of literature, blended learning and synchronous distance instruction. The literature provides various interpretations and definitions of blended learning. We define blended learning as a classroom learning model that integrates in-person and online asynchronous instruction with reduced time in class. We discuss blended learning with a synchronous distance teaching component that incorporates evidence-based instructional strategies. We explore a specific mode of synchronous distance instruction where the faculty member is physically located with one set of students and other students are connected into the class remotely. In our case study, students are located in two classrooms on two campuses that are sixty miles apart. The instructor facilitates instruction from either of the campuses. With these two definitions in mind, we present insights from this case study into student experiences in a linear controls course over a three year period (2016, 2018, 2019) in a blended, synchronous distance classroom. A follow-up on the impact of COVID-19 (2020) on the course is also presented along with a comparison of student performance on an individual design project during the years of the study and during COVID-19. Throughout the three-cohort study, students experienced high levels of perceived benefit and engagement in the online course content. Empirical data indicates that the course design proved to be effective in facilitating student achievement both before and during COVID-19.

Keywords: blended learning, synchronous distance instruction, evidencebased instructional strategies

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1 Introduction

Over the course of 3 years, we explored instructional strategies, student opinions, and instructor perceptions around the use of a blended, synchronous distance learning environment in higher education. We begin our discussion with a review of blended learning with a focus on STEM classrooms. Then, we transition to a review of synchronous teaching and its benefits and drawbacks. We follow up this review of the literature with our motivation for applying a blended learning design.

1.1 Blended Learning

The body of literature on blended learning discusses a wide range of blending ranging from incorporating technologies and a focus on active learning, to a large percentage of reduced class seat time offset by an intentionally designed set of online learning activities. When blended learning classrooms are compared to traditional lecturing and distance teaching, studies reported either comparable student performance or increased performance in Blended classrooms. Overall, student and faculty perceptions seem to be positive in nature.

Blended learning classrooms have been shown to enhance student performance in STEM classrooms. For example, Naidoo and Naidoo [1] studied the performance of undergraduate students from chemical engineering participating in a calculus course. Naidoo found that students taught with the traditional lecture style exhibited more structural and executive errors than students taught the exact same material in a blended classroom. Students in the blended learning class tended to describe the concepts using deep structures rather than surface structures, an indication of deeper learning. Shen et al. [2] studied 177 vocational students in two consecutive semesters of a compulsory Database management systems course. The eighty-three students who took part in the class that applied blended learning outperformed the ninety-four students who took part in the traditionally taught class. Bazelais and Doleck [3] conducted a comparative case study that examined the differences in student performance between a traditional lecture-based class and a blended classroom approach in a college mechanics course. They found that students in the blended classroom experienced more conceptual change and higher performance compared to the students in the traditional lecture-based class. Tritrakan et al. [4] compared pre-test and post-test scores on programming conceptual understanding, problem-solving using programming skills, and program analytical skills of undergraduate students in a computer science program. They found that the students' conceptual understanding, problem-solving, and analytical skills related to programming were significantly increased in a blended classroom.

In some studies, blended learning yielded no statistically significant performance advantages when compared to distance or e-learning courses. However, these studies provide insight into other benefits of the blended classroom design. For example, Alonso et al. [5] found no pronounced differences between the grades achieved by students in the distance learning (e-learning) and blended learning versions of a software engineering course. However, they did report a significant decrease in students' dropout rates. Daher et al.'s [6] study provided similar results and reported that first-year engineering students had a higher completion rate on assignments in comparison to previous years where the course was taught following a traditional lecture-based, teacher-centered environment. Napier et al. [7] found comparable performance between students' learning in traditional and blended classrooms, however students reported an increase in interactions with the faculty instructors in comparison to other classes. Clark et al. [8] compared the effectiveness of blended, semi-flipped, and flipped formats in an engineering numerical methods course. They also reported comparable results in terms of students' performance with regards to effect sizes with students having a slight preference for the blended format.

In terms of student and faculty perceptions of blended learning, the literature provides us with some insights. Shen et al. [2] gathered quantitative data on students' experiences with blended learning and reported that 75% of students thought the blended approach was very helpful for learning. In qualitative interviews, students agreed that the digital learning materials used for the out-of-class portions of the blended learning structure contributed to their learning and were helpful for their preparation. It is common to find instructor generated videos provided to the students in the online portion of a blended class. Similarly, Tritrakan et al. [4] found that computer science students' aptitude for learning programming increased in a blended classroom. Daher et al. [6] studied both student and instructor perceptions in a blended learning class with reduced time in class ("seat time"). They reported that as the semester progressed, students found the blended approach more enjoyable. The instructor in the study reported that in the in-person sessions, students demonstrated increased engagement. The instructor reported using the in-person sessions to focus on interactive activities that were more complex in nature. Similarly from an instructors' perspective, Napier et al. [7] reported faculty perceptions of teaching in a blended format. Faculty participants in the study highlighted the importance of making decisions about which activities and learning experiences needed to happen online and which should happen in the classroom. Additionally faculty discussed the need to be creative in using both in- and out-of-class time. Some faculty referred to the fact that the reduced class seat time made them be more intentional in incorporating more complex topics in the in-person class sessions.

1.2 Synchronous Distance Instruction

The present study investigates blended learning that incorporates synchronous distance instruction. Similar to Blended learning classrooms, synchronous distance instruction shows promise in both undergraduate and graduate education. There are many attributes that define synchronous instruction [9]. At its core, distance teaching and learning occur where a physical separation exists between at least some students and their instructor. Goodridge et al. [10] compared the performance of students in engineering graphics courses using synchronous Online and Face-to-Face instruction. In this quasi-experimental study of just over 100 participants, students in the synchronous online environment performed significantly better on the final open-ended project than their face-to-face taught peers. The synchronous distance model can also allow for several individuals to connect with an instructor for a synchronous distance class session. For example, Bondi et al. [11] included synchronous sessions in an online course as an avenue for students and instructors to reflect upon in-class events. They found that students reported increased motivation and engagement.

Synchronous distance classrooms also fare well when compared to traditional courses with regard to building community among students. McDaniels et al. [12] studied the integration of learning communities in synchronous online courses. Their analysis of both quantitative and qualitative data indicated that the synchronous distance environment was successful in creating a strong sense of community among the participants. With regards to student perceptions, Peslak et al. [13] studied students' acceptance of the delivery of an information systems course. Students were located on three campuses. Students reported an overall suitability of 4.05, and a 3.8 (scale of 1 = strongly disagree to 5 = strongly agree) for wanting to enroll in another course delivered the same way. They also found that the technical reliability of online teaching tools, perceived substitutability of online teaching tools versus face-to-face teaching, perceived interaction via online teaching tools significantly influenced overall suitability ratings of the tools used for instruction.

An emerging set of literature discusses blended synchronous learning (BSL, also called "Blended Synchronous Classrooms"), with most studies examining several classrooms or individuals connected to an instructor via technology. In this literature, the "blend" is typically a blend of technology and classroom activities [14], not a blend of synchronous and asynchronous learning, as is the case in the present study. Significantly more research is needed to understand the BSL mode of delivery and how it might relate to our different view of integrating blended and synchronous distance learning.

2 Motivation for Blended Design

Instructors at higher education institutions choose 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 it is 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 synchronous distance learning as well as a more active method for teaching linear control systems. This course was designed well before institutions were forced to adapt to remote learning during the COVID-19 global pandemic in 2020. Thus, the findings are very relevant at a time when courses of this nature are no longer optional but are becoming necessary. The original study results, published in [15], have been updated and expanded to reflect application of this model during the time of COVID-19 and social distancing.

An elective course in Linear Control Systems is taught at a distance across two campuses separated by sixty miles (Omaha, Nebraska and Lincoln, Nebraska) in the University of Nebraska-Lincoln's electrical and computer engineering department. Traditionally, courses of this type are taught by an instructor who teaches one cohort of students 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 each location for 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, because time is lost while traveling (the instructor must devote 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 allowed to implement research-based instructional practices in a distance learning setting. The instructor previously taught the 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 allowed the instructor to use instructional time more strategically. This was, at the time, an entirely new approach for distance engineering courses at our university.

The uniqueness of the context for this course at the intersection of synchronous distance instruction and blended design prompted us to initiate this research using a case study approach. This case study thus combines two primary areas of literature, blended learning and synchronous distance instruction. The literature provides various interpretations and definitions of blended learning [16, 17]. 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 study, students are located in two classrooms on two campuses that are sixty miles apart. The instructor facilitates the instruction from either of the campuses. With these two definitions in mind for blended learning and synchronous distance instruction, the results of this case study of student experiences in a blended, synchronous distance classroom are now presented.

3 The Blended Synchronous Course Experience

3.1 Significance of the Study

While previous studies have shown the benefits and drawbacks of both blended learning and synchronous distance 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; first, the literature discussing methods of incorporating evidence-based instructional strategies in a blended synchronous distance classroom is sparse. Second, while the literature discussing instructors' and students' perceptions on synchronous distance instruction [18] and blended learning [6, 19] is rich, there is minimal literature examining the combination of synchronous distance instruction and blended learning in the context of undergraduate engineering education. Finally, contrary to the majority of research on blended synchronous learning (BSL), our students experience 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 [20–22]. Our design has unique implications as it discusses two classrooms connected synchronously with no remote individual connections.

3.2 Blended Learning Defined

Blended learning can 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.

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 and pre-class assignments are closed 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 and in-person activities. As depicted in Figure 1, online activities include reading assigned text sections, watching short narrated videos, and doing short assignments (automatically graded quizzes, simulations, and example problems). The module's in-class activities consist of doing a number of practice problems, working problems in groups, and being guided by the instructor into additional content that further supports the learning outcomes.

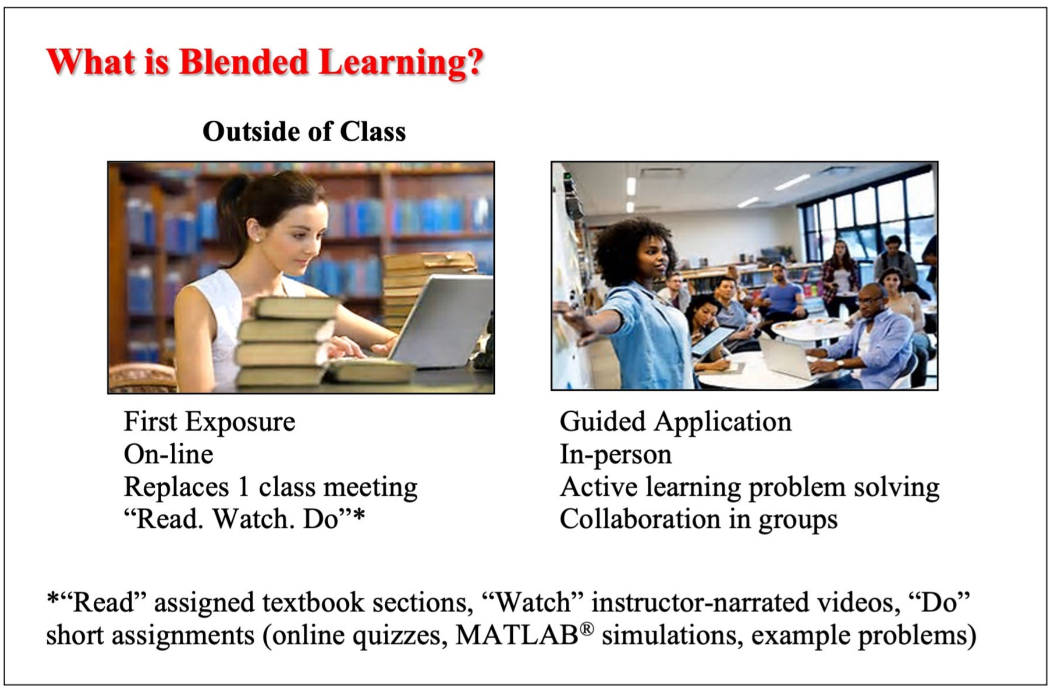

Figure 1. What is blended learning?

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 were 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 [14].

3.3 Course Design Pedagogy

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 (approximately 10 minutes in length) were created for each outcome as narrated, animated, PowerPoints. Finally, automatically graded, short online quizzes were created for each learning video. A number of additional online activities were created to support each learning outcome that included practice problems and MATLAB® code to explore.

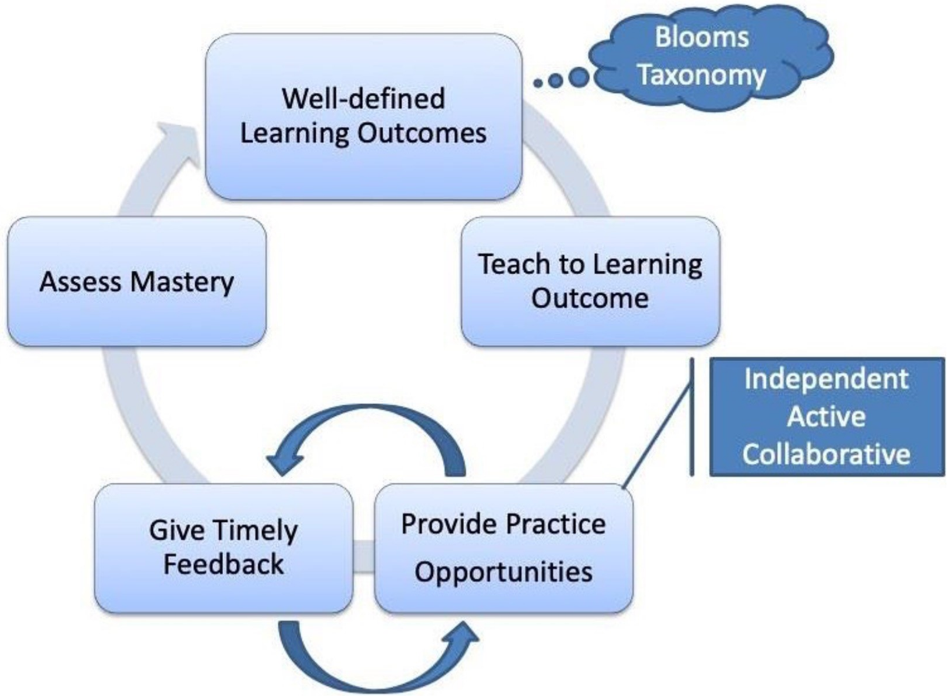

Figure 2. Backwards course design employed.

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. A series of in-class activities and problems were then designed to cover each learning outcome in depth and to build upon the online work. An individual quiz on each module was later added and given the week after the module was completed in class in order to provide formative feedback to students on their individual mastery of the learning outcomes. Thus, in-class activities each week included:

- An interactive, not for credit "check for understanding" quiz over the current week's learning outcomes
- A graded, written individual quiz over the previous week's learning outcomes
- Group activity problems, both for practice, and to turn in for a group grade
- Instructor facilitated progression of problems, discussion, simulations, and mini lectures

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 within a week of the turn-in date. All solutions were made accessible online for students to review in order to aid learning. 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.

3.4 Technology Employed

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

ELEC 4440/8446 Fall 2016 — Linear Control Systems

By the end of this module you will be able to:

Week #	START DATE (Monday)	Module #	Topics	Outside Class Work DUE DATE	Outcome #	Student Learning Outcomes: Begins Friday online, Ends Friday in class	Bloom's Taxonomy — Cognitive Dimension: Remember	Understand	Apply	Analyze	Evaluate	Create	Knowlege Dimension: 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.

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 present 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.

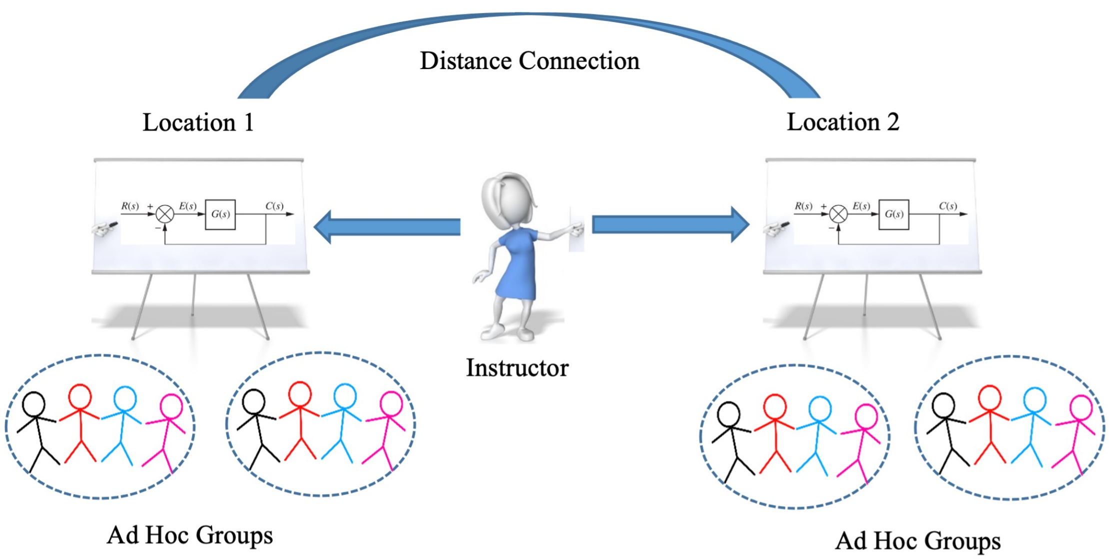

Figure 4. Course Classroom Structure before COVID-19 (2016, 2018, 2019) The Instructor teaches from either Location 1 or Location 2.

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 was due first, to a university-wide change in learning management systems which moved all courses from Blackboard^{TM} to Canvas ^{TM} 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 OneNote was used because it was free on campus and had much of the same functionality.

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
Blackboard	Learning management system.	X		
Canvas	Learning management system.		X	X
Google Forms	In-class group discussion questions.	X	X	X
Microsoft OneNote	Course notebook for weekly in-class group assignments and groups' turn-in problems.		X	X
Stoodle	On-line digital whiteboard for in-class group activities.	X		
Personal Devices	Students' personal cell phones and laptop computers.	X	X	X
Kahoot	In-class polling system.	X	X	X
Matlab	Software tool for analysis and design of control systems.	X	X	X

4 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 (the instructor did not teach the course in 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.

4.1 Student Behaviors & Course Experience Statements

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 very high rates of both completing pre-class online activities and watching pre-class videos ranging from 85% to 98% of the time on average. In 2018, participants were additionally asked about how they used the pre-class slides which were made available to students for the first time this year. Students reported viewing pre-class slides on average 74% of the time, taking notes on the slides 66% of the time, and viewing the slides with the videos 72% of the time. On average students used the slides 63% of time during in-class problem solving activities, and as a study aide for exams. They reported using slides during quizzes at a lower rate, 47% of the time. In 2019, when asked the same questions, students reported high but more variable rates for viewing pre-class slides alone (88%) or with the videos (59%), taking notes on the slides (71%), and using the slides during other parts of their work such as during quizzes (64%), in-class problem solving (63%), and as a study aid for exams(79%). 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 (which was made available for the first time this year) 50% of the time. Students reported reviewing solutions to in-class quizzes, group problems, and example problems 67%, 53% and 56% of the time, respectively. See Table 2 for item means and standard deviations each year, and item multi-year averages.

Table 2. Student Reported Frequency of Outside-of-Class Behaviors (0-100%)[1].

Survey Questions	2016 Mean (StdDev)	2018 Mean (StdDev)	2019 Mean (StdDev)	Overall Multi-year Average
Completed pre-class online activites	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-call 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)	68.96
View pre-class slides with videos		72.1 (36.06)	59.83 (34.45)	65.97
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
Viewed in-class problems before class	*In-class problems shown before class in 2019*		50.94 (37.54)	*N/A*
Began work on in-class problems before class			52 (39.5)	
Reviewed solutions to in-class quizzes outside of class			67.65 (26.64)	
Reviewed your graded group problems and/or the posted solutions to the graded problems			53.94 (35.06)	
Reviewed solutions to in-class example problems (not turned in for a grade) outside of class			56.81 (34.59)	

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.[2]

Statements (1 = strongly disagree to 5 strongly agree)	2016 (n=25) Mean (StdDev)	2018 (n=12) Mean (StdDev)	2019 (n=20) Mean (StdDev)	Overall 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 activites 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 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 (3.16)	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 processor 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

4.2 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). Due to negative student feedback in 2016, discussion boards were used less often in 2018. 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 PowerPoint videos that students watched outside of class were consistently considered a favorite aspect.

4.3 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. An in depth summary of all student responses received to these questions is included in [15]. 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. 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). Three students in 2019 identified challenges they had 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 lecture,". Three participants also indicated that it was difficult to ask questions when the professor was in the opposite location."

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, while 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).

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).

4.4 Changes after Each Iteration and the COVID-19 Response

From 2016 to 2019, strategic changes were implemented in the course to address student survey feedback and instructor observations. The changes made after 2016 are detailed in Table 4 . Changes made after 2018 are shown in Table 5 . The changes shown represent an application of iterative course design based on student feedback that has been shown to be very successful for improving student learning outcomes [23].

The impact of several of these changes showed up in the survey data. In 2018, pdfs of video slides were made available to students. The data shows that students reported high levels of using this new course resource, viewing the slides 74% of the time in 2018, and 88% of the time in 2019. They also used slides during quizzes, while solving group problems, and to study for the exam (Table 2). In 2019, in-class activities were shown in advance, and students reported reviewing or attempting the activities before class at least half of the time on average (Table 2). Students reported that doing these problems ahead of time led to greater preparation for in-class group work (in open-ended survey responses). This was the expected impact of making this change.

In 2020, educational institutions around the globe were forced to contend with changes in the delivery of courses due to the global COVID-19 pandemic. This course was designed to be completed one half online, which worked very well for the pandemic, however class meetings each week were designed to have interactive in-person group collaboration. How would this group collaboration be facilitated during COVID-19? The solution included using OneNote for digital collaboration and introducing Zoom break out-rooms for group work time, along with socially distanced in-person group collaboration. OneNote was the perfect platform for facilitating group collaboration particularly when some group members were attending remotely due to quarantine or capacity limits and some were in person in class. Table 6 summarizes all of the changes that were made to this course in fall 2020 to quickly adapt to teaching within the constraints of physical distancing and reduced classroom capacity. A depiction of the course classroom structure before COVID-19 is shown in Figure 4 , and the course classroom structure during COVID-19 is depicted in Figure 5 .

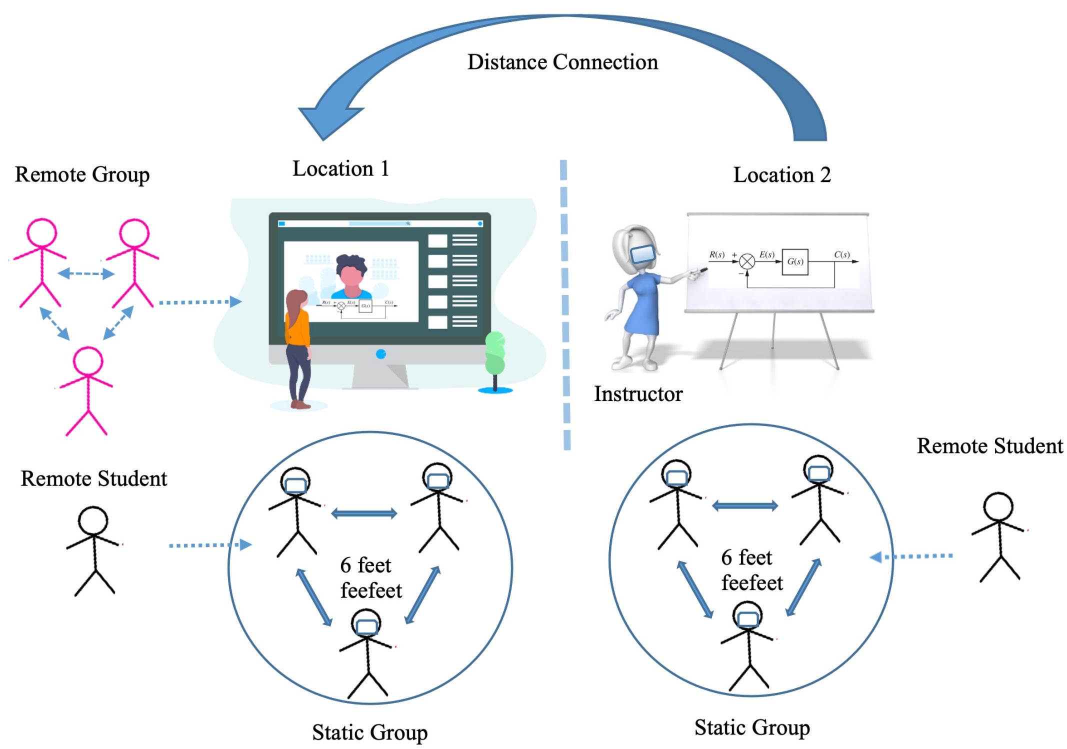

Figure 5. Course Classroom Structure during COVID-19(2020)

While this course design was envisioned well before the COVID-19 pandemic, an important exploration in this study relates to the impact of COVID-19 on classroom structure and course delivery and the students' ability to achieve course outcomes within this structure. In a time that many were forced to quickly adapt to the reality of remote learning and hybrid teaching, the identification of course designs that perform well in such environments is relevant and timely. Based on observations during fall 2020, the course design transitioned very well to support students during the COVID-19 pandemic.

In 2020, Zoom proved to be a more robust delivery mechanism to share course content to the distant classroom than the content sharing software used previously (AirTame). It also provided a seamless method to engage students in Lincoln and Omaha as well as those students attending from home (whether in Nebraska or across the globe, as one student participated virtually from Oman). It enabled an ease of connectivity and interaction between instructor and students regardless of their physical location. With the combination of sharing course content on screen, using the chat window to communicate, facilitating student group work using break-out rooms, and joining break-out rooms to address remote students' questions in small groups, etc., aspects of facilitating the course were surprisingly improved during this physically distanced semester. All students were also able to consistently meet for group work whether they were in person or remote and had direct access to the instructor.

A GTA present in the classroom in Lincoln in 2020 for each Zoom class session provided feedback that the students in Lincoln were very engaged in their groups, both when in person and remote. She commented: "I would say that the students…seemed to find the group assignments especially helpful...It seemed that the Lincoln students were often reluctant to speak up in class because they felt awkward talking to you over Zoom, but I'm not sure of what a solution to that would be. The breakout rooms seemed to work well, though, and the students in Lincoln were very engaged while they were talking to their groups in the breakout rooms." The instructor also observed a high level of interaction among students in groups in the Omaha classroom.

While student survey data were not collected in 2020, student performance on individual design projects can be compared to previous years to provide a very compelling litmus test on the effectiveness of this course design within this new environment.

4.5 Student Performance on the Design Project

Students are assigned an individual design project near the end of the course entitled "Analysis and Design of a Single Input, Single Output Linear Control System using Classical Methods". For this project, a unique plant is assigned to each student based on their student I.D. that consists of 3 poles and no zeros and it is placed in a unity feedback configuration. Students decide what device their plant represents, research realistic performance criteria for the device, then step through a process to analyze the system's initial operation and ultimately design controllers to meet the system's desired performance criteria.[3] Students design in MATLAB® and must use an iterative design technique. The project is indeed a cumulative assignment that requires successful application of a number of course outcomes.

In 2018, based upon observations of student work in 2016, the project assignment was tweaked to provide more guidance as to what is expected of students at each phase of the project. A rubric was also created and posted for the design project. The modified design project assignment and the design project rubric, shown in Table 7 , was used in the course in 2018, 2019, and 2020.

Student performance on the design project for each portion of the rubric is detailed for the years 2018, 2019, and 2020 in Table 8 . It is of particular note that students performed nearly equally as well under the constraints of COVID-19 as in the years before the pandemic. In addition, because the annual average achievement on this assignment exceeded 80% each year, a majority of students each year were able to successfully demonstrate rubric design competencies by mastering key

[3] The design project scenario was created by Dr. John Boye, Professor Emeritus in ECE at UNL.

Table 4. Course Changes after the First Offering

Changes after 2016	Why & Expected Impact
The pdfs of all video slides were published for students.	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.
Online formative quizzes were changed 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.
Online office hours were offered to students	Offer office hours while present on a remote campus. This was used by only one student.
OneNote 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, OneNote 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 were given additional time to turn in group work, up to one or two days after 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.
Additional structure was added into the design project assignment and a design project rubric was created and published for 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 noticeable improvement of students' projects year over year.

learning outcomes in this course in the years before COVID-19 (2018-2019) as well as during COVID-19 (2020).

5 Discussion of Study Results

Student experiences in this course show a high level of engagement in completing online assignments during all three years of the case study (Table 2) with a multi-year average of 90% of the time. Online assignments provided the foundation for student mastery of course learning outcomes as students were directed to read text sections, watch instructor narrated videos, and do short quizzes, problems and simulations. The cornerstone of the online work was the narrated PowerPoint videos which were rated overwhelmingly helpful by students (Table 2 and Table 3 and open-ended survey responses). Thus, the data shows that students experienced high levels of perceived benefit and engagement in online course content, which is a keystone to any successful blended course design. Furthermore, students' online preparation provided the necessary foundation for in-person class meetings where they worked in groups to solve more complex problems and apply the concepts they were introduced to online.

Table 5. Course Changes after the SecondOffering

Changes after 2018	Why & Expected Impact
In-class activities/problems were made visible in the LMS before class for students to preview.	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 assignments with individual exposure and the opportunity to work on them before class.
The number of problems worked in class was reduced.	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.
Formative points were structured into a formula that was clearly articulated in the syllabus to allow students to track progress on low stakes assignments.	Due to feedback from mid-term survey in 2018, students expressed that they were anxious about their grades on the formative assignments, which were 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).
Office hours were hosted in person in Lincoln in addition to in person office hours in Omaha. The option for online office hours was retained 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.
Writing out problem solutions real time during class was drastically reduced compared to earlier semesters. Instead, solution steps were explained from document solutions that 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 significant WiFi connectivity issues that were experienced in the classrooms this semester.
Students were guided in 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.

Table 6. Course Changes in Response to the COVID-19 Pandemic

Changes during Fall 2020	Why & Expected Impact
The instructor taught from Location 2 the entire semester and did not travel between locations.	Campus safety in the spread of COVID-19
The classroom capacity was reduced to 1/3 for in-person attendance. All students were required to wear masks and sit 6 feet apart at all times. A subset of students attended remotely each week.	Campus safety and physical distancing
Classrooms were upgraded with Zoom connectivity between distance classrooms and for remote learning.	To better facilitate remote learning
The instructor divided students into static groups at the beginning of the semester using the CATME system, taking into consideration students' schedules and demographic factors.	This was done to better manage group collaboration: it eliminated the need to divide students into groups every class, it allowed the instructor the ability schedule students' in-person vs. remote attendance days and to ensure each student had others with whom to work, regardless of if they attended in person or remotely. Due to classroom capacity limits, every week a subset of students in Lincoln had to attend class remotely.
Group work was moved to the end of class (the last 15-30 minutes) instead of dispersed throughout. Students worked with their groups either in-person, 6 feet apart, and/or via Zoom breakout rooms, or both in the case of groups who had some members attend in person and others remotely.	A subset of students attended class remotely each week, so all remote students were broken up into group specific Zoom rooms to collaborate on group work. Once in these rooms, students no longer had access to hear the instructor in the classroom. To avoid going back and forth, all group work was moved to the last part of class. During group time, students had the option to contact the instructor or ask questions using the Zoom chat window, or by writing questions in OneNote.
Student quizzes were changed to online submissions. Exams were given remotely via Zoom. Otherwise, the course structure remained intact.	Campus safety and physical distancing.

While not a formal part of this study, students' performance on individual design projects demonstrated the extent to which course learning outcomes were mastered, and illustrated the ultimate success of the course. The high level of student performance on this project provided proof to the instructor that the course achieved the goal of producing students who can analyze a realistic system and design controllers to meet performance specifications, which required mastery of a number of significant course outcomes. The blended format was ideally suited for this higher level course in linear control theory. This design proved to be effective in facilitating student achievement both before and during COVID-19.

6 Lessons Learned

Much was learned over the years of this study as modifications were made each year to address the nuances of facilitating student learning in a blended, distance environment. It is believed that significant benefits were realized from the initial successful design of course elements using

Table 7. Control System Design Project Rubric (100 points total)

Plant/Device Description 20 points	2 points: Describe the plant device and its realistic operation 5 points: Unity feedback block diagram and plant transfer function 3 points: Closed loop transfer function 10 points: Root locus and Bode plots
Analysis 20 points	3 points: Stability range, gain margin, phase margin 5 points: Initial transient response spec, gain only design 5 points: Step response at gain K, transient specs 5 points: Steady-state error at gain K 2 points: Stability at gain K
Design Objectives 10 points	5 points: Objectives for improving transient response (desired specs) 5 points: Objectives for improving steady-state error (desired error)
Design Procedure 25 points	5 points: State how each design goal will be achieved (compensators) 10 points: Compensator 1, root locus, step response 10 points: Compensator 2, root locus, step response
Results 25 points	8 points: Impact of design toward design goals (chart) 2 points: Compensated system block diagram 10 points: Plots of uncompensated vs compensated systems 5 points: Summary of design success and limitations

Table 8. Student Performance on the Design Project: 2018, 2019, and 2020$[4]

Rubric Category	Points	2018 (N=25) Mean (StdDev)	2019 (N=33) Mean (StdDev)	2020 (N=30) Mean (StdDev)
Description of Plant/Device	20	19.56 (1.13)	18.24 (2.03)	19.00 (1.81)
Analysis	20	17.76 (3.35)	17.73 (3.93)	17.07 (4.05)
Design Objectives	10	8.86 (2.45)	9.30 (1.73)	9.20 (1.78)
Design Procedure	25	23.02 (6.07)	19.79 (6.65)	18.77 (7.36)
Results	25	20.44 (6.39)	19.73 (6.58)	19.50 (5.71)
TOTAL	100	89.64 (14.67)	84.80 (17.64)	83.53 (16.18)

meticulous backwards design (see Figure 2). The role of course management and technology was also key and evolved in surprising ways during the progress of this study.

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 case study provides a successful roadmap. This was this instructor's first experience with creating a blended course. With support from college instructional design staff, the time invested by the instructor to build this course was significant, but it ultimately paid dividends in engaging students in online work, and proved robust both before and during the COVID-19 pandemic.

Technology can make or break a distance student learning experience where active learning is the norm. The distance classrooms in our college were designed for lecture based courses, while the blended course design relies on an active learning paradigm. It was noted that a consistent amount of student 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 the high level of interaction in active, blended courses. The course design relied on the use of collaborative and interactive computer tools via a network, which when worked well helped to facilitate the design, but when the technology had disruptions, it halted progress.

A surprising discovery occurred in fall 2020. The move to Zoom for delivery of in-classroom content for distance and remote learning was a blessing in disguise. Most of the issues with connectivity failures were eliminated by no longer relying on WiFi, using a cabled Ethernet connection instead, and by taking advantage of the ease of connectivity via Zoom (e.g. sharing course content on screen, using the chat window to communicate, facilitating students group work using break-out rooms, joining break-out rooms to address remote students' questions in small groups, etc.). After a reasonable learning curve for Zoom, it was actually more efficient to deliver content remotely and to the distance location without interruption. Throughout the course of this study, two learning management systems were used, and multiple technology solutions and course management techniques were employed. The aspect of technology and course management in a blended course is a large part of what instructors must manage and be flexible to adapt to new tools and techniques, and in some cases, this flexibility can surprisingly make the course easier to manage!

7 Limitations of the Study and Future Directions

This study has several limitations that should be addressed in future research. First, as a case study of a single medium-enrollment course over several years, the sample sizes for each semester were small. Future research based on larger samples would allow for greater confidence in study findings. Second, data were collected from students in this study towards the end of the semester each term. Collecting data at multiple points during the semester could provide more nuanced information about how students used the course materials, challenges they faced, and other experiences with the course. Third, this research should be extended to examine student learning in relation to the various changes made over the years. Future research should also formally incorporate achievement outcomes to shed light on how using blended learning in a synchronous distance setting impacts the ultimate goal—student learning. Finally, as a case study, this research was based on a single course taught by a single instructor at one institution. Other instructors considering implementing blended learning in a synchronous distance setting at different institutions will have different options available for instructional technology and resources. Therefore, the results of this study cannot speak to how other instructional tools or choices might contribute to students' experiences in other courses or in other institutional contexts.

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