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RESEARCH

How Pivoting to Remote and Online Teaching Impacted Biological and Biomedical Engineering Students Engagement

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Due to the COVID-19 pandemic, millions of courses at all educational levels worldwide had to shift to remote teaching from face-to-face. Since the courses were not initially designed for online education, we need to understand the issues both students and instructors faced during this unplanned shift. Also, before the pandemic, only a portion of students had experience with online education, although it was successfully implemented in many different areas. This arbitrary shift provides an excellent opportunity for students to have an overall opinion about this course delivery method at a more significant ratio. This forced online learning experience offered potential opportunities (e.g., successful online lab experiences) and possible barriers (e.g., time, technology, mental health, limited interaction) that need further investigation. This paper presents the survey data collected during the Spring and Fall of 2020 from Biomedical/biological Engineering students to examine perceived barriers of online learning and impacts on course performance in order to provide support for students in the future online and remote experience.

1. Introduction and Background

A recently created distinction has been made between types of online course delivery, categorized as “online teaching” (or “online learning”) and “remote teaching” (or “emergency remote teaching”).[1] Online teaching refers to instruction designed from the start for online delivery. Online teaching also includes courses that were previously Face-to-Face (F2F) but have been taught online often enough to have the technical and pedagogical complications worked out. Students are reaching pre-determined educational goals in the far-reaching environment of academic online learning.[2] In comparison, remote teaching refers to instruction in an F2F course that has abruptly shifted online, which happened to millions of courses at all educational levels around the world in March 2020 due to the COVID-19 pandemic. As a result, communication became more complicated, requiring constant communication to resolve simple issues.[3] The outcomes of courses using remote teaching are not directly comparable to those of well-designed and planned online courses. Therefore, research has begun to contribute to our understanding of the issues faced by students and instructors when abrupt shifts to remote teaching occur. Further, while online teaching existed prior

to the COVID-19 pandemic, remote teaching has increased interest in understanding student experiences in courses that use online delivery.[4,5] This timely paper presents data from Biomedical/Biological Engineering (BME/BE) students who participated in remote teaching in Spring 2020 and online teaching during Fall 2020 to examine perceived barriers to learning and impacts on course performance. Our survey was designed and administered in real-time during the pandemic. The data in this paper contributes to the ongoing conversation about how best to support students in online and remote teaching environments.

Prior to the pandemic, online teaching was successfully implemented in both lecture and lab courses. Many previous studies in literature have investigated students' perceptions about the advantages and disadvantages of online classes.[6-8] Similar to F2F teaching, good online teaching requires instructors to implement proven teaching practices. For example, in a study examining student motivation during online courses, increased engagement was seen when the lecture and topic were related to students' lives.[9] Relating topics to students' lives is a good teaching practice regardless of course delivery method; personal relevance is one way to trigger situational interest, the first of four phases of interest development.[10] However, online teaching provides benefits that cannot be realized in F2F courses. For example, in asynchronous online classes, lectures can easily be divided into multiple shorter segments since instructors are not restricted by the traditional 50 to 90-minute scheduled lecture time. Shorter lectures have been shown to be more effective during asynchronous learning.[11] Online teaching has also been effective in allowing educators to allocate less time to material development and more time to interact with students. For example, the use of pre-existing online course material, rather than recording new lectures, has proven beneficial to students as it allowed educators to focus their time on helping students understand the material.[12] Online teaching has also been successfully used in tandem with F2F; Fogg and Maki found that students were more engaged and had higher course grades when pre-recorded lectures were assigned before the in-class lecture time.[13]

Prior to the pandemic, online learning for lab-based courses was less common, which are typically offered at the upper division.[14] Some have argued that online learning cannot fully replace hands-on experience in a lab setting.[12,15] However, in other cases, students performed better and reported more positive perceptions of online labs than their F2F counterparts.[16] Another study that surveyed an online vs. in-person biology lab course found that test scores and measures of motivation did not differ greatly between the groups, indicating that students can effectively learn from both online labs and in-person labs.[17]

Likely due to the pandemic-driven remote teaching transition, since mid-2020, there has been an increase in the number of studies related to online and remote teaching for laboratory courses. Researchers[18] found that for labs, through hybrid learning, students can have hands-on experiences; however, if the lab is entirely online, a recorded lecture can provide an overview of how to operate machines and conduct experiments. Others[19] used short lecture recordings in combination with home lab kits and recorded experiments for training as a successful alternative to F2F labs. In another study, a two-model, team-based biomedical lab course was created based on a flipped concept that allowed students to participate and collect data from home. The experiences from the students were positive, and feedback indicated students were willing to continue this method of learning after the pandemic.[20] Results from another study found that when using short videos of the instructor setting up and implementing the lab, there were no significant differences in the average scores of students between the F2F lab and the online lab.[15] Another study compared an online lab at the University of California Irvine to the in-person lab experience of students. Students completed pre-lab quizzes, analyzed data at home, completed post-lab quizzes, and turned in lab reports. Students gave feedback on the online course, and the results showed that most students had positive views of the online experience.[21] Allen and Barker concluded that lab topics might be related to the successful transition to remote teaching, with topics such as lab safety, how to culture cells, and other lab skill explanations especially suited for remote learning.[22] In their experience, students performed comparably well or better in the online courses compared to the traditional F2F course. Educators have identified multiple successful strategies for converting lab-based courses to successful remote learning experiences. One of these approaches is to use a backward course design that ensures educators and faculty align research activities with the learning outcomes. This also helps to provide adequate evidence of student achievements, visualized via curriculum mapping.[23] Remote teaching was unavoidable due to restrictions put in place during the pandemic. This caused many educators with no online teaching experience to learn about and use tools that support online course delivery. Despite the reports of success with online learning in lectures and lab courses, many educators still believe that online learning cannot replace F2F learning. Some reasoning includes:

- Technology / Infrastructure: Some countries are more prepared to use technology. They are more connected and have technology more widely available, while others may be behind. In times of crisis, the educator must focus on the best way to transmit lectures and make sure students understand the material.[24] Research has shown that technology can positively impact student engagement, motivation,

and academic performance through interactive e-learning activities, real-time feedback mechanisms, and access to a wealth of online resources.[25]

- Technology / Laboratory equipment: Especially for laboratory experiences, a downside to virtual instruction is the lack of hands-on experience in handling equipment. Students do not have lab equipment at home. Workarounds do exist, but they are less than ideal. For example, in one report, at-home lab kits were shipped to students who then created designs in 3D CAD software. Since the students could not print designs at home, the instructor shipped parts for testing. However, some limitations on device testing capabilities remained.[26,27]

- Stress and Mental Health: Online learning provides flexibility for students to study material at their own pace, thus allowing them time to focus on their personal well-being.[28] However, stress and mental health were concerns for many online learners. A survey of mental health of taking courses during the pandemic revealed increased stress and anxiety in students.[29,30] Twenty universities in Lebanon participated in a study and observed that undergraduate students were psychologically challenged by online learning methods, affecting their learning and achievements.[31-34]

- Limited Interaction with Faculty: A study focused on underrepresented and underprivileged students found that they felt they were on their own in finding the most effective way of learning material.[21,35] Several studies have indicated that students like the flexibility of recorded lectures, but many prefer synchronous learning due to the interaction it provides with the instructor.[2,3]

These four barriers represent the primary concerns that are reported in the literature when university educators compare remote learning to F2F instruction. They also represent the major concerns that we had for remote learning while in the midst of the forced transition in March 2020.

An additional barrier that we identified but have not seen reported in the literature is "Time Constraints." Tips for learning (and teaching) from a neurological perspective include the fact that it takes time to assimilate new knowledge and store it in long-term memory.[24,25] As educators, we noted that transitioning to remote teaching in Spring 2020 required devoting significant additional time to instructional responsibilities. Thus, we hypothesized that students needed to commit extra time to their remote learning classes. Since there are a set number of hours in a day, this additional time commitment would subtract time from students' other responsibilities. This shift in time could negatively impact students' perception of their classes

or the online instructional tools.[36,37] Further, if students did not devote additional time to learning these tools, then they would likely not be as successful in remote learning classes as they would have been in F2F classes.

Recent studies on online and remote learning demonstrate their growing potential as reliable methods in academia. While online learning was already prevalent before the pandemic, both online and remote learning have now become widely accepted and accessible in higher education. Notably, offering lab-based courses through remote teaching has become more acceptable, enhancing the quality of lab instruction, particularly in engineering programs. A gap in the literature addressed in this paper is the revision of engineering curricula to incorporate the advantages of remote learning.

In summary, online and remote teaching (and learning) are two different but similar concepts.[38] Typically, online course delivery is successful when it is deployed in a thoughtful manner with the course activities designed specifically for online learning. By forcing all learning experiences online, remote teaching has exposed potential opportunities (e.g., successful online lab experiences) and possible barriers (e.g., time, technology, mental health, limited interaction) that should be further explored. The intention of the study was to capture the potential impact the COVID-19 pandemic had on students' learning at a university with high research activity located in a rural state with limited high-speed internet outside of the university community. Specifically, we examine the following hypotheses:

> H1 Remote learning students must dedicate extra time to accommodate learning in the new online environment.
>
> H2 Remote learning students must dedicate more time to complete their course than online learning students.
>
> H3 Students perceive technology as a barrier to online learning.
>
> H4 Students believe online systems negatively impact student learning.
>
> H5 Students believe they and their university were adequately prepared to cope with the COVID-19 adjustments.
>
> H6 Students believe factors outside their course negatively impacted their course performance during COVID-19.

This paper builds on recently published papers focused on student perceptions of online course features for technology students (e.g.,[24,26]) and engineering students (e.g.,[28,29]). While there has been some investigation into how the pandemic and the pivot to online instruction specifically impacted BME/BE students in first-year courses[13] and laboratories,[22] this paper furthers the conversation about the pandemic impacts by investigating

impacts on upper-level students (primarily seniors) who enrolled in lecture-based courses. This population should arguably have the easiest transition as they were more mature university students who were already familiar with university life and learning management systems used in their classes. Our investigation into barriers identified in prior investigations combined with the time barrier provides data that can be compared with existing investigations to create a more complete understanding of the pandemic impacts.

2. Study Context

To adjust to the potential impacts of COVID-19, the University where the study was conducted extended the spring break of 2020 for an additional week and announced that the remainder of the semester would be completed online. Thus, instructors and students had approximately ten days to adapt to the new instructional system, which was very challenging. Clearly, there were issues that resulted from the quick transition and required adaptation to the new system. In the subsequent semester taught in Fall 2020, the University transitioned to mixed instruction; some classes stayed entirely online while some hybrid classes, a combination of F2F and online, were offered. To examine instructional impacts on students in "forced" online courses, in this paper, we focused on two lecture-based Agricultural and Biological Engineering (ABE) courses that were offered fully online. The two courses were "Transport in Biological Engineering" (ABE 3303) and "Physiological Systems in Biomedical Engineering" (ABE 4323).

In ABE 3303, "Transport," the course initially started in January 2020 as three hours F2F lecture with two office hours available to all students and possible extra help outside the office hours. All course materials were available online via Canvas (the learning management system used at the study site). To transition to remote learning, the instructor set up WebEx classes during regular class hours. During the WebEx classes, class sessions were recorded and posted online for anyone who needed to go back through the lecture. Also, Microsoft OneNote (created explicitly for this class) was used to write lecture material through the WebEx classes. These lecture notes were also available through OneNote for the course. Office hours were provided like before through WebEx sessions, while additional study sessions were offered extra help. For the Fall 2020 offering, the lectures were again set up via WebEx during regular class hours, and class sessions were recorded and posted online for anyone. For the lecture notes, PowerPoint slides were used while all course materials were available online via Canvas. The course syllabus was reduced compared to the spring semester, and the extra class hours were used to answer questions and provide additional help.

In ABE 4323, "Physiological Systems," we only surveyed students in Fall 2020, so the course was an online course from the beginning of the semester with no "transition." It was the first semester to be offered as a fully online course. Students were required to have access to a computer that connects

to the internet, have an up-to-date browser, operating system, and additional software, including Microsoft Office and WebEx. The course materials were accessible through Canvas, and all assignment submissions were utilized there. Students were obligated to log in to Canvas no less than three times per week to access course information, lectures, and updates. They could correspond to the instructor directly via the mail feature in Canvas and communicate with each other via the general course discussion board. The course assignments included homework, quizzes, and final exam. Homework was question sets pertaining to each reading and were assigned and submitted via Canvas. Quizzes were fully online and given after each main topic for a total of 4 quizzes over the semester. Although there was no "drop" grade for quizzes, students were allowed to select one quiz to retake. The final exam was optional if the student had an "A" for pre-final grade calculated from quizzes (70%) and homework (30%). For these synchronous class events, students had to mute their mic upon entering the online classroom and use the chat box for any questions. However, they were allowed to use their microphone for any remaining questions at the end of the class. All this information/ instruction was available to the students via Canvas ten days before the beginning of the semester.

3. Methods

The primary research question focused on the extent to which students perceived various aspects of remote teaching and its impact on their learning experience. The motivation for this study arose from the significant and sudden shifts in instructional methods during and after the pandemic. Key concepts explored included online teaching, remote learning, student performance, and the potential benefits and challenges of these approaches. A thorough literature review was conducted, identifying recurring themes and influential factors. Based on this, the research team developed a structured action plan and research agenda. A quantitative approach was selected to capture a broad spectrum of student responses. A survey instrument was then designed and developed, aligned with the identified themes. To ensure clarity and relevance, the survey was reviewed by a small group of eligible participants and subject matter experts. After incorporating their feedback, the final survey was prepared for distribution to a sample of students in engineering programs.

In order to better understand the impact of the remote instructional change on students and their education, in Spring 2020, we surveyed BME and BE (Biological Engineering) students at a large southern land grant institution. The Institutional Review Board for the Protection of Human Subjects in Research (IRB) at the study site reviewed and approved the study (IRB-20-474). The survey had 14 questions and was designed to take approximately 5 minutes to complete. The link to the online questionnaire was made via Qualtrics Survey Software and was shared with students via the Canvas course announcement board. All respondent information was

Table 1. Details of courses surveyed for this study

Semester	Course Name	Meeting dates	Meeting time	Number of students
Spring 2020	ABE 3303	MWF	3:00 - 3:50 PM	33
Fall 2020	ABE 3303	MWF	11:30-12:20 PM	58
Fall 2020	ABE 4323	MWF	9:10 - 10:00 AM	83

anonymous, the participation was voluntary, and it did not impact students' course performance. We collected these data to understand students' perceptions of remote education and how to improve the online educational system by reinforcing the positive aspects and minimizing possible issues.

3.1. Participants

The questionnaire responses are from 72 students, including 20 responses from the Spring semester and 52 responses from the Fall semester. All 20 students from the Spring semester were in the "Transport in Biological Engineering" class (ABE 3303). Out of 52 students from the Fall semester, 15 students were in the "Transport in Biological Engineering" class (ABE 3303), and the rest of 37 students were in the "Physiological Systems in Biomedical Engineering" class (ABE 4323). Course details can be found in Table 1.

Participants included 49% males (n=35) and 51% females (n=37), of which they were 2.8% Sophomores (n=2), 23.6% at the junior level (n=17), and 73.6% were senior students (n=53) in the biomedical/biological engineering major.

3.2. Survey Instrument

Based on our experiences transitioning our courses to remote teaching and conversations with colleagues who were doing the same in March 2020, we designed a survey to collect data from students about their experiences transitioning to remote learning. We were interested in understanding if time demands and technology requirements were negatively impacting students. We also asked students how prepared they were for coping with the transition and their perceptions of how well their instructor, department, college, and University were prepared for the transition. Finally, we asked students if factors outside the course impacted their performance in the course.

These questions were designed to be limited in scope but based on a big enough database to be suitable for statistical tests of significance. The students of the Spring 2020 semester went through the transition when they were halfway through the semester. Thus, the courses had the opportunity to cover the basics in person, while the Fall semester students had the whole semester online. However, Fall students had the experience of online systems in the previous semester. This is why we performed an identical survey at the end of the Fall semester to capture any potential differences in student perceptions about their learning.

Table 2. Survey questions with mapping to original research questions

Hypothesis	Survey Question	Question
H1 & H2	SQ1	Did you need to spend extra hours to accommodate the online system for this class?
	SQ2	If you answered yes, on average, how many extra hours you needed for this class?
H3	SQ3	To what extent have you had proper Internet access/Software/Guidelines to do this class online?
	SQ4	To what extent have you had proper Hardware/Equipment to do this class online?
H4	SQ5	How significant do you estimate the impact of the online system on your performance for this class?
	SQ8	After this experience, do you consider taking more online classes rather in-person classes?
	SQ9	To what extent do you think the online system negatively impacted your overall grade in this course?
	SQ10	To what extent do you think the online system negatively impacted your overall GPA?
H5	SQ6	Please rate to what extent each item was prepared to cope with/adjust to the COVID-19 situation: Personal life, Instructor, Department, College, University.
H6	SQ7	Please rate to what extent each item negatively impacted your performance due to the COVID-19 crisis: Family, health, technical, subject difficulty, low productivity, course design, communication, time management, resources, class interaction.

The first three questions were demographic questions that asked 1) which course they were completing the survey for, 2) their gender, and 3) their academic level. The rest of the survey questions and their mapping to research questions are provided in Table 2.

3.3. Statistical analysis

Bar charts were created to represent the responses to SQ1-SQ5 and SQ8-SQ10. Stacked charts were created to represent the responses to SQ6 and SQ7. Bar charts were used to measure the different response percentages of students in the online courses between the Spring and Fall semesters, and the responses for each of the survey questions were separated by course. Each chart shows the percentage of students who responded to each question and separates the data by the course and semester, i.e., Spring ABE 3303, Fall ABE 3303, Fall ABE 4323. To analyze the responses to SQ6-SQ7, stacked charts were generated to properly illustrate the diverse categories (a measure of significance or impact and the item in question). The stacked charts demonstrate the category of the response (very low to very high) percentage that corresponds to the category of the item in question (e.g., personal life, instructor, family, health). We also included tables to show the percentage of students who rated each category for SQ6-7.

To analyze the correlation between the research questions, Spearman's rho tests were conducted using IBM SPSS statistics 27. The main interest was determining if a correlation exists between the following survey responses:

- SQ3, SQ4, and SQ5 to determine if technology infrastructure (e.g., Intranet access) combined with technology equipment (e.g., computer equipment) negatively impacts student performance in the course;

- SQ8, SQ9, and SQ10 to determine if 'students' preference for taking courses online in the future was related to perceived negative impacts on their grades;
- SQ5, SQ9, and SQ10 to determine if 'students' perceived impacts from the online system were related to perceived impacts on learning.

Separate Spearman's rho tests were conducted to represent different correlations for the combination of the ABE 3303 and ABE 4323 classes. For all these analyses, the IBM SPSS Statistics 27 software (2020 IBM SPSS Statistics for Windows, IBM Corp, Armonk, NY) and Microsoft Excel were used to plot the charts.

4. Results

SQ1: Percent of Students Requiring Additional Time Commitment

Figure 1 shows the number of students who needed to spend additional time to accommodate the online system versus those who did not need additional hours (SQ1). Figure 1 shows that students in ABE 3303 required more time to accommodate the online system (65.00% and 73.33% for Spring and Fall semesters, respectively), while ABE 4323 students had evenly mixed experiences (only 48.67% needed extra time). For ABE 3303, For ABE 3303, most students (77.33%) needed extra hours to accommodate the class and coursework, even though students were more familiar with the online system for the Fall semester.

SQ2: Amount of Additional Time Commitment Required

Figure 2 shows the average amount of extra hours students who answered yes to SQ1 needed to spend per week to accommodate the online system (SQ2). Overall, the majority of students spent less than one hour (44.45%) or up to two hours (36.12%) extra for the online courses. For ABE 3303, during the Spring semester, 50.00% of the students needed less than one extra hour, 20.00% needed 1-2 extra hours, 20.00% needed 2-3 extra hours, and 10.00% needed more than 3 extra hours. While, for the same course during the Fall semester, 20.00% of students needed less than one extra hour, 60.00% needed 1-2 extra hours, and 20.00% needed 2-3 extra hours. From the Fall ABE 4323 class, 51.35% required less than one extra hour, 35.14% required 1-2 extra hours, 10.81% needed 2-3 extra hours, and 2.70% required more than 3 extra hours. This trend is similar to Spring ABE 3303.

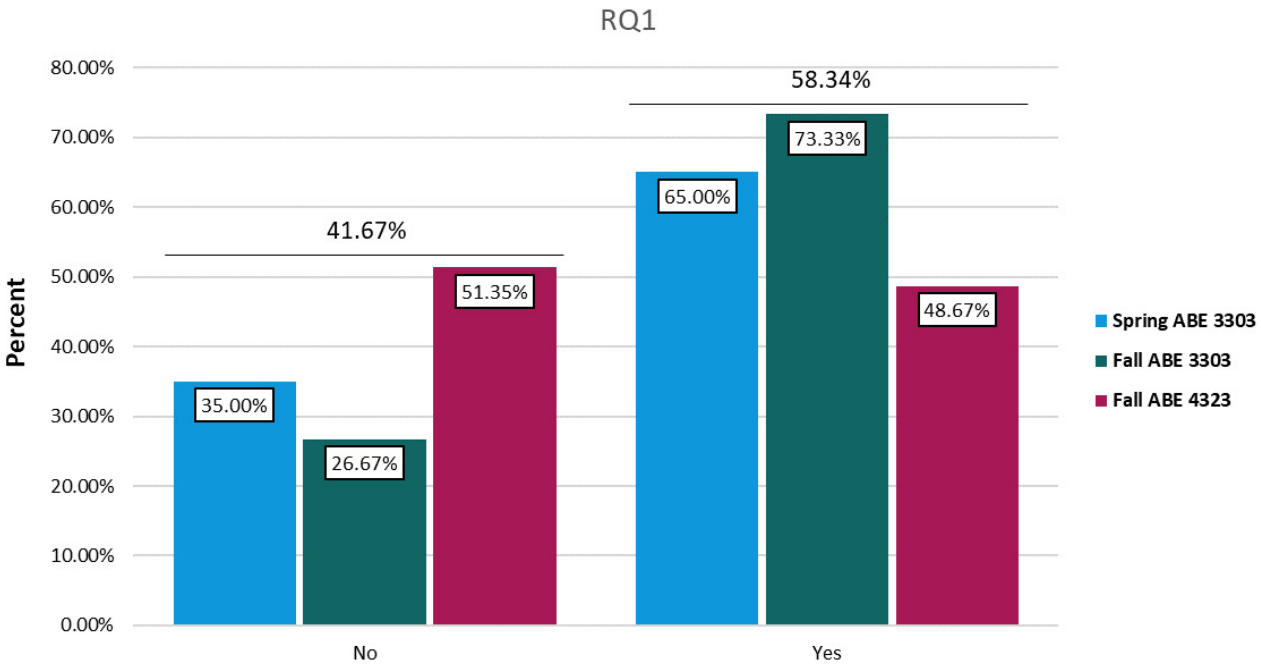

Figure 1. (SQ1) Number of students who did and did not need extra hours to accommodate the online system for (a) Spring ABE 3303, (b) Fall ABE 3303, (c) Fall ABE 4323. Generally, students in ABE 3303 required more time to accommodate the online system, while ABE 4323 students had evenly mixed experiences.

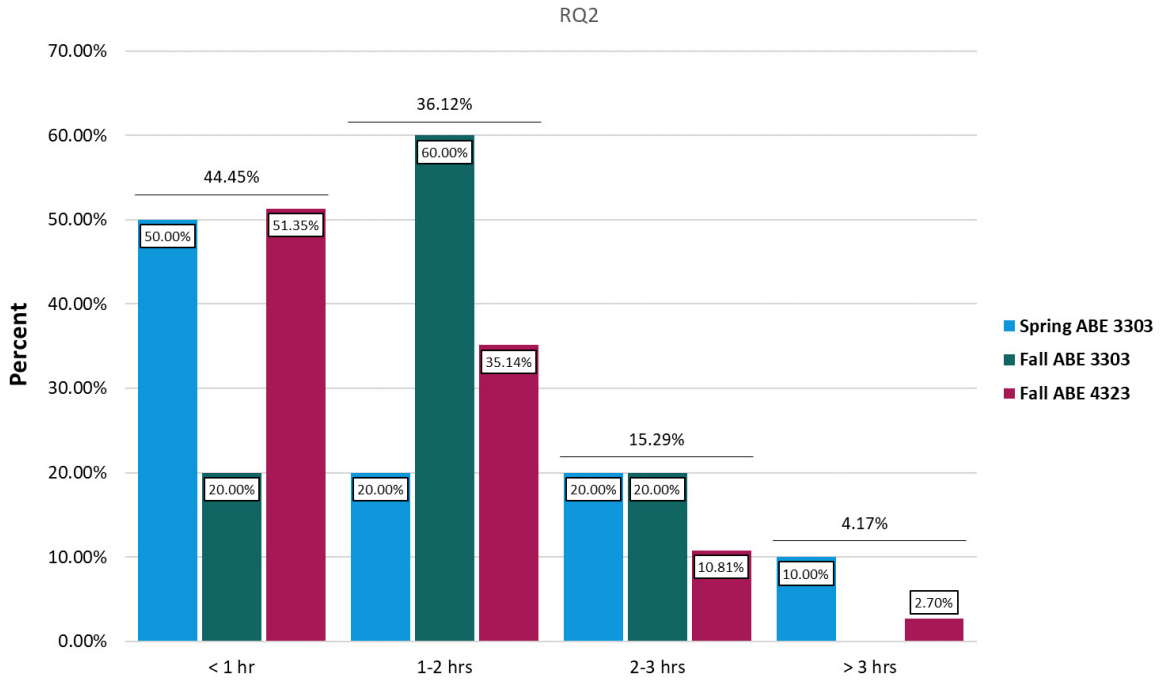

Figure 2. Comparison of additional hours required to accommodate online system (SQ2) for those answering yes to SQ1 in (a) Spring ABE 3303, (b) Fall ABE 3303, (c) Fall ABE 4323 courses. Most students across all examined courses required less than 2 additional h hours to accommodate the online system.

SQ3: Technology / Infrastructure Barriers

Figure 3 shows to what extent students had proper internet access/software/guidelines to take online courses (SQ3). Overall, most students (97.22%) expressed they had the proper technological infrastructures (total percentage from moderate to very high categories). In the Spring ABE 3303 class, 10.00% of the students specified having very low internet access/software/guideline to take the courses online, 0.00% specified it as low, 25.00% specified it as moderate, 45.00% specified it as high, and 20.00% specified it as very high. In the Fall ABE 3303 class, 0.00% of the students specified having very low internet access/software/guideline to take the courses online, 0.00% specified it as low, 40.00% specified it as moderate, 33.33% specified it as high, and 26.67% specified it as very high. In the Fall ABE 4323 class, 0.00% of the students specified having very low internet access/software/guideline to take the courses online, 0.00% specified it as low, 27.03% specified it as moderate, 32.43% specified it as high, and 40.54% specified it as very high.

SQ4: Technology / Equipment Barriers

Figure 4 shows to what extent students had the proper hardware/equipment to take the online classes (SQ4). As with the technology/infrastructure barriers, most students (27.23%) expressed they had proper technological equipment (total percentage from moderate to very high categories). In the Spring ABE 3303 class, 5.00% of the students specified having very low hardware/equipment to take the courses online, 5.00% specified it as low, 10.00% specified it as moderate, 55.00% specified it as high, and 25.00% specified it as very high. In the Fall ABE 3303 class, 0.00% of the students specified having very low hardware/equipment to take the courses online, 0.00% specified it as low, 26.67% specified it as moderate, 53.33% specified it as high, and 20.00% specified it as very high. In the Fall ABE 4323 class, 0.00% of the students specified having very low hardware/equipment to take the courses online, 0.00% specified it as low, 13.51% specified it as moderate, 35.14% specified it as high, and 51.35% specified it as very high.

SQ5: Online System Impact Course Performance

Figure 5 shows the degree of impact the online system had on the students' class performance (SQ5). Most students overall (44.45%) specified the effect on their class performance as moderate. In the Spring ABE 3303 class, 0.00% of the students specified a very low impact on their class performance, 10.00% specified it as low, 60.00% specified it as moderate, 25.00% specified it as high, and 5.0% identified it as very high. In the Fall ABE 3303 class, 0.00% of the students specified very low impact on their class performance, 13.33% specified it as low, 46.67% specified it as moderate, 28.87% specified it as high, and 13.33% specified it as very high. In the Fall ABE 4323 class, 2.70% of

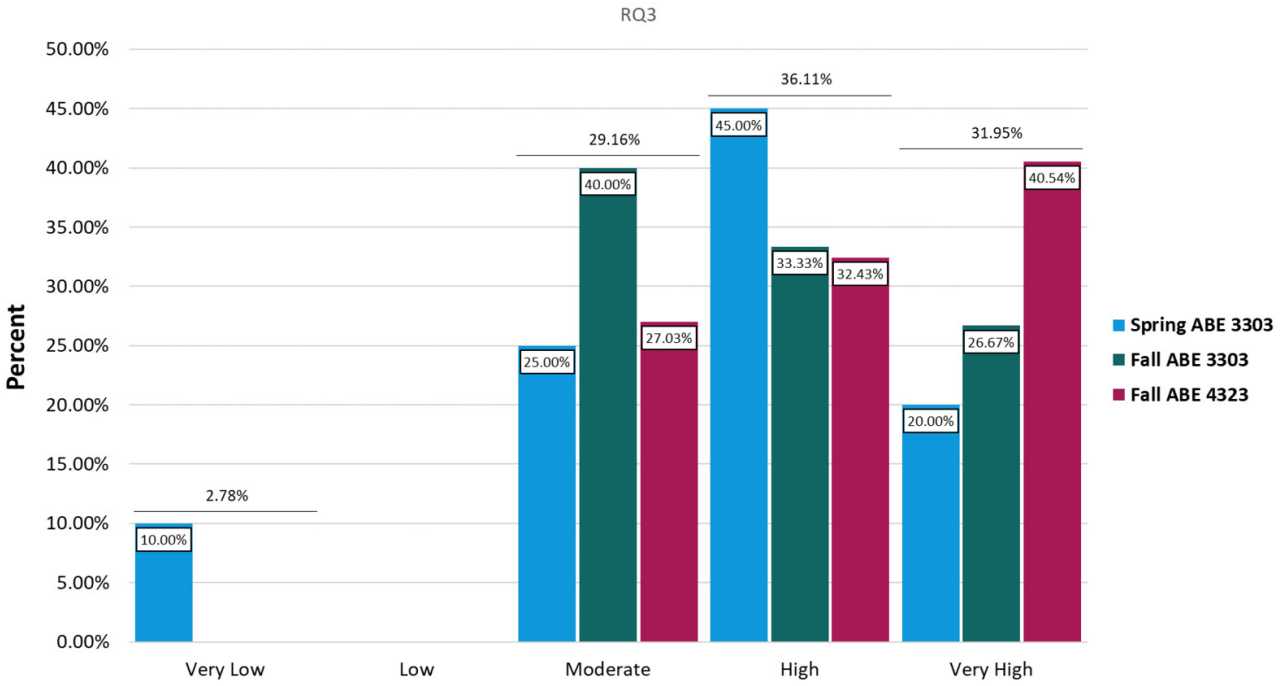

Figure 3. Comparison of the extent that students had proper internet access/software/guidelines for online classes (SQ3) for (a) Spring ABE 3303, (b) Fall ABE 3303, (c) Fall ABE 4323 courses. Most students in each course had adequate internet access/software/ guidelines for online classes.

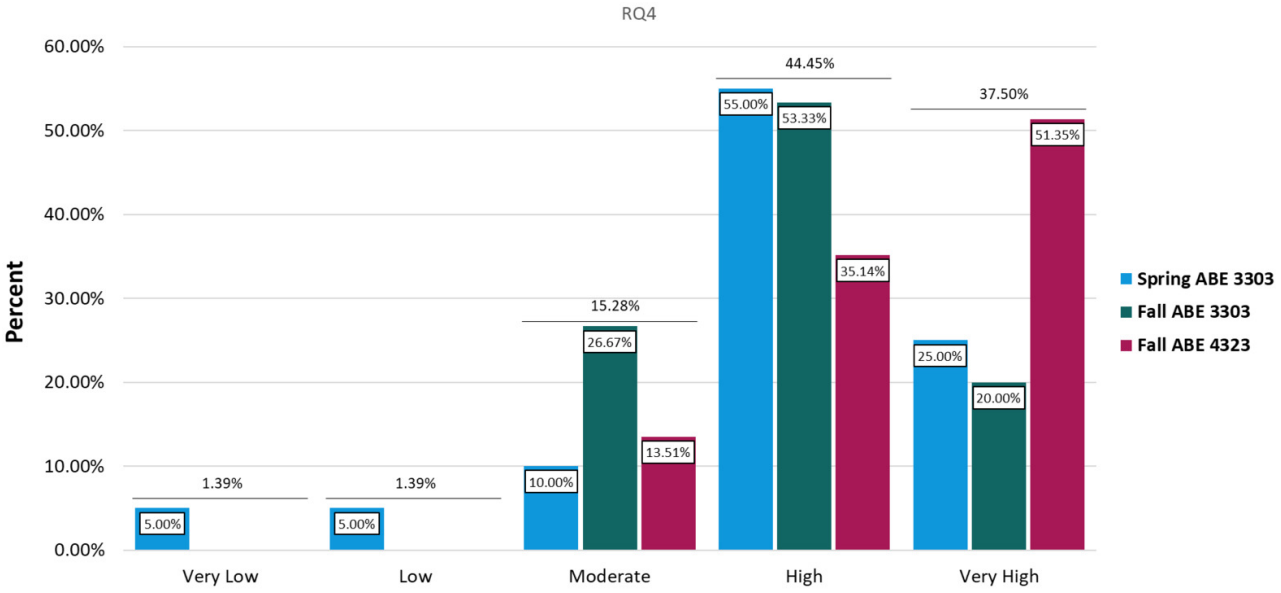

Figure 4. Comparison of the extent that students had proper hardware/equipment to take online classes (SQ4) for (a) Spring ABE 3303, (b) Fall ABE 3303, and (c) Fall ABE 4323 courses. Most students possessed adequate hardware/ equipment for online classes across the observed courses.

the students specified a very low impact on their class performance, 24.32% specified it as low, 35.14% specified it as moderate, 18.92% specified it high, and 18.92% identified it as very high.

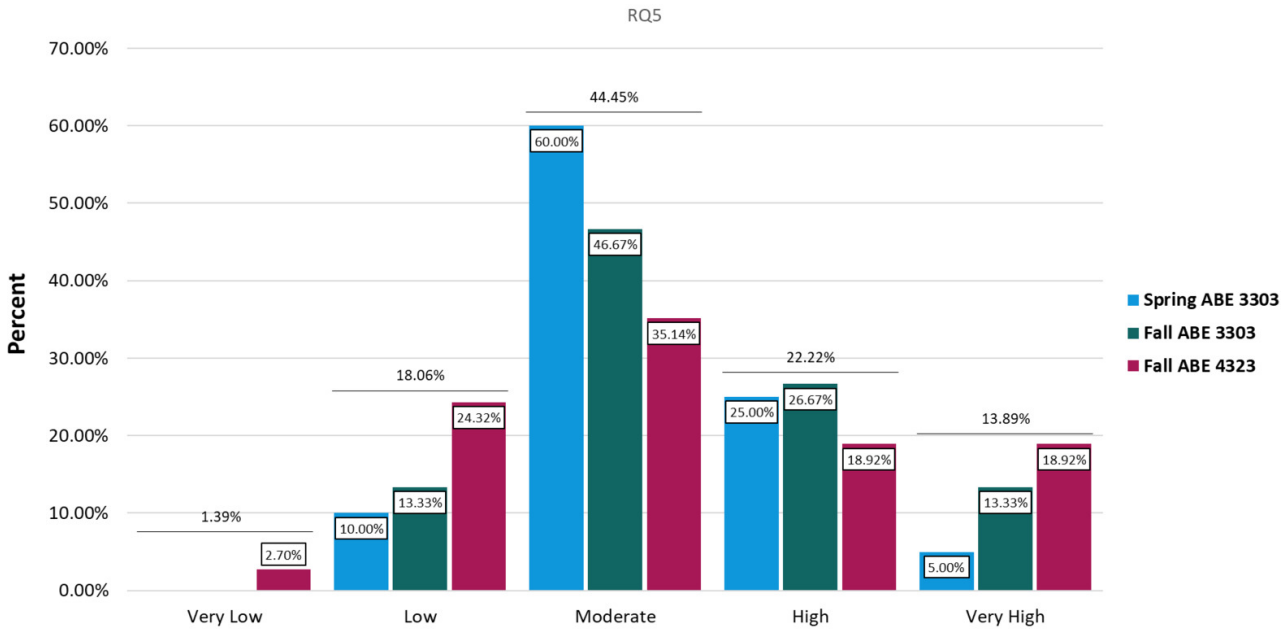

Figure 5. Comparison of student estimated degree of impact online systems had on class performance for (SQ5) for students in (a) Spring ABE 3303, (b) Fall ABE 3303, and (c) Fall ABE 4323 courses. Generally, students estimated online systems had a moderate to high impact on their class performance.

SQ6: Ability to Cope with COVID-19 Adjustments

Figure 6 represents to what extent the students, overall, believed each item was prepared to cope with/adjust to the COVID-19 situation: Personal life, Instructor, Department, College, and University (SQ6). From the combination of the three classes and two semesters, most students (40.30%) observed that the University was moderately prepared to adjust to the COVID-19 situation. The same was observed for the college (40.30%), department (40.30%), and personal life (48.60%). On the other hand, most of the students (63.80%) observed that their instructor was at least highly prepared to adjust to the COVID-19 situation.

SQ7: External Factors Negatively Impacting Course Performance

Figure 7 represents to what extent the students, overall, believed each item negatively impacted their performance due to the COVID-19 crisis: Family, health, technical, subject difficulty, low productivity, course design, communication, time management, resources, and class interaction (SQ7). From the combination of the three classes and two semesters, a large portion of students (34.70%) observed that lack of class interaction had a moderate negative impact on their performance. The same was observed for time management (31.90%), course design (38.90%), subject difficulty (48.60%), technology (30.60%), and family (29.20%). On the other hand, the number of students was tied between a moderate (33.30%) or low (33.30%) negative impact on their performance due to communication. Most students (34.70%)

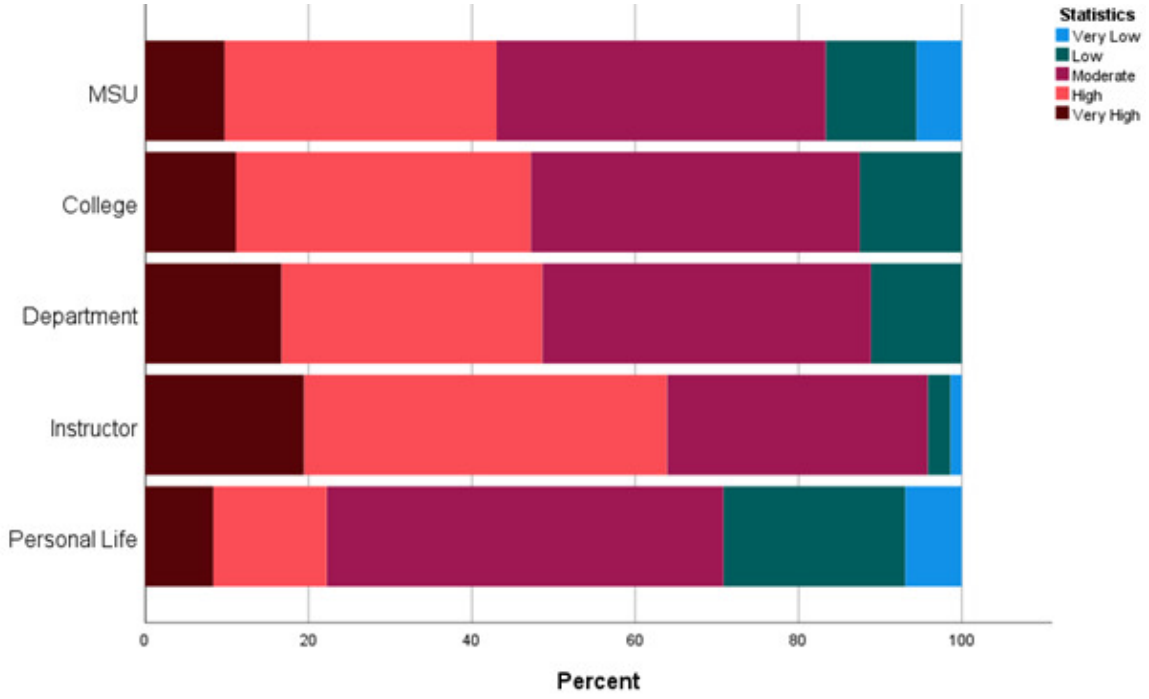

Figure 6. Comparison of the extent to which University, College, Department, Instructor, and Personal Life items were prepared to cope with/adjust to the COVID-19 situation (SQ6). Most students perceived that the external items adequately adjusted to COVID-19; however, more students felt negative about their preparedness to adjust their own lives to the COVID-19 situation.

observed that resources had a low negative impact on their performance, 30.60% observed that low productivity had a very high negative impact, and 27.80% observed that health had a low negative impact.

SQ8: Preference for Online versus F2F Courses

Figure 8 shows the number of students who consider taking more online classes rather than in-person classes after their experience pivoting to online classes due to the COVID-19 hit (SQ8). It can be seen that most students stated the chances they take online classes over in-person classes are low (38.89%) or very low (23.61%). Interestingly, students in the Spring semester were about 5% and 13% more willing to take online classes in the future than those in the Fall ABE 3303 course and Fall ABE 4323 course, respectively, since their semester was suddenly interrupted and transferred to an online setting. One potential reason for the higher willingness in the spring could be the adoption of a semi-online mode, which offered perceived opportunities compared to the regular face-to-face mode. Another possible reason is the abrupt shift in teaching methods, which disrupted students' learning processes. This disruption may have led to a preference for the online mode as it represented a more stable situation.

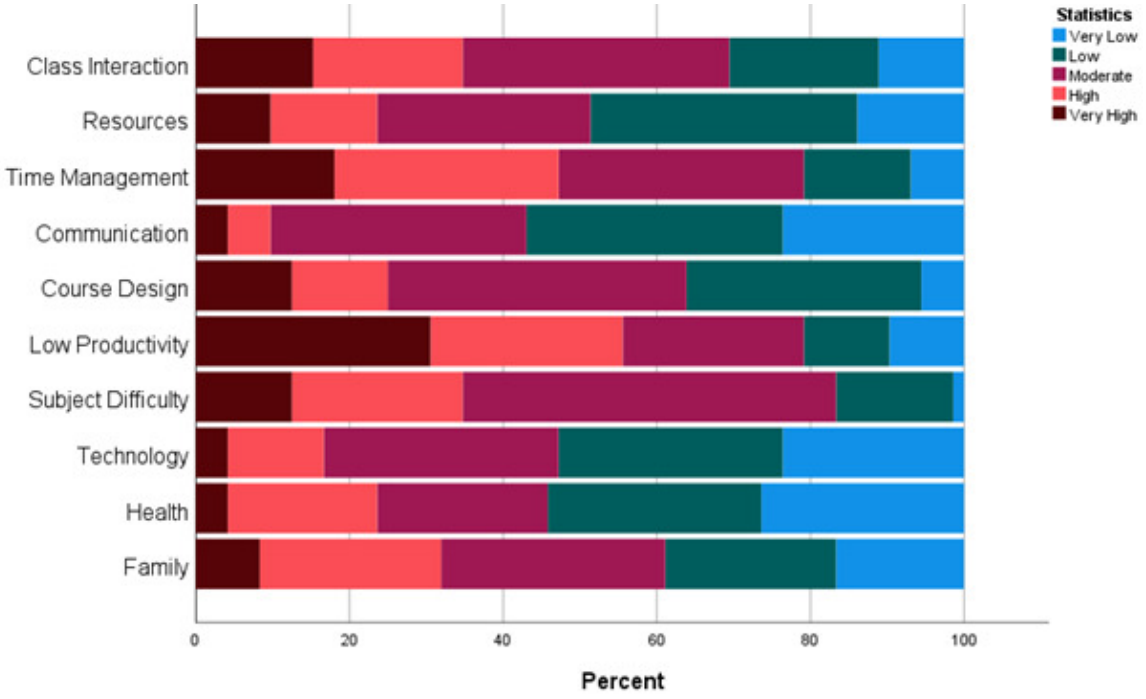

Figure 7. Comparison of the degree to which class interaction, resources, time management, communication, course design, low productivity, subject difficulty, technology, health, and family affected student performance during the COVID-19 crisis (SQ7). Generally, students found that resources, communication, technology, and their own health had low effect on their overall performance. Time Management and low productivity were perceived to have a significant impact on student performance.

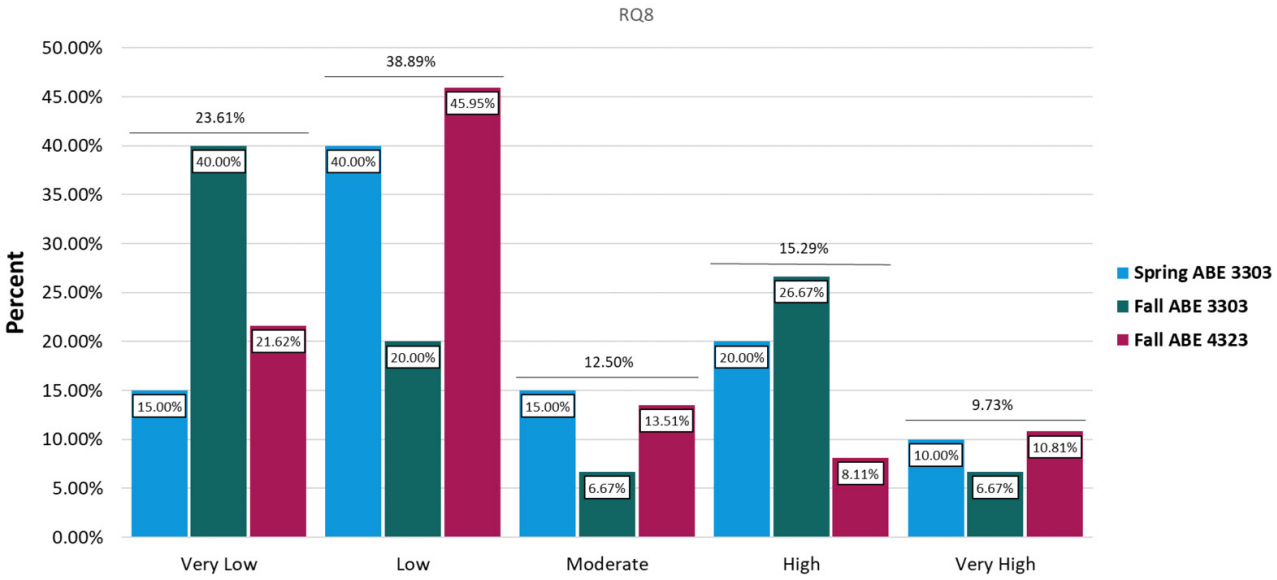

Figure 8. This figure illustrates whether the students would consider taking more online than in-person classes (SQ8). After their experience with online classes, majority of the students still prefer in-person classes.

SQ9: Online System Impacts on Course Grade

Figure 9 shows to what extent students think the online system negatively impacted their overall grade in that specific course. The range of answers for this research question was different and somewhat equally distributed among

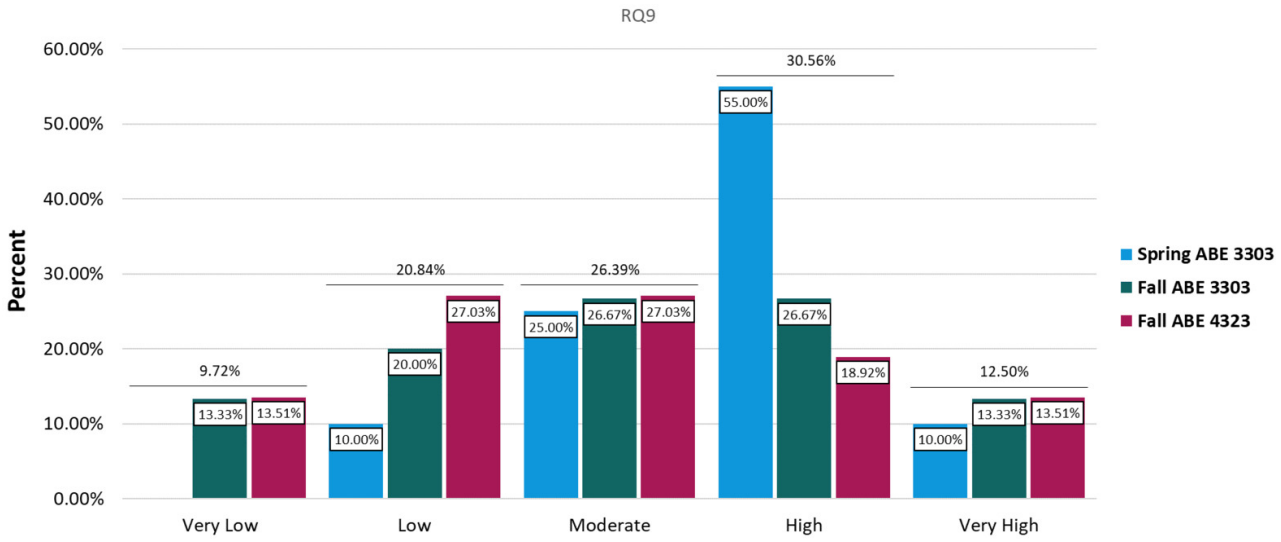

Figure 9. This figure illustrates to what extent students think the online system negatively impacted their overall grade in the course (SQ9)

the low, moderate, or high categories. However, 55.00% of students in the Spring ABE 3303 course, the remote learning course, reported that pivoting to the online system highly impacted their overall course grade negatively.

SQ10: Online System Impacts on GPA

Figure 10 shows to what extent students think the online system negatively impacted their overall GPA. For the remote learning course, Spring ABE 3303, 70.00% of students reported a moderate or high negative impact on their overall GPA. This was similar for the Fall ABE 3303 online offering – with 60.00% of students reporting a moderate or high impact on GPA. In the ABE 4323, fewer students reported a moderate to high impact (40.54%), but many said a very high GPA impact (16.22% versus less than 7% for each ABE 3303 course). Although the impact of remote learning on students' GPA and grades could be further explored by comparing perceived outcomes with actual grades, such comparisons were deemed out of scope. This is because collecting data that identifies individual students could introduce bias in their survey responses.

SQ3, SQ4, and SQ5 Correlation: Technology Impacts Related to Course Performance

Table 5 shows the correlation matrix examining whether perceived technology impacts were related to course performance. There was a significant but weak association between having proper internet access/software (SQ3) and having proper hardware/equipment (SQ4) ($r = +0.496$, $n=72$, $p<0.000$, two-tailed). However, there was no significant relationship between having proper technology and the students' performance in the Fall and Spring online courses (SQ5).

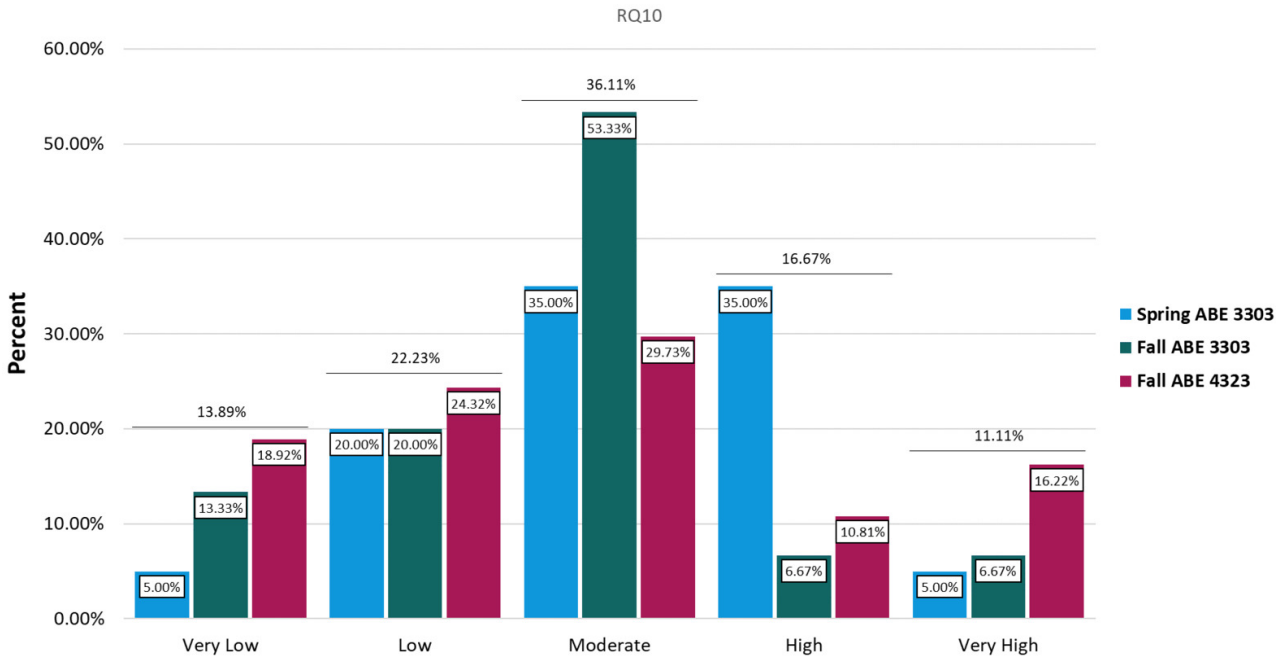

Figure 10. This figure illustrates to what extent students think the online system negatively impacted their overall GPA (SQ10).

SQ8, SQ9, and SQ10 Correlation: Preference for Online Related to Grades

Table 6 shows the correlation matrix examining whether preferences for online or F2F learning were related to the perceived impact of online learning on grades. Regarding performance within the three ABE courses in this study, there was no association between a student preferring F2F courses (SQ8) and the online system negatively impacting the students' course grades (SQ9). There was a weak association between preferring F2F (SQ8, reverse coded) and impacts on overall GPA (SQ10) ($r= -0.264$, $n=72$, $p=0.025$, two-tailed). Further, when considering only the Fall ABE 3303 course, a moderate correlation ($r=+0.557$, $n=15$, $p=0.031$, two-tailed) between the preference for F2F (SQ8, reverse coded) and reports of the online system negatively impacting the overall GPA of a student (SQ10). There is a strong correlation between reports of negative impacts on course grades (SQ9) and reports of adverse effects on overall GPA (SQ10) ($r= 0.639$, $n=72$, $p<0.000$, two-tailed).

SQ5, SQ9, and SQ10 Correlation: Technology Impacts Related to Learning Impacts

Table 7 shows that there is a significant association between the impact of online components on a student's performance in the Fall and Spring classes (SQ5) and the online system negatively impacts the overall grade of a student in their ABE class (SQ9) ($r=+0.497$, $n=72$, $p<0.000$, two-tailed) and their overall GPA (SQ10) ($r=+0.403$, $n=72$, $p<0.000$, two-tailed).

Table 5. Fall and Spring classes combination correlations for research questions SQ3, SQ4, and SQ5.

			SQ3	SQ4	SQ5
Spearman's rho	SQ3	Correlation Coefficient	1.000	0.496**	-0.054
		Sig. (2-tailed)	0.000	0.000	0.651
		N	72	72	72
	SQ4	Correlation Coefficient	0.496**	1.000	-0.190
		Sig. (2-tailed)	0.000	0.000	0.111
		N	72	72	72
	SQ5	Correlation Coefficient	-0.054	-0.190	1.000
		Sig. (2-tailed)	0.651	0.111	0.000
		N	72	72	72

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6. Fall and Spring classes combination correlations for research questions SQ8, SQ9, and SQ10.

			SQ8	SQ9	SQ10
Spearman's rho	SQ8	Correlation Coefficient	0.000	0.192	0.264*
		Sig. (2-tailed)	0.000	0.106	0.025
		N	72	72	72
	SQ9	Correlation Coefficient	-0.192	1.000	0.639**
		Sig. (2-tailed)	0.106	0.000	0.000
		N	72	72	72
	SQ10	Correlation Coefficient	-0.264*	0.639**	1.000
		Sig. (2-tailed)	0.025	0.000	0.000
		N	72	72	72

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. Fall and Spring classes combination correlations for research questions SQ5, SQ9, and SQ10.

			SQ5	SQ9	SQ10
Spearman's rho	SQ5	Correlation Coefficient	1.000	0.497**	0.403**
		Sig. (2-tailed)	0.000	0.000	0.000
		N	72	72	72
	SQ9	Correlation Coefficient	0.497**	1.000	0.639**
		Sig. (2-tailed)	0.000	0.000	0.000
		N	72	72	72
	SQ10	Correlation Coefficient	0.403**	0.639**	1.000
		Sig. (2-tailed)	0.000	0.000	0.000
		N	72	72	72

**. Correlation is significant at the 0.01 level (2-tailed).

5. Discussion

H1: Remote learning students must dedicate extra time to accommodate learning in the new online environment

Confirming our hypothesis, 65% of students enrolled in the remote learning course (Spring ABE 3303) agreed that they needed to dedicate extra time to accommodate learning in the new online environment. However, half of the students indicated they only needed an additional hour, and only 10% needed more than 3 hours per lecture. This suggests that online learning, even when forced mid-way through the semester, may not require significant, burdensome additional time demands. This finding alleviates some concern that online learning environments may detract from learning; if students are not spending considerable extra time struggling with the learning environment, then the learning environment is not taking time away from learning. However, we did not track individual student academic records, so it is possible that the students who indicate large amounts of extra time required (2-3 hours or 3+ hours) are at-risk students who are especially vulnerable to any activity that requires additional time detracts from learning.

H2: Remote learning students must dedicate more time to complete their course than online learning students

We hypothesized that students who began their class in the online format (Fall 2020) rather than pivoting to remote learning as the Spring ABE 3303 students did, would report less extra time needed to be devoted to their course in the online format. We believed that students would have become familiar with the online system during remote teaching and that online courses, which had more development time available than their remote counterparts, could be more effectively designed to accommodate learners. Comparing ABE 4323 to Spring ABE 3303, we did see that fewer students needed additional time to complete the course. However, for both courses, most of the students who needed additional time needed less than one additional hour. Surprisingly, a higher percentage of students in the Fall ABE 3303 course indicated that the online course required more time than the F2F counterpart. Further, those Fall students showed 1-2 additional hours compared with the less than 1 additional hour Spring ABE 3303 reported needing. Perhaps this finding is due to the Spring ABE 3303 students completing some in-person sessions, making it easier for them to accommodate the online system. It could also be related to changes in remote teaching expectations, which were created in an emergency setting, versus the more planned online offering. Finally, the additional time requirement could be related to the specific course content, course difficulty level, or differences with instructor expectations.

H3: Students perceive technology as a barrier to online learning

Although very few students reported technology as a barrier to online learning, all of the students who did report the barrier were part of the remote learning Spring ABE 3303 course. With regards to technology /infrastructure, the majority of the students specified their internet access/ software/guidelines were adequate for online classes (31.95% very high, 36.11% high, and 29.16% moderate), while only 2.78% of students reported that they had very low proper internet access/software/guidelines for online classes and they were all from the Spring ABE 3303 class (10.00% of the students from that class). Similarly, for technology/equipment, most of the students had proper hardware/equipment to take online classes (37.5% very high, 44.44% high, and 15.28% moderate). Only 1.39% of the students had low, and 1.39% had very low proper Hardware/Equipment for online classes that were all from the Spring ABE 3303 class (5.00% of the students from that class in low and 5% in very low categories). The barrier for remote learning students is expected since the switch was sudden, and all students were not 100% ready to shift everything online. However, due to the rural nature of our State, we did expect more students to have issues with access to the internet. It is possible that the studied students, who are primarily juniors and seniors, stayed in local apartments rather than returning to their hometowns. If that is the case, then the university town, especially local apartment complexes, do have adequate Internet access. Regarding technology/equipment, we expected fewer students to report this barrier because all college of engineering students are required to purchase a laptop computer when they enroll in the University.

H4: Students believe online systems negatively impact student learning

Students reported that the online system negatively impacted student learning. More students in the Fall classes (both ABE 3303 and ABE 4323) reported high and very high impacts on course grades (SQ5). Those students were enrolled in online courses with no F2F components, while the students in the Spring semester had half of the sessions in person. Therefore, not being present at the classes and having everything entirely online was perceived as negatively impacting student performance. This finding is supported by the moderate correlation between the preference for F2F and reports of the online system negatively impacting the overall GPA (Tables 5 and 6). Further, the students in the Spring ABE 3303 course, the remote learning course, reported that pivoting to the online system had a high, negative impact on their overall course grade. We note that this group of students was the only student group to have a portion of the course F2F and that these students already had some quiz/homework grades before going to fully online classes. Therefore, these students were able to directly compare F2F with their remote experience in the same course with the same instructor, and they reported

that the online system negatively affects their performance. However, we also note that courses are usually more complicated and tense in the second part of the semester, and their answer might be affected by the nature of the course. Also, differences in perceptions of the impact on course grades could be related to differences in instructor expectations and the fact that there was more forgiveness and flexibility during the remote learning classes as everyone understood the pivot to online instructional methods was quick and completed under emergency conditions.

Regarding the impact on overall GPA, ABE 3303 students in both the spring (remote) and fall (online) reported moderate to high negative GPA impact. This is despite a university policy that was introduced to mitigate GPA impacts for remote learning students. That policy allowed students to change their grades from an A/B/C/D/F format that counted in GPA calculations to a S/P/U format that did not impact GPA calculations. With the mitigation policy, an A/B/C translated to an S, a D translated to a P, and an F translated to a U, which was available on a course-by-course basis. For example, a student with a 3.5 GPA could elect to leave any earned as alone to improve their GPA while simultaneously electing to change Bs and below to S/P/U so that those grades would not lower their GPA. This option to change the grade format was provided to the student after instructors posted final course grades in Spring 2020. However, students may not have perceived the mitigation policy as helpful since 70% reported moderate to high negative impacts on their overall GPAs. Alternatively, perhaps the GPA impact reports for Spring ABE 3303 would be higher if the mitigation policy had not been in effect. We noted that more ABE 4323 students reported very high impacts on overall GPA than the Spring ABE 3303 offering. The ABE 4323 students were primarily at the senior level (97.3%), while we had a combination of senior and junior students in the other classes. The ABE 4323 student response of very high impact could be indicative of students who used the mitigation policy in the spring that was then not available to them in the fall. In the future, further examination of how students utilized and perceived GPA mitigation policies is warranted.

H5: Students believe they and their university were adequately prepared to cope with the COVID-19 adjustments

As the authors are instructors who personally experienced the pivot to online, it was surprising and encouraging to see that students believed instructors were prepared to cope with the transition to remote learning. At times, we did not feel prepared, but we did work hard to make our remote courses successful. Moving beyond ABE instructors, the ABE Department, and the college of engineering, students reported that the University was less prepared to cope. This could reflect the experiences of students enrolled in courses outside engineering. Faculty outside engineering may be less experienced with technology or may have encountered barriers that do not apply to engineering

faculty; for example, non-engineering majors are not required to purchase laptops, so non-engineering faculty cannot assume their students have access to that equipment.

Students reported that their personal lives were least prepared to cope with or adjust to the COVID-19 situation. Many students reported that they were not able to fully handle their new situations, which impacted their performance as a result.[39] This finding is important for instructors to consider as we prepare to return to F2F and "normal" operations at our universities: students may be back on campus, but there are real, lasting changes that occurred during the past few years. Students are in yet another period of transition and adjustment and may still be managing or processing personal situations that resulted from COVID-19. Instructors should strive to continue to maintain high expectations but also, whenever possible, provide flexibility to accommodate students working through personal situations. Further, instructors can raise awareness of existing university resources, including student counseling centers.

H6: Students believe factors outside their course negatively impacted their course performance during COVID-19

Low productivity and time management were reported to have the highest impact on course performance. The good news is that these are skills that can be taught. For example, instructors can point students to existing online resources for time management and project (or work task) management applications. While improving time management and productivity is challenging, it is a skill that can be regulated.

The next grouping of factors that impact course performance were subject difficulty, class interaction, and family. As expected, subject difficulty impacts course performance regardless of instructional method. The studied courses were junior and senior-level engineering courses; the course subjects were challenging, and student grade distributions reflect the challenge across all forms of instructional methods (F2F, remote, and online). To some degree, the subject's difficulty is outside the instructor's control. However, this finding supports the importance of instructors using proven teaching practices, such as metaphors, to assist students in learning course concepts. On the other hand, students noting that class interaction impacted their course performance is telling. Astin and Light identified both student-to-student and student-to-teacher interaction as critical elements in students' academic development.[30,31,40] Astin reports that interaction had more impact on student development than any other evaluated factor, including curriculum details. To support student success, instructors in remote and online courses must consider ways to increase interaction among students and between students and instructors. Finally, family demands were ranked as one of the major negative impacts on course performance. This is a reminder

that our students are human, and, especially during times of rapid change, it is important to consider ways that courses can be designed to be flexible in order to accommodate non-course-related matters.

6. Conclusions

We completed this study to examine how remote learning in Spring 2020 and online learning in Fall 2020 impacted students. Students in both remote and online courses reported needing additional time to complete the courses compared to F2F courses. In order to help instructors improve course design, future investigations could determine why students need additional time. Our study surprisingly found that online students who were taking a course that had previously transitioned to remote learning reported needing even more time than their remote counterparts to complete the course. This could be due to less flexibility once the course was online (versus the quick pivot to remote learning). If that is the case, increasing flexibility within the course may both alleviate additional time demands and support those students who are personally struggling to cope with or adjust to changes that remote and online learning brings to their courses. Finally, students in our study, engineering juniors and seniors, reported few technology barriers, and there was no association between the report of barriers and the preference to enroll in online courses in the future. Students reported that remote learning and subsequent online learning negatively impacted their grades and GPAs. In the future, examinations could consider whether student perceptions matched reality and how grade forgiveness policies were received by students.

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Conflicts of interest

None.

Ethics approval

The institutional review board for the protection of human subjects in research (HRPP/IRB) at Mississippi State University reviewed and approved the study and granted Exemption Determination (IRB-20-474).

Consent to participate

All respondent information was anonymous. It was assumed that there was no risk associated with responding to this survey and it did not have any impact on course performance.

Availability of data and material

Study data is available from the authors upon request.

Code availability

Online questionnaire was made via Qualtrics Survey Software and the link to that was shared with students via the Canvas (the LMS of Mississippi State University) course announcement board.

Authors' contributions

Conceptualization: Raheleh Miralami (Lead). Data curation: Raheleh Miralami (Lead). Writing – original draft: Raheleh Miralami (Equal), Tonya W. Stone (Lead), Luke Peterson (Equal), Daniela Tellkamp (Equal), M. Jean Mohammadi-Aragh (Equal). Writing – review & editing: Raheleh Miralami (Equal), Tonya W. Stone (Equal), Luke Peterson (Equal), Daniela Tellkamp (Equal), M. Jean Mohammadi-Aragh (Equal). Formal Analysis: Raheleh Miralami (Equal), Luke Peterson (Equal), Daniela Tellkamp (Equal). Validation: M. Jean Mohammadi-Aragh (Lead).

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