Evaluation of the COVID-19 Shock on STEM Laboratory Courses

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2021 IEEE Global Engineering Education Conference (EDUCON) | 978-1-7281-8478-4/20/$31.00 ©2021 IEEE | DOI: 10.1109/EDUCON46332.2021.9453900

***Abstract*—Universities across the U.S. have moved to various virtual teaching models in response to the health threats caused by the COVID-19 pandemic. When converting to an online-only mode, STEM and related fields face additional challenges over the lab portion of courses because laboratory courses and active-learning projects frequently require specialized equipment and manual dexterity interactions. In this paper, we report the results of a study on students' perceptions about online learning during the initial phase of the pandemic at a public university in California, U.S. We focus on the overall reaction to the rapid conversion to online, the negative impressions created, "structural" concerns that would be difficult to mitigate, concerns readily amenable to mitigation, and side effects such as impact on equity. Twenty-five recommendations for those factors deemed improvable are provided.**

Keywords—COVID-19, STEM Laboratory, Online Teaching

I. Introduction

The aim of this study was to evaluate the initial impact of the COVID-19 crisis on STEM laboratory courses from students' perspectives. Findings from this study inform instructors about how to better design and deliver online lab courses after the pandemic. We evaluated the COVID-19 shock on STEM laboratory courses by considering three factors: 1) Teaching Presence, i.e., the quality of the lecture and student's perception of instructor's techniques. An important question is to understand students' preferences between synchronous lectures (i.e., live virtual class meetings) and asynchronous lectures (i.e., pre-recorded lectures); 2) Cognitive Presence, i.e., the engagement of students such that they are stimulated by the material and instructor to reflect deeply and think critically. In particular, we explore how COVID-19 affects students' perceptions of their own learning; and 3) Online Modality, i.e., issues related to the use of online class tools and functionalities.

The primary research questions related to whether there was a positive or negative impression about online learning, in particular about labs, due to temporary conditions related to the online conversion. What were considered structural flaws in online teaching that would be difficult to fix given the current state of technology? What concerns could be addressed through advanced planning, faculty training, experience, better protocols and program structures, provision of greater choice, etc.? Additional questions that were investigated related to any side effects such as attendance and equity.

II. Related Work

A great deal of research has been published regarding student engagement and learning in online synchronous and asynchronous courses [1]. Much of this work has focused on the benefits and limitations of synchronous, asynchronous and hybrid online learning [2-4]. Van Wart et al. provided a detailed, comprehensive literature review of online teaching effectiveness and discussed the concerns for learning achievement, student satisfaction, faculty satisfaction, and institutional results. They provided a model to identify the significant factors leading to adequate online teaching and learning potential [6]. Online learning poses challenges in sustaining the same degree of student involvement that is usually demonstrated in face-to-face classroom teaching environments, and has often been perceived as inferior to the face-to-face learning in social and learning climate aspects [1]. Although students and faculty report an overall preference for face-to-face instruction, the online learning literature has consistently shown no difference in learning achievement in face-to-face environments when online classes are well designed [20]. Of course, online learning comes with some important advantages compared to face-to-face such as: time and space flexibility, long-term access to written and recorded lectures, opportunities for self-regulated learning, and efficient programmed learning. However, online learning demands more design preparation, can fail to create a robust human interaction, may lack real-time feedback if not well designed, and may induce student computer fatigue from watching recorded lectures. Sun et al. conclude, however, that students' real-time interaction in synchronous classes can significantly increase the sense of community and improve interactions [7].

STEM-based courses with laboratory components add another layer of complexity and widen the gap between online and face-to-face learning. The laboratory components enforce the concepts learned during the regular lectures and provide hands-on experience for the students. Online and remote laboratories have been developed and accepted among universities with STEM education [8]. They come with some advantages over traditional face-to-face labs such as: remote access over the Internet, flexibility in providing a diverse range of experimentations, cost reduction, and mitigation of safety issues [8]. However, in some courses with laboratory components, virtual or remote laboratories are not currently perceived as an adequate substitute for the hands-on experience needed for students to fully understand course concepts. The effectiveness of remote and virtual labs, compared to face-to-face labs, is an ongoing debate between the educators who advocate for each. For example, research has shown that implementing a virtual laboratory learning experience in online classes can provide an opportunity to train students and gain confidence for future interactions in real laboratory settings. In addition, some studies suggest educational video games can improve students' knowledge acquisition, and develop mental speed and reaction, dexterity, and concentration [9].

With the current COVID-19 pandemic, online education temporarily became the only available option. According to the report of the United Nations [10], "While temporary school closures as a result of health and other crises are not new, unfortunately, the global scale and speed of the current educational disruption are unparalleled and, if prolonged, could threaten the right to education." Because of the pandemic, there was an abrupt transition from face-to-face learning to the online learning model. Virtual or distance learning requires new pedagogical activities and changes in content delivery, and laboratory components incur unique challenges. Of course, laboratory experiences are an integral part of STEM Education; they are proven to help students retain information and develop skills to solve open-ended problems [11].

There are different modalities for conducting labs: 1) Fully online is usually an inexpensive solution which helps students simulate different scenarios, but in many cases lacks hands-on skills training. 2) Physical hardware that is remotely controlled is good for labs where students can adjust settings and parameters and observe the response to these changes using cameras. 3) Physical hardware can be given to the students with online instructions and remote support. Students' are provided with take-home lab kits such as Arduino or Raspberry Pi, FPGA development kits, inverted pendulum, etc., and 4) Virtual labs can use virtual reality technology to give students more control on semi-real hands-on experiences.

A few published studies have evaluated the impact of the COVID-19 crisis on the learning process and the transition into distance learning from different perspectives. The authors in [13] examined the relationship of the students' attitude towards online classes using the Unified Theory of Acceptance and Use of Technology model [14]. Along with model constructs, they studied perceived cost items (the cost that students need to bear to assist them in online courses such as laptops/desktops, smart devices, and internet connectivity) and found that perceived cost has an insignificant impact on behavioral intention. Li Ma et al. found that best practices in online teaching during the pandemic included the effective use of instructor voice and presence; sufficient online material; recorded lectures; annotated notes for self-learning; and the use of supplementary tools and technologies to assist students' learning [15]. Several researchers studied students' perceptions of online teaching specific to individual courses or a single course feature. Matthew et al. examined the rapid transition to online learning specific to software engineering education. With the intensive nature of teaching, they found little time to adapt and develop instructional design. Further, they found no "one-size-fits-all" approach for online delivery [16]. Nugroho et al. examined the teaching procedures for translation in English courses during the COVID-19 pandemic. They assessed students' perceptions of these courses' teaching [17]. Choi et al. discussed the effectiveness of face-to-face and online education in the computing and engineering department. They found that technology itself is not a barrier for computing and engineering students and faculty compared to other disciplines. They also found that students easily adopted online education with few issues to be addressed and proposed future steps to resolve them [18]. Kelum et al. examined the different approaches taken by universities to deliver teaching and laboratory practices remotely in the fields of Engineering Science and Technology during the pandemic and studied the impact on student learning [19].

Our work differs from existing and previous literature at the time of writing. We study the shock of the transition to distance learning in a cohort of over 600 STEM and related majors with an emphasis on courses with laboratory components such as hands-on labs. In addition, we investigate the students' perceptions of this process by examining Teaching Presence, Cognitive Presence, and Online Modality.

III. Methodology

A. Survey

After a comprehensive literature review, a survey was created to measure students' perceptions about three of the key factors (i.e., Teaching Presence, Cognitive Presence, and Online Modality) leading to quality online laboratory classes. The questionnaire was designed to explore new challenges raised by the COVID-19 pandemic while incorporating the (ongoing) major factors in the literature. The first direct impact of COVID-19 to the university is on March 15, 2020, when the university announced that campus will be closed at the end of the Winter quarter. The survey was conducted in June 2020 at the end of the academic year. Spring 2020 (from April 4th to June 16th) was the first quarter that the university moved to fully online instruction. We emphasize that unlike semester systems, the entire Spring quarter was taught fully online. In addition to providing descriptive statistics on survey results, we investigated the correlation between different student groups (major, class standing, financial aid status etc.) and their responses to questions using One-way ANOVA and Binomial Logistic Regression methods. Additionally, two open ended questions asked for general feedback on the online experience during the first, all-online term, and issues related specifically to technical problems. The responses were coded by general online learning experience, lab experience, miscellaneous challenges, and faculty/staff effort.

B. Participants

The university in this study is the region's largest public, comprehensive university, with a student population over 20,000. Hispanic minorities make up over half of the student population. 58% of undergraduate students receive financial aid (Pell Grant recipients). The survey was sent to current students in the College of Natural Sciences, which has about 5,000 students. Departments in the college are mostly in STEM and related fields which include: Biology, Chemistry and Biochemistry, Computer Science and Engineering, Geological Sciences, Health Science and Human Ecology, Kinesiology, Mathematics, Nursing and Physics. The survey was targeted at students taking laboratory courses and/or activity-based courses.

IV. Results

We received a total of 664 responses. The top five majors by respondents are: Computer Science and Engineering (193 responses), Biology (125), Kinesiology (93), Nursing (64), and Chemistry and Biochemistry (49). Class standings of the participants are: 14.83% Freshman, 12.33% Sophomore, 25.52% Junior, 43.32% Senior, and 4.99% Graduate. Given that most of the laboratory and project-based courses are offered at the junior or senior level, it leads to a higher percentage of survey respondents from these two categories. The surveyed students are taking an average of 3.82 courses (SD = 0.98) during the quarter studies, of which 1.43 courses (SD = 1.13) have a lab component and 0.62 courses (SD = 1.05) that are project-based or activity-based. Major results of this study can be summarized in four categories: Teaching Presence, Cognitive Presence, Online Modality and Classroom Climate. Of the 664 responses to the survey, 220 respondents provided open-ended qualitative remarks. Insights from the qualitative open-ended responses are integrated into the discussion below. The actual coding of responses can be found in the Appendix.

A. Teaching Presence

Teaching Presence refers to student's perceptions about the quality of lectures and the feedback they received from instructors. Specifically, instructions are clear and focused, and feedback is encouraging and timely. To assess the student perceptions of quality during the pandemic, we asked three types of questions: 1) their preferences regarding online teaching compared to traditional classroom, face-to-face courses; 2) degree of satisfaction with online lab and project-based courses; and 3) their preferences in online courses regarding synchronous (i.e., scheduled, live virtual engagements with students, such as Zoom meetings with professors) and asynchronous (i.e., pre-recorded lectures).

The empirical data indicates that traditional online courses are preferred by STEM students. The results indicate that 70.88% students prefer traditional classroom lectures, 14.79% prefer online teaching, and 14.33% answered there was no significant difference. In a follow-up question, we asked them to choose the overall biggest concerns for online classes in general: 39.9% of the respondents selected learning motivation, 21.2% selected communication issues, 18.0% selected time management, 11.3% selected technology-related struggles, and 9.6% selected learning supervision.

The qualitative responses indicate that major negative factors in their overall preferences were too much additional work and/or busy work, lack of interaction, slow responsiveness, and poor course design. The qualitative responses are primarily related to issues with teaching presence that are, at least in part, amendable to improvement. For example, typically online classes require more activities in lieu of some lectures, which may feel like more work even if the time is equivalent. Improved faculty explanation for activities and crafting the activity design very carefully can significantly reduce these perceptions. Positive factors were clustered around convenience (e.g., less driving and flexibility of location), and the ability to review material again.

Questions about the labs largely elicited a high percentage of negative responses. More positive results occurred when students were asked about their satisfaction with labs. Satisfaction with online laboratory and project-based courses was split relatively evenly among those satisfied, neutral, and dissatisfied. See Figure 1.

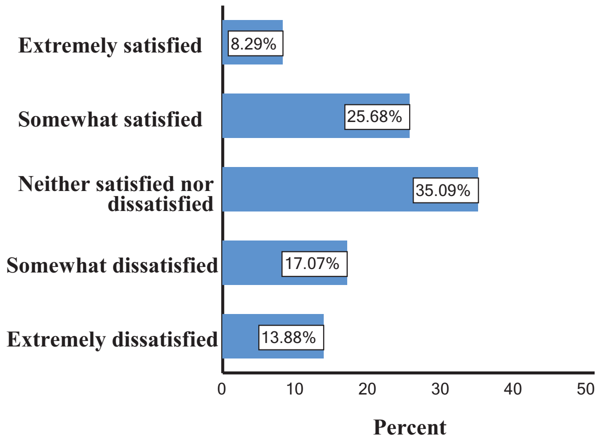

Fig. 1. Question: How would you rate the perception of lab resources and overall satisfaction with the lab/project course?

However, when asked about the learning efficiency of online labs, 70% of the respondents indicated that it was reduced in an online environment. (Virtually no online labs had been available prior to the pandemic.) See Figure 2. When asked about whether technical difficulties may have affected their grades, 66% said yes, not including the neutral category. Finally, when asked about the ease of use in acquiring lab equipment, only 22% indicated that it was very easy or easy to acquire the necessary tools to conduct their online labs.

In the case of labs, unlike online classes in general, there were significant disciplinary differences. For example, lab efficiency ratings from Computer Science students were significantly higher (i.e., more favorable) than other majors (ANOVA: .000, $F(2, 376)=18.954$, $p<.001$), which could indicate that they are better prepared in technology literacy skills. Also, the wide use of software-based simulations in Computer Science programs could make it easier for students to adapt to online courses. Qualitative responses indicated that some majors were not perceived to transfer to an online environment well or at all (e.g., clinical sessions for Nursing), while others did (e.g., Physics). Qualitative responses indicated that students perceived that faculty expertise, motivation, and alacrity-to-adapt made an enormous difference in the success of lab and project-oriented classes.

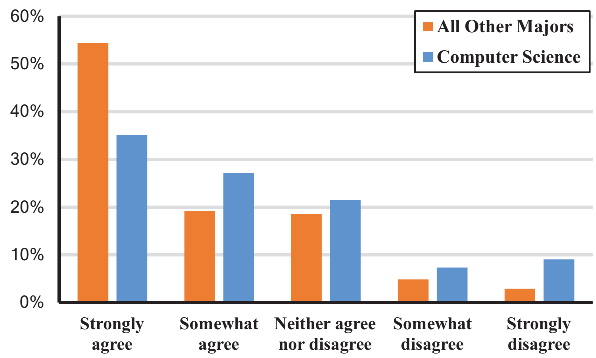

Fig. 2. Question: Would you agree that your lab learning efficiency was reduced after switching to online class?

Qualitative responses were extensive and provide additional insight. Numerous students expressed their appreciation for the effort made by instructors and the institution to adapt and cope as well as possible in the rapid transition. Those who thought that the efforts were good, though the learning achievement had been reduced (even significantly) were more likely to be "satisfied." (Students were nearly evenly split over their perceptions of faculty/staff effort.) Yet in an open-ended question, over four times as many students reported that their lab experience suffered by going online in the qualitative responses, as opposed to being the same or better. Lack of interaction was the major reason, followed by lab issues and confusion about instructions, purpose, etc. As with the question about learning efficiency of labs, the qualitative data reviewed high intensity of displeasure among a large portion of the students.

When considering the preferences regarding online courses that were offered either synchronously vs. asynchronously, it was evenly divided. There was no significant correlation by majors (Logistic Regression p ≥.506). See Figure 3.

When students were asked for their opinion on the biggest advantages and disadvantages related to synchronous and asynchronous courses, the primary positive factor for synchronous teaching was interaction and flexibility for the asynchronous courses. On the other hand, students reported that in synchronous classes distractions were a major liability, while in asynchronous courses the major issues were lack of instant feedback and lower student motivation. The results are shown in Table I.

TABLE I. STUDENTS OPINIONS ON ADVANTAGES AND DISADVANTAGES OF SYNCHRONOUS AND ASYCHRONOUS TEACHING

	Synchronous Teaching		Asynchronous Teaching	
Pros	Interaction with the lecturer	50.8%	Allow self-paced learning	43.5%
	Convenient to attend class	29.2%	Easy to review previous lectures	27.8%
	Highly motivating for learning	10.8%	Convenient to attend class	23.8%
	Foster a sense of community	9.2%	Less social stress	4.9%
Cons	Too many distractions when using computer	34.7%	Lack of instant feedback	35.8%
	Intense requirement for self-discipline	23.7%	Lack of motivation for learning	26.1%
	Demand high-speed Internet connection	21.9%	Intense requirement for self-discipline	19.5%
	Little or no face-to-face interaction	19.7%	Lack of collaboration and activity	18.6%

B. *Cognitive Presence*

Cognitive Presence refers to the engagement of students in learning such that they are stimulated by the material and instructor to reflect deeply and think critically. We explored how COVID-19 affected students' perceptions of their own learning by asking: 1) what are the major impacts of COVID-19 to their studies; and 2) to what extent did the rushed online teaching reduce their lab learning efficiency?

The survey result shows that the top five COVID-19 impacts affecting student learning were: study environment (19.67%), interaction with faculty (15.42%), work efficiency (15.26%), lab resources (14.14%), and family responsibility (12.75%). See Figure 4. It is worth noting that no single option was chosen significantly more often than others, which indicates students are facing a variety of challenges during the pandemic.

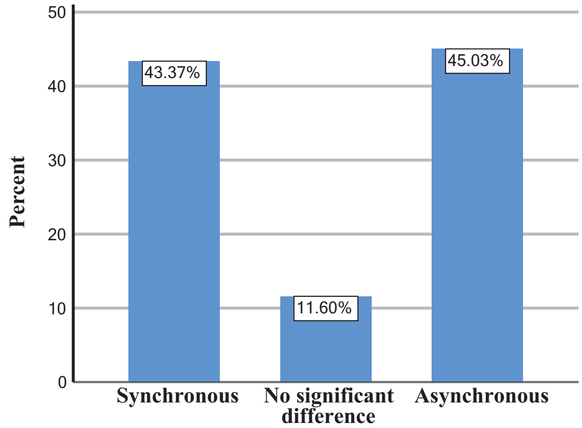

Fig. 3. Question: Which type of online teaching are you more comfortable with?

The qualitative data added additional insights. Over 10% of the students reported stress and mental health issues. A substantial number of students were concerned and distracted by the civil rights issues that flared up in the spring and early summer of 2020. Over 10% of the students felt that there should have been tuition reductions.

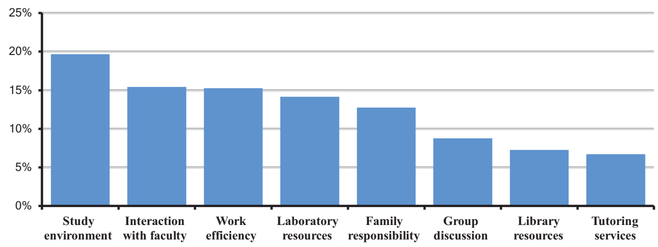

Fig. 4. Question: In what ways has the COVID-19 affected your studies? (select all that apply)

C. *Online Modality*

Online Modality refers to issues related to the use of technology tools and online functionalities. Specifically, how well does the instructor use interactive online tools such as video conferencing, online grading, and video lecture. At the university in this study, technology tools for online teaching were readily available before the pandemic, which include: Blackboard, a learning management system; Zoom, a video conference app, and Google Cloud and Adobe Creative Cloud. To evaluate students' experiences, we surveyed perceptions about the use of software and asked about what technical difficulties they encountered.

In general, students were satisfied with the technology tools provided by the university, see Figure 5. The approval rating for the learning management systems (i.e., Blackboard) and online conference tools (i.e., Zoom) was high. Only 7.64% were unsatisfied with Blackboard, and 14.05% unsatisfied with Zoom. Correlation analysis showed no significant difference among majors, class standing and financial aid status.

A large portion of students (i.e., 39.4%) reported that they encountered technical difficulties during the online quarter. The causes of their technical difficulties are mainly network related issues. When asked what technical difficulties they had

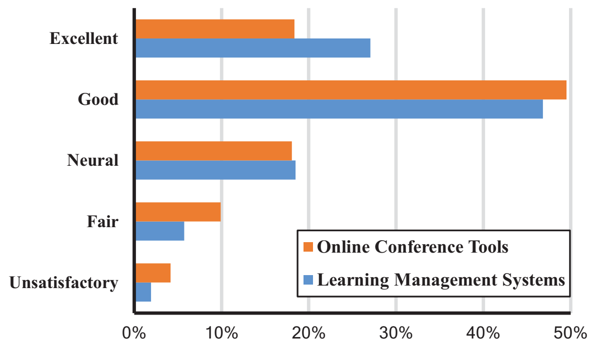

Fig. 5. Question: How would you rate the use of Learning Management Systems & Online Conference Tools?

(more than one option can be selected), among the 39.4% of all respondents, 61.3% reported network reliability issues (slow network, frequent interruptions, etc.) and 51.8% reported Internet Access (lack of WiFi/Cellular connection). Other technical difficulties included a slow computer (43.9%), lab/project equipment not available (24.9%), purchases taking a long time to arrive (23.3%), teleconference equipment needed (mic, headset, webcam etc.) (13.8%), and software unavailable (5.9%). To alleviate the technical challenges during the pandemic, the university expanded its Laptop Lending program for students. The program is free for students and allows them to borrow laptops and mobile hotspots (i.e., cellular WiFi routers) for a quarter. As of September 2020, the university distributed 332 mobile hotspots and 619 laptops to students. Qualitative comments indicated that many of these issues could be resolved over time, as students improved network accessibility and computers and equipment were updated. However, many students indicated severe financial constraints, and many were extensively affected by the downturn in the economy and job layoffs.

D. Side Effects of Conversion to Online

To get a sense of the overall effect of rapid conversion to online, respondents were asked "Given that the transition to online teaching has been rushed due to COVID-19, will it leave a negative impression on online teaching?" 29% indicated that it probably or definitely would not leave a negative effect, 24% were unsure if leave a negative effect, and 46% of the students answered that it would probably or definitely leave a negative impression. See Figure 6.

The relatively poor showing of the rapidly-deployed classes raises a number of questions that will be addressed in the discussion section. How much of the negative impression was due to temporary conditions related to the online rollout (what potentially could be improved or fixed?) and what were considered structural flaws in online teaching that would be difficult to fix given the current state of technology? Additional questions that were investigated related to any side effects such as attendance and equity.

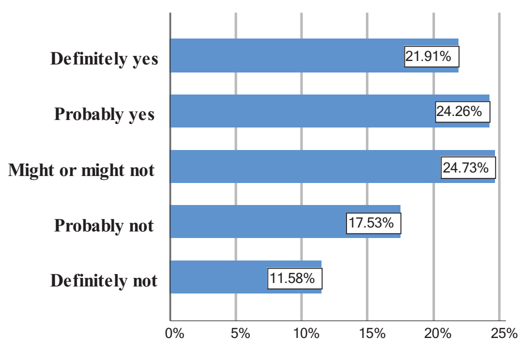

Fig. 6. Question: Given that the transition to online teaching is rushed due to COVID-19, will it leave a negative impression on online teaching?

Table II shows class attendance reported by the students from different quarters. It is interesting to note that the overall class attendance of the college increased by about 10% when compared to the pre-pandemic quarters (i.e., 77.5% in Spring 2020 compared to 67.1% in Winter 2020 and 69.7% in Fall 2019). Generally, class attendance is weakest in the spring quarter. This would seem to be a relatively positive side-effect.

TABLE II. COMPARISON ON STUDENT SELF-REPORTED CLASS ATTENDANCE

	Fall 2019 CNS*	**Winter 2020 CNS**	**Spring 2020 CNS**
All	69.70%	67.10%	77.50%
Almost All	27.90%	30.50%	17.50%
More than Half	1.90%	1.90%	2.80%
Less than Half	0.50%	0.40%	2.20%
Count	12481	9030	6548

*abbreviation for College of Natural Sciences

On the other hand, there was clearly a negative impact on equity for a significant portion of the students. 86% of the respondents reported being on some sort of financial aid, and the majority of all students work while going to school. Thus, the students in the study would be particularly sensitive to financial shifts. 14% of the students indicated that high tuition was an issue. In the qualitative data, tuition concerns were raised frequently and with intensity. Many students reported financial challenges related to job loss, inability to leave children at home in order to work, and increased costs for better Internet service and equipment upgrades.

V. DISCUSSION

STEM students in the study are not keen on online courses in general, and the rapid deployment of online courses did not enhance student perceptions. Only 15% of the students actually prefer online classes, while 14% do not have a preference. Compared to the social sciences, humanities, and professional programs such as business, this is a high rate of face-to-face preference [21]. However, preference for online teaching does not mean that students do not register for online classes in greater numbers because of convenience, scheduling flexibility, and travel reduction. When asked about whether the spring quarter experience would leave a negative impression, 46% said yes, and another 24% thought it might. These general responses beg several questions. First, what are the causes of the low preference for online classes among STEM students? Second, how much were these negative impressions situational and potentially partially remedial, and how much were "structural" or fundamental to the nature of online instruction with the current state of technology? Finally, were there any significant side effects such as with student equity?

We turn first to the aspects of online learning that were more negative than positive in the perceptions of students. In terms of the challenges that students felt online lecture portions presented, they pointed to distractions in their home environment, difficulties with self-discipline, lack of instant feedback as would be the case in a face-to-face class, and reduced motivation of online lectures. All of these learning concerns can be addressed to some degree. Distractions were more acute than before the pandemic because in many homes families were more cramped due to full or partial lock-downs. Additionally, university facilities were shut. While distractions will continue to have some salience after the pandemic, it should be much reduced as students can travel to the university and homes may be less crowded. Faculty cannot provide students with self-discipline per se, but they can make their classes more engaging and provide more prodding mechanisms given the easily accessible data regarding participation. Instant feedback is available in synchronous lectures, so it is primarily in recorded lectures or pre-recorded lectures that this is problematic. This concern can be mitigated by more rapid response times to student questions, better use of electronic office hours, and integration of synchronous classes. Motivation can be improved by higher-quality lectures and better-crafted rehearsal opportunities such as small group activities with ample instructor monitoring and feedback. Synchronous lectures are more motivating than the same lecture when it is viewed as a recording later. Lectures recorded from live synchronous sessions tend to be perceived as more tedious because they are both two-dimensional and the viewer is no longer the primary audience. Instructors who are serious about providing high-engagement lectures may consider providing pre-recorded lectures that are denser, graphically interesting, use high-quality sound, and potentially have participation features built into them such as in PlayPosit. While there will always be some underlying human contact loss, multiple methods are available to build up perceptions of communication richness [22].

Some perceptions about online lectures are positive. Students pointed to interaction and convenience in synchronous lectures, and, self-pacing and reviewability for recorded lectures. Synchronous lectures can offer equal feedback opportunities to students via unmuting, the chat function, or the raise-hand function. While synchronous lectures require a specific time, they eliminate travel time. Asynchronous lectures allow for temporal flexibility, and also provide the opportunity to replay the lecture or portions of it multiple times. Many students found these features critical in their busy and stress-filled lives, even though they might have a preference for face-to-face in their idealized learning model. Finally, some students found the better pre-recorded lectures superior to face-to-face because of the precision and focus that such lectures can achieve.

Recommendations where problems with lectures are identified include:

1. *Enhance course design by creating multiple lecture choices*
2. *Improve Zoom utilization via training, exhibitions, modeling*
3. *Provide and/or increase the quality of pre-recorded lectures: greater instructor time commitment, more presenter rehearsal, graphics, etc.*
4. *Utilize small groups and design where appropriate*
5. *Reduce of perceptions of busywork (i.e., can be poorly related to course goals or sophomoric exercises, but generally poorly or unmonitored practice and rehearsal exercises); provide meaningful and timely feedback regarding activities*
6. *More customized communication and feedback*
7. *Faster and better responsiveness*

Labs and clinical sessions had more, and more intense, critique than online lectures. Essentially one third said that they were pleased with the performance of online labs and satisfied, one third said although they were not particularly pleased with the performance they were satisfied under the circumstance, and one third indicated that they found the performance unacceptable under any conditions. This is further supported by the fact that 70% of the students reported a drop in learning achievement. However, examining qualitative data provides important insights. Reactions to the labs varied by discipline. Nursing students were highly critical of the inability to replicate hands-on clinical sessions providing manual dexterity exercises among other things, but online labs were considered more acceptable for some subjects such as Physics. Additionally, the success of labs seemed to vary substantially within disciplines because of instructor experience with online lab options, teaching online labs, and faculty ability to focus on lab conversion amidst the pandemic. A number of students suggested that the quality of labs could be improved by instructors over time.

Recommendations where problems with the effectiveness of labs are identified include:

8. *Identify and build on the most successful lab designs*
9. *Identify and address as many student concerns as possible, in particular, clear directions and support*
10. *Carefully assess when sufficient quality can be attained for asynchronous or synchronous labs, versus hybrid or fully face-to-face labs and choose accordingly*
11. *Verify that all commercially available options have been explored*
12. *Provide instructor training on lab design and student support for online labs*

While the potential effectiveness of online labs was questioned by many students (above), technical difficulties exacerbated the negative sentiments toward labs. Technical difficulties were identified as overwhelmingly related to the labs. Difficulties in getting the lab equipment were identified by 78% of the participants as problematic. Lab software and/or apparatus was asserted to have affected two-thirds of the students' grades. Some of the problems were due to the rush to convert the lab experience from face-to-face to virtual. Many students commented about the delays in receiving instructions on major set-ups and delays receiving purchased software or equipment. Because online labs had not been planned more than a couple of weeks in advance of teaching the courses, many of the delays were understandable, and especially stressful for both students and faculty given the short 10-instructional week quarter. Many students were unhappy with poor responsiveness to lab questions, but it is likely that lab facilitators were somewhat overwhelmed. Students also complained about the necessity of computer and equipment upgrades which will be addressed below under equity concerns.

Recommendations where problems are identified with labs:

13. *Ensure that equipment and software access is easy*
14. *Make certain that lab instructions are modified for the online environment: provide more detailed instructions, instructional lecturettes, etc.*
15. *Reduce response time to questions about labs*

Negative effects partially or wholly related to the pandemic were substantial. Crowded households made it distracting to be trying to learn online. Faculty interaction was reduced as faculty coped with rapid conversion. Work issues related to job loss, job replacement, changes in hours, etc. were critical for many students. The pandemic shifted family responsibilities with children staying home from school. Access to alternate study facilities (such as the library or study rooms), was cut off, except a provision to make certain parking lots temporary hotspots. Major civil rights protests were simultaneously occurring across the country and were very traumatic for a significant portion of the students. While these factors may be largely alleviated over time, it remains to be seen about how much residual negativity toward online classes will result from poor initial experiences.

Recommendations where problems are identified that were aggravated by the pandemic:

16. *Ensure library and study-space access when campus facilities are available*
17. *Encourage the use of virtual office hours; improve response times and responsiveness in general*

Equity issues relate to the ability of some students to be able to afford educational access. Numerous students complained about the expense of having to upgrade their Internet connections and buy new equipment (e.g., laptops with more capacity). Some complained about the expense of lab equipment. Some of these complaints were intensified by the suddenness of the conversion and might be integrated as standard educational costs over time for those students electing to take advantage of online courses when choices are made accessible. The University did provide a laptop loan program that was extensively utilized by over 600 students.

Recommendations where problems with equity are identified:

18. *Provide for alternate modes of labs when at all possible and appropriate*
19. *Provide laptop and equipment loan options*
20. *Create realistic student expectations about the necessity of basic technology expenditures*

It is also important to note areas that were not of particular concern to students regarding their online experience. Students were evenly split regarding their preferences of synchronous or asynchronous delivery modes. Faculty need to evaluate when asynchronous labs are sufficiently robust for adequate learning achievement.

Basic online teaching technology was not a significant problem. The learning management system and videoconference technology were strongly rated as effective. Nonetheless, qualitative data indicated great frustration with select faculty who failed to master the basics of online teaching technology. Some students were also frustrated by the expression of faculty frustrations.

Recommendations where problems are identified with the use of basic online technology:

21. *Ensure a variety of options for LMS and Zoom training*
22. *Provide instructional design classes and support*
23. *Provide multiple types of faculty acknowledgment to encourage faculty excellence in teaching (including basic technology skills)*
24. *Provide faculty stipends for the major changes required*

Finally, it should be noted that despite student concerns about online teaching, attendance was actually reported as going up in the affected quarter according to institutional data. Maintaining and building on this unexpected trend should be encouraged.

A recommendation where problems are identified with attendance in online classes includes:

25. *Train faculty to use one or more methods to promote attendance and participation, e.g., PlayPosit lectures requiring responses during recorded lectures, linking LMS usage to automated attendance protocols, comprehension quizzes, etc.*

VI. Conclusion

This study investigated the student's perception of online courses, in particular those courses with laboratory and project-based sections, during the first quarter affected by the COVID-19 pandemic. Students reported a strong preference for face-to-face classes in STEM courses from an ideal learning perspective, although they acknowledged the convenience, flexibility, and efficiency of online learning which might lead them to nonetheless choose online options in some cases. While online lecture components were critiqued as lacking sufficient interaction and motivation, these concerns were relatively minor compared to the concerns with lab components. Also, many of concerns with online lectures could be largely mitigated with better training, design, management of student expectations, etc. While some students found their online lab experience equivalent or superior (especially for non-majors in the courses), the vast majority did not. Significant questions were raised about some labs and clinical sessions when manual dexterity (e.g., practice medical injections) or practice with specialized equipment were critical to the learning experience. The critique in these cases was fundamental to the mode itself, with only hybrid formats being a reasonable solution in terms of reducing, not entirely replacing, face-to-face portions. However, many of the concerns were either situational or amenable to mitigation. Advanced planning, better instructions, investigation of best products and best practices, increased responsiveness, back-up options, and provision of student choice would improve or fix this set of concerns. Wholly situational factors related to the negative perceptions by students included the rush-to-convert courses and the civil unrest that was of heightened interest at a Hispanic-serving institution. The success of labs was also somewhat dependent on several invariant factors: academic discipline and status of student major vis-à-vis the lab course involved. One variable factor was the quality of faculty implementation. The preference for the type of mode—synchronous versus asynchronous—was largely situational for students. Side effects were significant short-term equity issues, with a positive effect occurring related to attendance. Recommendations for improvements when areas were identified as problematic were identified in the Discussion section.

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APPENDIX

QUALITATIVE RESPONSES ABOUT PANDEMIC TEACHING EXPERIENCE

“Tell us anything you want your department to hear during the COVID-19 pandemic.” N = 220 individuals responded to the open-ended questions		
Online learning experience in general	Worse	23
	Same & better	9+7 = 16
Reasons against	Lack of interaction	14
	Slow or unresponsive	12
	Poor course design	12
	Too much busy work	16
Reasons for	Convenience, review, savings	12
Lab experience*	Worse	49
	Same & better	7 + 4 = 11
Reasons against	Lab equipment issues	13
	No hands on	25
	Confusing	11
Civil rights unrest		12
Stress and mental health issues		24
Perceptions of faculty/staff effort	Good	19
	Mixed	10
	Poor	19
Tuition		24
TOTAL responses*		323

*Students knew that labs were the focus of the survey, multiple responses allowed per individual.