Student Anxiety and Engagement with Online Instruction across Two Semesters of COVID-19 Disruptions

Eric Pennino,[a] Catherine Ishikawa,[b] Sayonita Ghosh Hajra,[c] Navneet Singh,[d] and Kelly McDonald[a]

[a]Department of Biological Sciences, California State University, Sacramento, Sacramento, California, USA
[b]Department of Environmental Studies, California State University, Sacramento, Sacramento, California, USA
[c]Department of Mathematics & Statistics, California State University, Sacramento, Sacramento, California, USA
[d]Department of Public Health, California State University, Sacramento, Sacramento, California, USA

The sudden shift to online learning due to the COVID-19 pandemic left many instructors wondering how to minimize anxiety while keeping students engaged in their virtual courses. In this study, we explored (i) specific online instructional tasks that caused students to experience anxiety, (ii) factors that hindered student engagement with online instruction, and (iii) changes in student anxiety and engagement between spring 2020 and fall 2020. Students enrolled in STEM classes were surveyed at the end of spring 2020 (N = 425) and fall 2020 (N = 347) semesters. Our results show that the majority of student respondents had more anxiety in fall 2020 than in spring 2020 with online learning in general, and less anonymous class activities tended to cause the greatest anxiety. Distractions from the environment and personal technologies commonly prevented engagement in both semesters, but no significant differences were observed between the spring and fall. In contrast, more students reported that health-related stress, work-related stress, and issues with technology prevented participation in fall 2020 than in spring 2020. As institutions consider expanding their online course offerings post-pandemic, these data provide valuable insight into the challenges students experienced with online instruction that can inform future pedagogical choices.

INTRODUCTION

When the COVID-19 pandemic resulted in an abrupt shift to online instruction during spring 2020, few faculty had expertise in effective online teaching (1–3), and most institutions were unprepared to support faculty and students during the transition (4). The speed with which faculty had to adapt their instruction and students had to modify their learning created additional challenges for all. While instructors grappled with technology and logistics, they also faced the challenge of engaging students who were coping with their own technological, logistical, and personal challenges (5, 6). Many students faced unforeseen financial hardships, health issues, and other difficulties that interfered with attention and learning.

Learning is impaired when the brain is in a state of heightened arousal—ready to fight, flee, or freeze. Perry (7)

and England et al. (8, 9) found that students with higher anxiety reported being more likely to leave the biology major. Because students' mental health was taxed during the spring 2020 semester (10), instructional activities that increased anxiety may have been counterproductive. Studies published before the pandemic found that volunteering or being called on to answer a question or participating in active learning exercises could increase anxiety (8, 11, 12). Working in groups or answering clicker questions produced mixed results, with anxiety decreasing or increasing depending on how the activity was implemented (8, 12, 13).

Some of these practices that induced anxiety are typically implemented to increase student engagement, and engaging students was another challenge during emergency-response teaching. Students often reported feeling less motivated and engaged with online learning (2, 6, 14), and a recent study found these effects to be amplified for Persons Excluded because of Ethnicity or Race (PEERs) or first-generation students (5). Choe et al. (15) found that certain styles of online lectures were more satisfying for students (e.g., use of glass whiteboards), but formats instructors could adopt quickly (e.g., recording in a classroom, showing slides with or without the instructor's "talking head") were less satisfying. Faculty reported some successes keeping students engaged when using COVID-19 as a theme for course

content (1), creating at-home versions of field and lab exercises (6), and integrating trauma-informed pedagogical practices (16). These engagement strategies were critical given the challenges students faced accessing materials and maintaining focus in environments with distractions.

As the pandemic persisted, the continuation of online instruction provided a unique opportunity for STEM educators across the United States to study the evolving landscape of online teaching and learning. While both spring 2020 and fall 2020 were unusual in the degree of collective stress students and faculty experienced, by fall 2020 the initial shock and novelty of online teaching and learning had abated. Faculty learned more about online pedagogy, and emergency funds allowed campuses to provide students with the required technology. Thus, studying student experiences in online STEM courses during fall 2020 could hypothetically provide insight into challenges students could face with post-pandemic online instruction.

Because our institution decided to stay online in fall 2020 earlier than many institutions, with an announcement in May 2020, it offered a case study for large-scale implementation of online instruction with a relatively high level of support available to faculty and students. During the summer of 2020, our faculty had access to paid training and additional resources to help them implement best practices. These practices were informed by frameworks such as the Community of Inquiry Model (17) and curricula created by non-profit organizations like Quality Matters (https://www.qualitymatters.org/). Computers and hotspots were made available to students, and a guide to learning online, which incorporated growth mindset and time management modules, was available to students. We surveyed students in fall 2020 (after planned online instruction), in addition to spring 2020 (after emergency-response online instruction), to better understand how their experiences changed between semesters. In this article, we compare student anxiety and engagement between the two semesters and address the following research questions:

i. Which online instructional tasks caused the greatest/least anxiety in students?
ii. What factors prevented student engagement in the online environment?
iii. How did student anxiety and engagement change from spring 2020 to fall 2020?

We hypothesized that student anxiety with online learning, in general and with specific instructional practices, would decrease and engagement would increase as students grew accustomed to learning and faculty received training and gained experience teaching in a virtual environment.

METHODOLOGY

Participants and data collection

This study was conducted at a large, public Master's granting institution on the west coast over two semesters: spring 2020 and fall 2020. The university is a Hispanic-Serving and Asian American, Native American, and Pacific Islander-Serving Institution with nearly 29,000 undergraduate and over 2,500 graduate students. At the institutional level, 30% of students identify as first-generation, 43% are eligible for federal Pell grants, nearly 70% identify as students of color (43% from underrepresented groups) and 58% identify as female (42% male and 0% non-binary, although 24 students report belonging to the latter category). Participants in our study identified as 38% first-generation, 55% Pell-eligible, 67% students of color (43% underrepresented), and 69% female (29% male; 2% not reported). Participants ranged from first-year to graduating seniors and were enrolled in STEM courses, although not required to be STEM majors.

We recruited instructors through email during spring 2020 and fall 2020 and requested they administer the survey to their students in the last 2 weeks of the semester. While some courses were surveyed both semesters, some instructors dropped out and others were added in fall 2020. The survey was administered online via the Qualtrics software platform. The Institutional Review Board approved this study under protocol #19-20-291.

Survey instrument and analysis

During the spring 2020 semester, we developed a 29-question survey to explore STEM students' anxiety and engagement with online learning (Appendix 1). The survey was created in-house, with several questions adapted from a survey created by Carl Weinman about students' experiences with online instruction (C. Weinman, personal communication, April 16, 2020). In fall 2020, the survey was administered again in an identical manner; however, the fall survey was reduced to 20 questions with a greater focus on student anxiety (Appendix 2). Both surveys were validated for timing and clarity using student volunteers. Student participants indicated the degree of anxiety specific online tasks produced on a Likert-type scale (1 = *no anxiety*, 2 = *low anxiety*, 3 = *moderate anxiety*, 4 = *high anxiety*, 5 = *very high anxiety*). We used "anxiety" as a colloquial term rather than a clinical one, leaving the interpretation to students. To assess engagement, specifically behavioral engagement (2), the spring and fall surveys asked students to rate how much they agreed that specific factors prevented them from participating or performing in their online courses using a 5-point Likert scale from *strongly disagree* to *strongly agree*. Multiple-choice questions on the spring 2020 and fall 2020 surveys were also used to gauge students' overall anxiety and engagement with online instruction. Chi-square tests of homogeneity were used to compare Likert-like responses across the spring and fall semesters for anxiety and engagement. All data were managed in Microsoft Excel and analyzed in R studio v. 4.0.3 using psych package.

TABLE 1
Breakdown of courses and student respondents

Department	Spring 2020		Fall 2020	
	No. of courses	No. of students	No. of courses	No. of students
Biology	11	295	8	280
Environmental studies	2	15	1	18
Physics & astronomy	1	64	2	11
Civil engineering	1	51	1	1
Chemistry			1	11
Mathematics & statistics			5	26
Total	15	425	18	347

RESULTS

In spring 2020, 425 student respondents from 15 courses spanning four STEM disciplines (biology, environmental studies, physics, and civil engineering) participated in the study. In the fall 2020 semester, data were collected from 347 student respondents from 18 courses across six STEM disciplines (Table 1). In both semesters, most respondents were in biology classes (69% in spring 2020 and 81% in fall 2020).

Overall, a slight majority of students (51%) reported feeling more anxious about learning online, in general, in fall 2020 compared with spring 2020 (Fig. 1). Only 16% were less anxious and 23% reported the same level of anxiety with online learning between the two semesters. Both semesters, students reported more anxiety toward some online tasks and activities than others. For instance, unmuting audio,
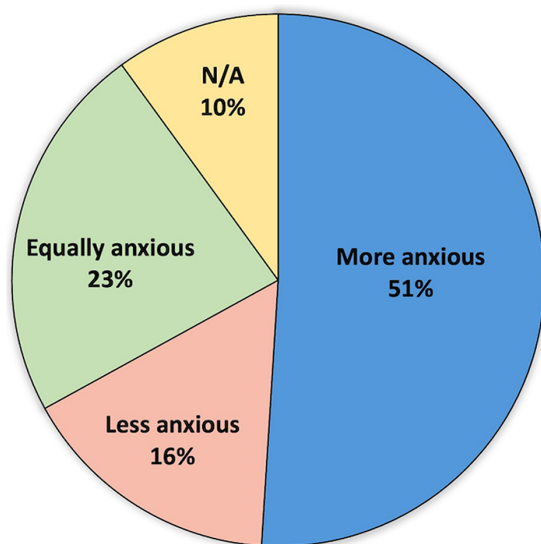

FIG 1. Self-reported comparison of anxiety levels between fall 2020 and spring 2020. Students responded to the question "How anxious were you about learning online this semester [fall 2020] compared to spring 2020?" The N/A category was included for new students, who were unable to compare their fall 2020 experience to their spring 2020 experience.

working with others in a breakout room, or having video feeds on caused the majority of students to experience at least low levels of anxiety, with at least 10% of students experiencing very high anxiety. Other tasks, such as answering a poll, using a discussion board, or replying to a question using the Zoom chat feature, caused less anxiety for most students. When comparing anxiety produced by specific online tasks across the two semesters, we found that some activities caused significantly more anxiety in fall 2020 than in spring 2020 (Fig. 2). These included replying to a question in the chat (P-value 0.0207), unmuting audio (P-value 0.0003), working with others in a breakout room (P-value < 0.0001), and having the video feed on during class (P-value 0.0152). There was no statistically significant difference between semesters for the degree of anxiety caused by answering a poll (P-value 0.2082) or using a discussion board (P-value 0.5645). The fall 2020 survey contained additional Likert-scale items that revealed that over 65% of students experienced at least some anxiety, and 20% of students experienced very high anxiety when asked to share their screens or use a lockdown browser for an exam or quiz (Fig. 3). Other tasks, like sharing ideas on external technology (e.g., Jamboard), using external communication platforms (e.g., Slack), and submitting assignments online, caused less anxiety. That said, using external technology and communication platforms still caused most students (over 50%) to have some degree of anxiety.

Student responses on the spring 2020 survey indicated a majority of students (66%) felt they were less engaged with course material after their classes transitioned online. When comparing engagement across semesters, a significantly larger proportion of students reported that limited access to technology (P-value 0.0348), health-related stress (P-value < 0.0001), and work-related stress (P-value 0.0004) prevented them from participating or performing in their online courses in the fall 2020 semester (Fig. 4). However, distractions from the environment and personal technologies played the greatest role in preventing participation/performance during both semesters, and differences between semesters were not statistically significant (P-values 0.3933
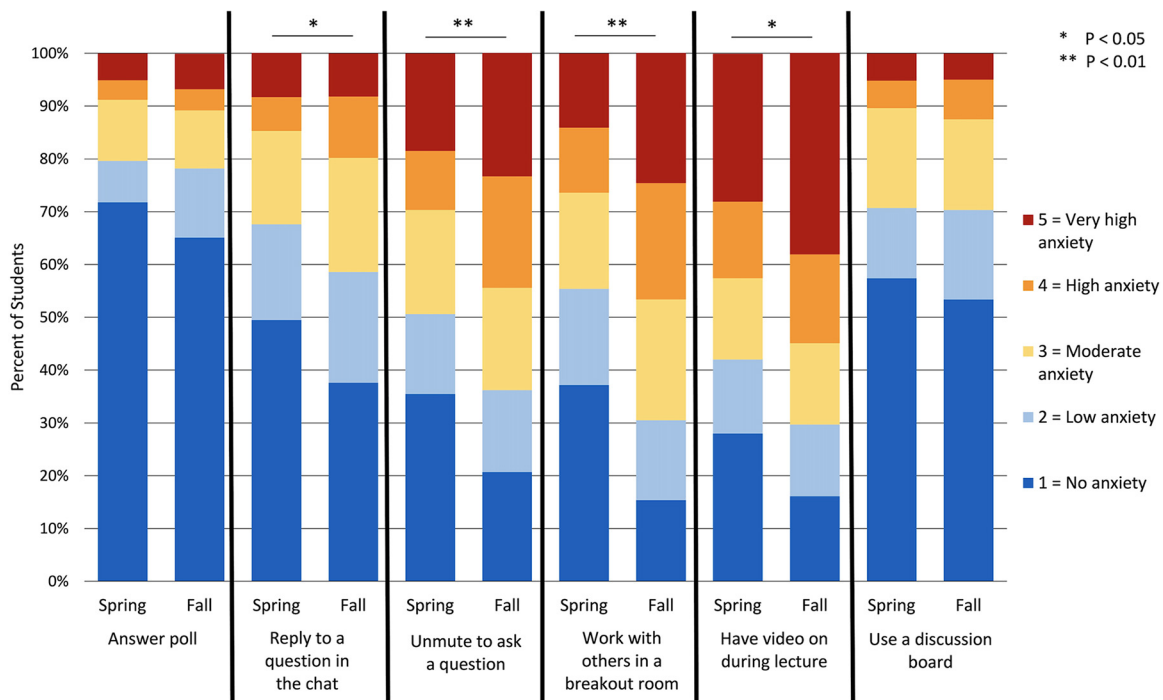
FIG 2. Fall 2020 and spring 2020 comparison of the amount of anxiety students felt from specific online tasks.

and 0.0897 for environment and personal technologies, respectively).

DISCUSSION

Our findings did not support our hypothesis that students would feel less anxious during the fall 2020 semester compared to spring 2020. One possible explanation for lower reported anxiety in spring 2020 is that students had half of the semester to interact with their instructors and classmates in person before transitioning online. This is supported by previous research, which suggests that students may benefit from face-to-face meetings and ice-breaker activities before working with each other online (18). At our institution, most students had no in-person instruction in fall 2020, which may have increased feelings of isolation leading to greater anxiety when asked to interact and work together online. An alternative explanation could be related to the teaching practices instructors employed in spring
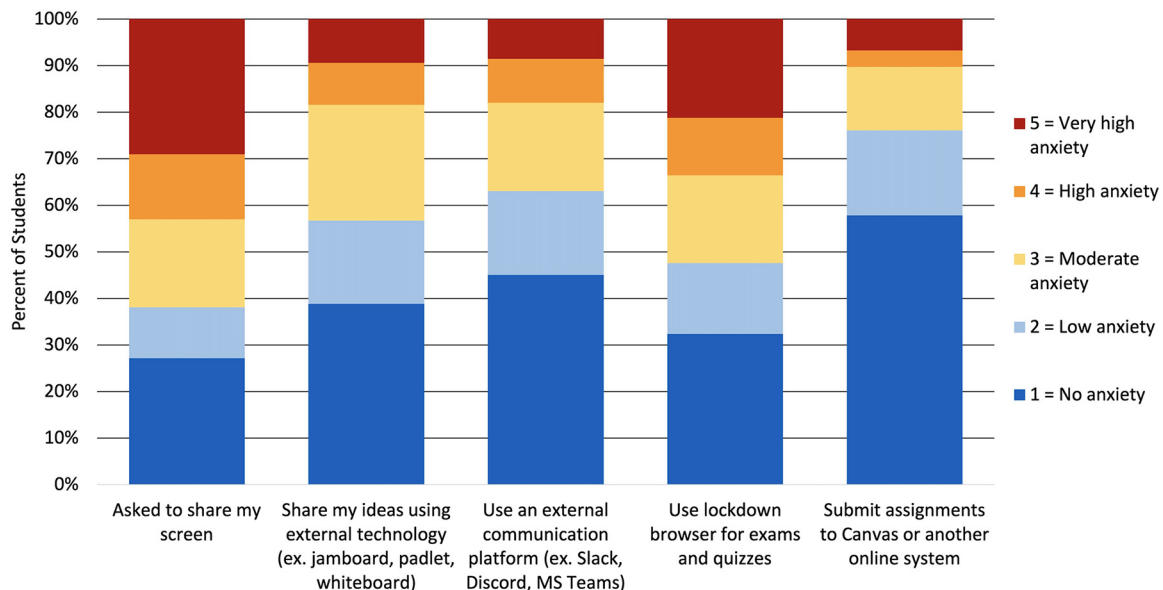

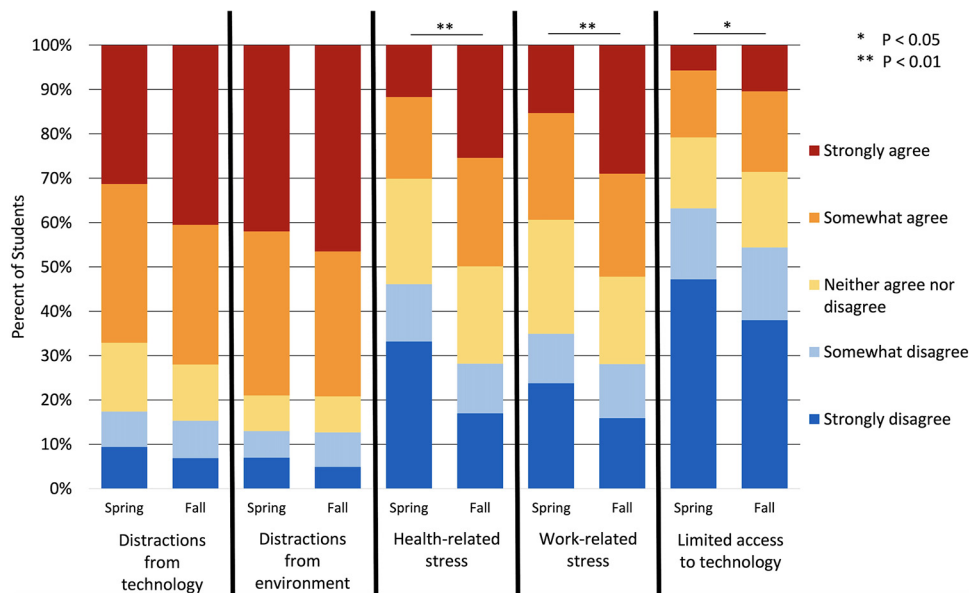FIG 3. Additional anxiety items asked to students in fall 2020.

FIG 4. Fall 2020 and spring 2020 comparison of agreement that specific factors prevented students' abilities to participate or perform in online courses.

2020 versus fall 2020. We found that student anxiety was higher with more "intrusive" tasks—those requiring students to be seen, heard, or interact directly with others—while activities requiring less direct or anonymous interaction produced less anxiety. These findings are consistent with other studies showing that active learning activities, especially tasks where students are expected to respond publicly, tend to increase anxiety (8, 12). After developing skills and confidence with synchronous technology, instructors in our study may have used more online active learning techniques in fall 2020, with the intention of increasing engagement and learning. Assigning grades to these activities can further increase anxiety (12), although it is unknown whether instructors in our study applied grades to online class activities in either semester. Studies have also shown that specific practices, such as frequent low-stakes assessment and having students write about their anxiety, can be used to address student stress and anxiety while maintaining an active learning environment in person or online (16, 19). Our results highlight the importance of identifying strategies to reduce anxiety and communicating them to instructors so they can build an environment that promotes learning regardless of the delivery format.

Our findings also did not support our initial hypothesis that students would feel more engaged in fall 2020 than spring 2020, but they are consistent with other reports focused on spring 2020. Distractions and unsuitable learning environments were common student challenges (5, 6, 20). Health, work, and technology concerns were also present and amplified for first generation students and PEERs (5). Research has also pointed to variations in student responses, focusing on resilience and adaptation strategies that allowed students to remain engaged despite non-ideal conditions (5, 6, 21). Our results also suggest heterogeneity

of experiences because some students strongly disagreed that factors like health, work, and technology reduced their ability to participate or perform. These results point to the need for a better understanding of the conditions under which students are working and strategies successful students use to maintain motivation and engagement, even under non-ideal conditions.

We expected that students would have been more prepared for learning online in fall 2020, and thus, would have been less likely to report factors like technology challenges and distractions reduced their participation or performance. The campus instructional technology office provided free laptops and Wi-Fi hotspots, so students theoretically could access the technology they needed. However, the reliability of technology may have been an issue for some. For example, in fall 2020, electricity providers shut off service to many communities for days at a time as a fire prevention measure. Also, in fall 2020, faculty may have relied more heavily on Internet-based tools or been less lenient with students who struggled with access (e.g., to stable Wi-Fi). For the health-related stress category, as the number of coronavirus cases increased in our region during the fall (https://www.cdph.ca.gov/), it is possible that more students contracted COVID-19 or had family members or coworkers fall ill in fall 2020 than in spring 2020. Financial burdens also increased for many as the pandemic continued, likely explaining the increased work-related stress students reported in fall 2020. While some students lost employment, others serving as essential workers were in growing demand, with increased and less flexible work hours. While health may be a less common barrier to student participation in future semesters, a subset of students will continue to contend with health, work, and technology challenges. Developing ways of uncovering and addressing these

barriers will be an important component of ensuring equity and inclusion in online STEM courses.

While we saw no significant shift in agreement that technological or environmental distractions reduced participation from spring 2020 to fall 2020, the very strong agreement these items received during both semesters merits further discussion. Given research on smartphones' effect on cognition (22, 23, 24), technological distractions are likely to continue challenging students in future online courses. And while we might expect students to choose in-person options if they do not have an ideal environment for online classes, the benefits of lower housing costs or commute time may outweigh the challenge of environmental distractions. One avenue for countering these distractions is to create course materials that are engaging enough to compete with social media, household noise, or other distractions. Another approach would be to help students develop skills that allow them to manage their time, learning space, and attention in ways that are more conducive to learning online.

Our study has some limitations, as we were forced to react quickly to the COVID-19 disruptions. Low response rates for some classes in both semesters limited our analyses. While our sample size of students from a wide range of STEM disciplines allowed us to gain a broad understanding of STEM students' anxiety and engagement, we lacked adequate numbers to look at student responses at the course or discipline level. Another limitation is that we did not have direct follow-up questions for some of the survey items, so we cannot conclusively explain why students answered the way they did (for example, why they reported that work-related stress limited their participation). However, we report only one part of a larger study here, and are currently analyzing faculty surveys and interviews, syllabi, and course management content, and we plan to examine student performance and demographic variables. As we triangulate data from multiple sources, we aim to develop a comprehensive picture of our student and faculty experiences. We expect that our findings will result in recommendations for reducing anxiety and increasing engagement and learning that faculty at our institutions and others can use to inform their future online instruction.

CONCLUSIONS

Our institution shifted to online learning halfway through the spring 2020 semester and continued almost entirely online through fall 2020 and spring 2021. We have only now returned to 50% in-person instruction in the fall 2021 semester. For many institutions, like our own, the expansion of online course offerings is likely to continue as we strive to increase access to more students, decrease operational costs, address insufficient facilities, and respond to frequent disruptions from natural disasters. The pandemic created an opportunity to evaluate not only the

challenges, but also the affordances that online education can provide when faculty are trained and supported, and best practices are adopted. The data we present here provide information about specific tasks that caused our students anxiety and potentially impeded their learning during and after the transition online in spring 2020. The results can be used to focus future research and development of best practices for easing anxiety and allowing greater engagement in online STEM courses.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.3 MB.

ACKNOWLEDGMENTS

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