Effects of the COVID-19 Pandemic on Student Engagement in a General Chemistry Course

Fan Wu* and Thomas S. Teets

ABSTRACT: In response to the COVID-19 pandemic, many colleges and universities transitioned their face-to-face courses to emergency remote online courses during the spring of 2020. This study, conducted at a large, urban, diverse public university in the United States, answers the questions of how the sudden switch to emergency remote online instruction and the encompassing events of the pandemic changed student learning and engagement in a college-level introductory chemistry course. The research addresses the demographic and lifestyle factors that determine the magnitude of these changes. The mixed-methods approach uses a 19-item Pandemic Online Student Engagement (POSE) scale to quantitatively evaluate changes in student engagement and combines it with a qualitative analysis of student essay responses. The results reveal a decrease in student engagement, with underrepresented people of color (URPOC) students particularly affected and reporting significantly greater decreases in three of the four engagement components: skills engagement, participation engagement, and performance engagement. The decreases in motivation and self-regulation occurred in part because the historic pandemic event made it more difficult to focus on studies, and because students’ home environments were not conducive to self-regulated learning. This study provides unique insights for chemistry instructors and college administrators into how the sudden changes in instructional dynamics affected students while the pandemic unfolded. Studies like this are necessary to prevent widening achievement gaps if the current pandemic lingers or if future threats dictate another widespread adoption of emergency remote online learning in general chemistry.

KEYWORDS: General Public, Chemical Education Research, Interdisciplinary, Computer-Based Learning, Distance Learning/Self Instruction, Administrative Issues, Learning Theories, Minorities in Chemistry

INTRODUCTION AND LITERATURE BACKGROUND

COVID-19, the infectious disease caused by the SARS coronavirus 2 (SARS-CoV-2), has spread throughout the world and impacted nearly all sectors of the economy and society since being identified in December 2019 in Wuhan, China. Whereas the public health ramifications of this pandemic have rightfully received the most focus, it is undeniable that a large portion of the population has directly experienced some consequences of COVID-19. These include not only physical and mental health effects, but also dire economic effects, especially for the low-income population.

Pandemic Effects on Higher Education

Among those sectors profoundly impacted by COVID-19 are colleges and universities, which have been forced to dramatically alter their educational activities to mitigate the threat on their campuses and in their local communities. In the U.S., over 1,100 higher education institutions across all 50 states either canceled their face-to-face classes or, more commonly, immediately converted them to emergency remote online instruction. In North America, these actions were primarily taken in the first two weeks of March 2020, as the severity of the pandemic became apparent; thus, in most American colleges and universities the first half of the Spring 2020 semester...
proceeded as normal, whereas the second half was executed remotely.

COVID-19 stands as the single biggest disruption to higher education in recent history, though there are some previous reports on the effects of pandemics and natural disasters on college instruction. In the more than one year since COVID-19 became a major threat, there has been a lot of research on the effects of the pandemic on higher education, including some studies related to chemistry education. There are studies that focused on chemistry faculty members’ perceptions and reflections of their adaptation to emergency remote online instruction, and specific curricular and pedagogical recommendations that emerged to best maintain continuity and effectively assess students. Most relevant to the present study, there have been some notable works that tracked the influences of COVID-19 and emergency remote online instruction on student engagement. Student engagement is a concept that combines ideas from several distinct fields, including psychology, sociology, and cognitive development. At the heart of this multifaceted concept are theories relating to student effort, academic and social integration, and student involvement. A paper from Miltiadous, Callahan, and Schultz compared student engagement in two sections of a general chemistry course, one taught in-person in 2019 and the other online in 2020 after pandemic restrictions were in place. The authors in this work primarily measured engagement by tracking student participation in learning activities and completion of assessments and included analysis of a survey on students’ expectations and perceptions during the interrupted semester. They noted a preference for face-to-face learning among students but did find that students adapted well and remained engaged with the online activities. Another study by Perets et al. measured the impact of the transition to emergency remote online teaching on student engagement in a non-STEM chemistry course. This study focused on a single group of students and used a pre- and post-survey, administered before and after the switch to emergency remote online instruction and completed by a small number of students (N = 15). They found that students noted difficulties staying committed to the course after the transition, and that individual research projects were more effective at retaining engagement than synchronous lectures and student presentations. A particularly detailed study by Pettillion and McNeil combined a quantitative survey with interviews of select participants to gauge the many effects of emergency remote online teaching on students in a second-year chemistry courses (N = 64). This study noted that there were many challenges with maintaining student motivation and engagement, and that increased stress and anxiety were detrimental to student learning. These findings point to the need for clear communication and flexible assessment during emergency remote instruction. Jeffery and Bauer published a 2020 study centered on students’ responses to two surveys on the transition from in-person to emergency remote online instruction in a general chemistry lecture and lab. This study found that students’ experiences were much more dramatically altered in the lab compared to the lecture portion of the course, and the loss of peer communication networks was deleterious to student learning and engagement. A 2021 study by Wester et al. reported on a survey that was distributed nationally to students across a few science disciplines, including chemistry, concluding that the emergency switch to remote instruction caused decreases in emotional engagement and positive attitudes toward science, with mixed effects on participation engagement.

The present work is complementary to these previous studies on undergraduate chemistry student engagement in the COVID-19 era and offers some new insights. What is distinct about our approach is that we are basing our study on a known scale, the Online Student Engagement (OSE) scale, which is a well-established measure of student engagement in an online setting. The OSE scale measures four factors of student engagement: skills, emotion, participation, and performance. We have adapted this scale to compare student engagement before and after the pandemic; the modified scale is referred to as the Pandemic Online Student Engagement (POSE) scale. Our sample population is large (N = 431) and diverse, allowing us to perform detailed statistical analysis on the results and determine which demographic factors are related to changes in student engagement caused by the COVID-19 pandemic and sudden switch to emergency remote online instruction. Due to a variety of societal factors, STEM retention and achievement differ significantly as a function of student ethnicity, gender, and parental education level, leading us to examine these variables in this research. It is also well-documented that the COVID-19 pandemic has had disparate health, economic, and educational impacts on different ethnic groups, further motivating us to consider demographic factors in our work. Moreover, the quantitative survey analysis is supplemented with qualitative analysis of an open-ended free-response prompt, which allows us to glean insight into other factors that contributed to student learning and engagement changes after the onset of COVID-19.

RESEARCH QUESTIONS

This study explores the following research questions:

1. How did the sudden switch to emergency remote online instruction and the encompassing events of the pandemic change college student learning and engagement in a large-format general chemistry course?
2. What demographic factors predicted the magnitude of these changes?
3. What personal and environmental factors influenced students’ ability to adapt to emergency remote online instruction during COVID-19?

METHODS AND FRAMEWORKS

Study Setting

The setting for this study is a large-format, lecture-style general chemistry class with a total enrollment of 516 at the start of this study, taught at a large, urban, public research university in the southern United States. The university is one of the most diverse research universities in the U.S. and is classified as a Hispanic-Serving Institution (HSI). In addition, a large percentage of the university student body consists of first-generation college students and transfer students, and the median family income is in the lower tier among typical American universities. The course that serves as the population for this study is titled “Fundamentals of Chemistry I.” It is a gateway course that represents a major hurdle to degree progress for many students, with many failing to earn high enough grades to progress in their degree plans. As a result, a study on this group of students is particularly relevant to how the COVID-19 disruption will

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impact degree progress and retention in diverse postsecondary institutions.

Course Design

This course is the first in a two-semester general chemistry sequence for science and engineering majors, taught in the spring semester as a “trailer” section. The topics covered follow the first nine chapters of Zumdahl and Zumdahl’s Chemistry: An Atoms First Approach textbook, with only minor deviations from the book’s content. The switch to remote instruction occurred immediately following the extended, two-week midsemester spring break, so the students spent nearly equal amounts of time in face-to-face instruction and emergency remote online instruction. Table 1 summarizes instructional and assessment content for the course and how they were altered after the switch to emergency remote online instruction.

Participants

A total of 516 students enrolled in the largest section of the General Chemistry I course in Spring 2020 in a large urban research university in the southern United States were invited to participate in this study. Table 2 summarizes the response rate and the breakdown of participants by the different demographic categories that are considered in the analysis. Participants consented and completed a Qualtrics online survey by the end of the Spring 2020 semester. The university institutional review board approved all procedures.

Variables and Coding

Independent variables included gender, race, first-year student status, STEM status, first-generation college student status, and transfer student status. For gender, females were coded as “0” and males were coded as “1”. For race, Asian and Caucasian/White were coded as “0” and underrepresented people of color (Native American/American Indian, Black/African American, Hispanic/Latino, and multiracial, as defined by the National Science Foundation30 and others38) were coded as “1”. For first-year student status, non-first-year students were coded as “0” and first-year students were coded as “1”. For STEM status, non-STEM colleges were coded as “0” and STEM colleges were coded as “1”. For first-generation student status and transfer student status questions, first-generation students or transfer students were coded as “1” for that specific question, and students who were not first-generation students or transfer students were coded as “0” for that specific question.

Dependent variables were self-reported student engagement components. A revised version of the Online Student Engagement Scale (OSE), consisting of 19 survey questions, was created to measure students’ changes in engagement before and after the switch to emergency remote online instruction. OSE was originally designed to measure student engagement in online courses and is rooted in theories related to the social aspects of learning, namely, social constructivist theories39 and the Community of Inquiry model.30 In the original Online Student Engagement Scale (OSE), the 19 items showed strong reliability (a = 0.91) and significant correlation with a course global engagement item (r = 0.67; p < 0.001).38 We rewrote items 6, 13, and 18 to make sure they were relevant to the general chemistry course and asked the students, “Within the general chemistry course, how much did your following behaviors, thoughts, and feelings change during the online instruction period, compared to face-to-face instruction?” Students responded using a 5-point Likert-type scale format ranging from 1 (significantly decreased) to 5 (significantly increased). This 19-item scale was named the Pandemic Online Student Engagement Scale (POSE). The entire text of the POSE survey, and a comparison to the original OSE survey, is included in Table S1 of the Supporting Information. In addition, one open-ended question was created to further explore students’ attitudes and behavior changes: “After the Coronavirus outbreak, how has online instruction changed your learning in the general chemistry course? Please type your answer in the text box below.”

Procedure

We obtained approval from the university institutional review board. Online survey participation invitations were sent to all students enrolled in the largest section of the general chemistry course and asked the students, Please type your answer in the text box below.”

Table 1. Summary of Course Curriculum Learning Activities and Graded Assessments.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Atomic structure and periodicity, acid–base and redox reactions, chemistry energy, ideal gases, aqueous solutions</td>
<td>Lecture hall, notes handwritten onto projected tablet screen, screen capture and audio uploaded to YouTube after class.</td>
<td>Asynchronous instruction. Only recorded lectures.</td>
</tr>
<tr>
<td>Bonding, molecular structure and solution stoichiometry, Chemical energy, ideal gases, liquids and solids</td>
<td>Recorded review of previous homework assignment, uploaded to YouTube</td>
<td>None</td>
</tr>
<tr>
<td>Exams reviews 1 per week, a few days before start of exam</td>
<td>Optional in-person session with mock exam and Q&amp;A. Recorded and uploaded to YouTube.</td>
<td>Synchronous Microsoft Teams web conference in lieu of in-person.</td>
</tr>
<tr>
<td>Homework assessments 1 per week, 4 attempts per assignment</td>
<td>12-question assessments with 48-min time limit administered and graded through LMS. Questions drawn from a large bank. Combination of multiple-choice, numerical, and short-answer questions.</td>
<td>Worth 6% of grade.</td>
</tr>
<tr>
<td>Exams 3 in-semester, 1 cumulative final</td>
<td>20 questions, 75 min for in-semester; 34 questions, 100 min for final. Computerized question format identical to homework. Administered in a secure on-campus testing facility using Respondus Lockdown Browser. Worth 94% of grade.</td>
<td>Students took exams at home. Respondus Lockdown Browser required, Respondus Monitor (webcam proctoring) strongly encouraged.</td>
</tr>
<tr>
<td>Bonus points Accumulated weekly</td>
<td>Determined by number of homework assignment attempts. Worth up to 2% of grade.</td>
<td>0.5% of bonus points determined from survey participation.</td>
</tr>
</tbody>
</table>
course via email in mid-April, 2020, and data collection ended in the beginning of May, 2020, before final grades were assigned. Weekly reminders were sent during the data collection period. Once students clicked the online survey participation link, they were given a copy of the consent form. After students read the consent form and agreed to participate in the study, they were directed to the online survey. Participants who completed the online survey before the deadline received a 0.5% bonus toward their final grade for this course.

Data Analysis

The SPSS statistical analysis package (Version 25) and R software were used to conduct all statistical analyses. Data were first screened for outliers, and missing data were removed by the listwise deletion method due to the low rate (<2%) of missing data. Mean, standard deviation, and correlation of each item in POSE were computed. Principal component analysis and confirmatory factor analysis of POSE were conducted afterward. Regression analysis was conducted to determine which demographic variables contribute to the variances of students’ perceived changes in their skills, emotion, participation, and performance engagement.

To analyze the open-ended essay question, both authors independently read each of the 406 responses and coded them using the language of the responses. After the initial coding process, the authors convened to create a list of themes that grouped together the related codes and resolved discrepancies in the interpretation of each essay. There were 1−3 themes assigned to 367 of the responses (90.4%), whereas the remaining 39 responses (9.6%) lacked sufficient detail to be able to assign a theme. Table S4 in the Supporting Information lists all the essay responses and the assigned themes. Frequency analysis was performed to determine the number of times that each theme occurred, and the responses were also analyzed by demographic group to determine if there were any notable differences in the frequency of themes between different groups.

FINDINGS

Research Question 1: Descriptive Results

The mean of most items in POSE is below 3, except for items 7, 15, 16, and 18. All of the items were measured by 5-point Likert scales, with values ranging from 1 (significantly decreased) to 5 (significantly increased). In general, participants reported that their chemistry online engagement did not change or somewhat decreased (M ranges from 2.48 to 3.22; SD ranges from 0.87 to 1.31). The inter-item correlations were significant between any two items of POSE (ranged from 0.25 to 0.86, $p < 0.01$). Table S2 presents the mean, standard deviation, and reliability for each item of POSE and the inter-item correlations of POSE (all statistical tables are in the Supporting Information).
Principal Component Analysis of POSE

Principal component analysis (PCA) with direct oblimin rotation was conducted to assess the underlying structure for the 19-item POSE scale. The results of the PCA are summarized in Figure 1 and Table S3. Four factors were requested, since the items were designed to index four constructs: skills, emotion, participation, and performance. 28 The factoriality of the 19 items in POSE was examined. Several well-recognized criteria for the factorability were used. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was used to test if the variables were too highly correlated to distinguish between them. 41 The KMO was 0.936, which is above the value of 0.5, suggesting a satisfactory factor analysis. 41 The Bartlett test of sphericity was assessed to find whether there was a relationship between the variables. 41 The result was $\chi^2(171) = 5665.28, p < 0.001$. Given these criteria, principal component analysis was deemed to be suitable with all 19 items.

After rotation, the first factor accounted for 50.42% of the variance, the second factor accounted for 24.87%, the third factor accounted for 10.47%, and the last factor accounted for 4.80%. Table S3 displays the items and factor loadings for the rotated factors. These factors were in line with our hypothesis. Internal consistency for each factor was examined using Cronbach’s $\alpha$. Analyses of the internal consistency yielded satisfactory results with adequate Cronbach’s $\alpha$ of 0.93 for Skills, 0.87 for Emotion, 0.83 for Participation, and 0.81 for Performance.

Confirmatory Factor Analysis of POSE

A confirmatory factor analysis (CFA) was conducted on the basis of the PCA results. The R software with lavaan package was used to conduct CFA. According to PCA results, we fitted multiple four-factor correlated models and proceeded with the model shown in Figure 2.

As shown in Figure 2, we removed items 6 and 11. Item 6 was rewritten from the original OSE survey, and item 11 had low factor loading in PCA. The $\chi^2$ statistics result was statistically significant ($p < 0.001$). The final model shows an acceptable fit to our data, where $\chi^2(6, 417) = 2.56, p < 0.05$. They also accounted for 4% of the variance in skills, $\chi^2(6, 417) = 2.56, p < 0.05$. Gender was a significant predictor in participation, and first-year student status was a significant predictor of performance. URPOC was a significant predictor of skills, participation, and performance. Female students received higher scale scores in participation than male students ($\beta = -0.11, p < 0.05$). First-year students received lower scale scores in performance than non-first-year students ($\beta = -0.11, p < 0.05$).

Research Question 2: Multiple Linear Regressions

Regression-based factor scores were obtained, and multiple linear regressions were conducted using SPSS to examine which variables contribute to the variances of students’ perceived changes in their skills, emotion, participation, and performance in the general chemistry course. Independent variables included gender (female or male), race (URPOC or non-URPOC), first-year student status (first-year student or non-first-year student), STEM status (STEM college or non-STEM college), first-generation student status (first-generation student or non-first-generation student), and transfer student status (transfer student or non-transfer student). Dependent variables included skills, emotion, participation, and performance scale scores. Independent variables were entered in the model to predict students’ perceived changes in their skills, emotion, participation, and performance. The possibility that multicollinearity among the predictors substantially influenced these results was evaluated. On the basis of Pallant’s recommendations, 45 all tolerance values are above 0.81, and all VIF values are less than 3.06; therefore, multicollinearity may be ignored at this time.

Results from the multiple linear regressions are presented in Table 3. All independent variables accounted for 4% of the variance in skills, $F(6, 417) = 2.56, p < 0.05$. They also accounted for 4% of the variance in participation, $F(6, 417) = 2.56, p < 0.05$. Gender was a significant predictor of participation, and first-year student status was a significant predictor of performance. URPOC was a significant predictor of skills, participation, and performance. Female students received higher scale scores in participation than male students ($\beta = -0.11, p < 0.05$). First-year students received lower scale scores in performance than non-first-year students ($\beta = -0.11, p < 0.05$). URPOC students received lower scale scores than non-URPOC students in skills ($\beta = -0.16, p < 0.01$), participation ($\beta = -0.11, p < 0.05$), and performance ($\beta = -0.11, p < 0.05$).

Table 3. Summary of Multiple Linear Regression Analyses Predicting Skills, Emotion, Participation, and Performance (N = 426)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Skills $^a$</th>
<th></th>
<th>Emotion $^b$</th>
<th></th>
<th>Participation $^c$</th>
<th></th>
<th>Performance $^d$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>SE $B$</td>
<td>$\beta$</td>
<td>$B$</td>
<td>SE $B$</td>
<td>$\beta$</td>
<td>$B$</td>
<td>SE $B$</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.12</td>
<td>0.10</td>
<td>-0.06</td>
<td>-0.13</td>
<td>0.10</td>
<td>-0.07</td>
<td>-0.22</td>
<td>0.10</td>
</tr>
<tr>
<td>URPOC</td>
<td>-0.31</td>
<td>0.10</td>
<td>-0.16</td>
<td>0.13</td>
<td>0.10</td>
<td>0.07</td>
<td>-0.22</td>
<td>0.10</td>
</tr>
<tr>
<td>First-year</td>
<td>-0.20</td>
<td>0.12</td>
<td>-0.09</td>
<td>-0.15</td>
<td>0.12</td>
<td>0.07</td>
<td>-0.09</td>
<td>0.12</td>
</tr>
<tr>
<td>STEM</td>
<td>-0.07</td>
<td>0.11</td>
<td>-0.04</td>
<td>-0.18</td>
<td>0.11</td>
<td>-0.09</td>
<td>-0.15</td>
<td>0.11</td>
</tr>
<tr>
<td>First-generation</td>
<td>0.04</td>
<td>0.11</td>
<td>0.02</td>
<td>0.02</td>
<td>0.11</td>
<td>0.01</td>
<td>0.05</td>
<td>0.11</td>
</tr>
<tr>
<td>Transfer</td>
<td>-0.04</td>
<td>0.15</td>
<td>-0.02</td>
<td>0.21</td>
<td>0.15</td>
<td>0.07</td>
<td>-0.17</td>
<td>0.15</td>
</tr>
</tbody>
</table>

$^a$R$^2 = 0.04, p = 0.02$. $^b$R$^2 = 0.03, p = 0.09$. $^c$R$^2 = 0.04, p = 0.02$. $^d$R$^2 = 0.03, p = 0.07$. $^{*}p < 0.05$. $^{**}p < 0.01$. 

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Research Question 3: Qualitative Analysis of Essay Responses

In addition to the 19-item POSE survey, students were also provided an opportunity to respond to an open-ended essay prompt, given as “After the Coronavirus outbreak, how has online instruction changed your learning in the general chemistry course? Please type your answer in the text box below.” The essay prompt was deliberately designed to be open-ended, to ensure that the students’ most significant thoughts were captured. Many of the responses centered on the personal and environmental factors that affected their ability to adapt to emergency remote online teaching. This led us to focus much of our analysis of the essays within the confines of research question 3, seeking insight into why some students were better able to maintain their engagement than others. Out of the 431 survey participants, 406 entered a response for the essay question, and of those responses, 367 were detailed enough to identify one or more clear themes. Figure 3 summarizes the most prevalent themes identified from the essay responses. The results show that motivation and self-regulation emerged as the two clearest themes from the essay responses: 79 essays mentioned motivation, with 77 of them reporting a decrease in motivation. Many of these stated that their coursework became less important or reported a lack of interest in chemistry against the backdrop of the global pandemic. As one student wrote:

“I find it hard to stay current or consistent with the material because I now work extra hours to fill in for those that were laid off at my job. I find it hard to find the time or motivation to study. Showing up to class and being forced to pay attention is a more structured and normal approach to my education, so I pay attention is a more structured and normal approach to my education,”

Students were forced to adapt to learning in their home environment, and they reported increased difficulty finding the motivation to complete schoolwork in an unfamiliar setting. One student’s essay stated:

“I have had to drastically change my school schedule to accommodate my home schedule. I live with my family and I still have to tend to my chores while doing school work. My motivation is practically obsolete and my mental health has not been well as not being able to physically interact with others puts a damper on one’s mood. I’ve heard from many of my friends that they cannot find the energy to do their school work because there [sic] were so mentally drained.”

Related to this, the next most prevalent themes of the essays were “decreased focus” and “increased distraction”. Of the 48 students who indicated increased distraction in their essay responses, 34 wrote that being in their home environment was responsible. These students felt that being on campus in a classroom environment was conducive to their studies, but that the presence of family members at home made it more challenging to self-regulate their academic schedule and learning habits. For example

“Online instruction has made it much more difficult for me to focus during the lectures and to stay on top of studying. Because my entire family is home, my house can be noisy and chaotic and it can be difficult to find a space that is quiet that allows me to have full focus. Additionally, it has become much easier to procrastinate because I do not have the separation between a learning space and a home space.”

Whereas many of the essays commented on aspects of motivation and focus, with the vast majority indicating additional challenges posed by the COVID-19 remote instruction period, other prominent themes revolve around the effects of the pandemic on the student’s learning habits and study effort, further elaborating on skills engagement. These responses were more mixed in tone. A total of 25 responses explicitly suggested that it was difficult to adapt to self-paced learning, and 17 specifically mentioned that they prefer face-to-face instruction. According to one student

“My learning in general chemistry has dropped significantly. I do not feel that I am really grasping the material that I am learning. I am on top of assignment and videos, but the face-to-face instruction is missing.”

However, there were a significant number of respondents who reported that the pandemic had little effect on their learning, since the course materials were all available online before the pandemic and many students chose to participate in self-paced learning for the entire course (even before the pandemic). Issues with focus at home were still noted by some students who felt comfortable with the online format. As described in one of the student’s essays:

Figure 3. Summary of most prevalent themes from the survey’s essay responses.
“Prior to the Coronavirus outbreak, I stopped attending lectures because I felt like [PROFESSOR NAME] went too fast for me to comprehend the material, and it felt like an hour and a half of time wasted because I couldn’t grasp anything in that time. Luckily, he posts his recorded lectures online, and instead of going to class, I took it upon myself to view the videos, listen and take notes on my own time and at my own pace. That way, I could actually take my time to understand the concepts instead of wasting my time in class feeling clueless about everything. After the outbreak, I just continued my normal routine of watching the videos after they were posted, so that didn’t change. The main issue is that being quarantined at home, there’s no way I can effectively study in peace and quiet with my whole family around. There’s always noise.”

In addition, 14 respondents reported that they preferred the more flexible schedule afforded by the emergency remote online instruction; relatedly, 16 students reported increased effort, and 18 others mentioned that the pandemic afforded them with more time for study. As described in one essay

“I watch the lecture videos multiple times and pause anytime he begins a practice problem and try to do it myself. Once I do it, I watch his process and [sic] see if I did it correctly. I am learning much better in this format because I can pause what he is saying and try problems myself.”

Finally, several essay responses indicate a decrease in participation engagement as a result of the pandemic. There were 15 students who specified participation engagement as a result of the pandemic. Luckily, he posts his recorded lectures online, and instead of going to class, I took it upon myself to view the videos, listen and take notes on my own time and at my own pace. That way, I could actually take my time to understand the concepts instead of wasting my time in class feeling clueless about everything. After the outbreak, I just continued my normal routine of watching the videos after they were posted, so that didn’t change. The main issue is that being quarantined at home, there’s no way I can effectively study in peace and quiet with my whole family around. There’s always noise.”

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Finally, several essay responses indicate a decrease in participation engagement as a result of the pandemic. There were 15 students who specifically mentioned that the emergency remote online instruction made it more difficult to interact with the professor or get help in other ways, and another 11 who mentioned deleterious effects of having less interaction with their classmates. This is compared to only 3 responses which indicated either that it was easier to ask questions or that their interactions with classmates increased. One student remarked

“I have felt like it has lowered my engagement in the course, feeling disconnected from peers, instructor, and the course material. Not to mention working from home doesn’t give me the incentive to put forth the same amount of effort I would in a school environment.”

We were also interested to determine whether the themes from the essay responses were distributed differently among the demographic groups considered in this study. Figures S1–S6 in the Supporting Information show the division of the 7 most prevalent essay themes among the demographic groups. In general, the themes are distributed fairly evenly, with the percentage of essay themes attributed to each demographic group correlating with the percentage of students in that group. The data for URPOC students (Figure S2) suggests that the themes of “increased distraction” and “decreased self-regulation” were more prevalent among the URPOC students, consistent with the quantitative results. Similarly, the results suggest that first-year students (Figure S5) more frequently commented on decreases in self-regulation, and the quantitative results showed that first-year students showed lower performance engagement.

LIMITATIONS

The biggest limitation of this study is that it was conducted on one section of a general chemistry course, so it is not clear that the perceptions measured in this survey are broadly applicable to college students or even general chemistry students as a whole. In addition, the survey did not include any items about changes in students’ study environments, which from the essay responses appears to be an important factor but one we are unable to measure quantitatively. Finally, we did not receive permission from the registrar’s office to release grading data as part of this study, so it is impossible to correlate students’ perceptions of the course with their grades in this course.

IMPLICATIONS

In this work, we present the Pandemic Online Student Engagement (POSE) scale, which evaluates students’ changes in engagement following a sudden switch to emergency remote online instruction in response to COVID-19. The survey is derived from Dixson’s Online Student Engagement (OSE) scale, with the key difference that POSE uses a comparative Likert scale (1 = significantly decreased to 5 = significantly increased), as opposed to the absolute Likert scale (1 = not at all characteristic of me to 5 = very characteristic of me) in OSE. We performed principal component analysis and confirmatory factor analysis on the POSE scale and found similar factoring to the original OSE scale. The two exceptions are item 2 (putting forth effort), which was factored under skills engagement in POSE, but was factored under emotion engagement in OSE. In addition, we found that item 11 (really desiring to learn the material) had a relatively low factor loading on emotion engagement, and the presented fitted CFA model involved removing items 6 and 11. Nevertheless, the results validate the POSE scale as an effective tool to assess self-reported changes in student engagement as a result of the COVID-19 pandemic, and that it can provide insight into all four components of student engagement (skills engagement, emotion engagement, performance engagement, and participation engagement).

Looking at the descriptive results, we find that for most survey items the average response was near or slightly below 3 with standard deviations around 1, indicating on average that student engagement remained nearly constant or slightly decreased following the conversion to emergency remote online instruction albeit with significant variations among students. As we describe in more detail below, student demographic characteristics could relate to their responses to a scale component, and essay responses provide insight into some of the external factors that influenced a student’s engagement before and after the pandemic. In contrast to our hypothesis, the performance engagement factor is the only one in which all survey items had average scores >3, indicating that on average students expected their performance to improve after the change to emergency remote online instruction, despite decreases in other engagement categories. The grade for the course served as the survey setting is mostly (94%) determined by the students’ grades on online exams, scored in a binary fashion. Thus, this result suggests that students anticipated scoring better on their exams when taking them at home.

More compelling insights into the quantitative results comes from regression analysis, which determines the factors contributing to the variances of skills, emotion, participation, and performance engagement. Comparing males and females, we find that female students report significantly higher participation engagement than male students; participation includes the more social aspects of learning, such as group work, seeking help from the instructor, and online interactions with classmates. Both groups had means below 3 on the 5-point scale, indicating that their participation decreased during the emergency remote online instruction period, but for female students the decrease in participation was less pronounced. This course does not have any formalized group work requirements,
and class sessions were all lecture-style and delivered asynchronously during the emergency remote online instruction period, so the activities that would classify under participation engagement all require voluntary engagement outside of lecture. Previous research on gender differences in student participation is mixed, though one recent report did find that while masculinity is associated with in-class participation, femininity is associated with out-of-class interactions with the instructor, such as seeking help in office hours and emailing the instructor with questions. Thus, we believe that female students’ greater willingness to seek help from the instructor outside of class is a major factor behind their higher participation score in this survey. First-year student status is also a significant predictor of performance engagement. This suggests that first-year students, still tackling the challenges associated with the transition to college, feel less prepared to suddenly adapt to a changing course environment and achieve success.

URPOC is a significant predictor of three engagement components. URPOC students reported significantly lower skills, participation, and performance engagement. The course used for this study has a very diverse student population, with nearly equal numbers of URPOC (N = 206) and non-URPOC (N = 219) students included in the analysis. It has long been established that URPOC students face a stereotype threat, which is a significant source of anxiety and can decrease their academic motivation and performance. This is likely one reason why URPOC students reported steeper decreases in participation and performance engagement, since the stereotype threat makes them less willing to proactively seek help outside of class from classmates or the instructor. Beyond the stereotype threat, there are a number of other challenges faced by URPOC students that contribute to their underrepresentation in STEM fields. URPOC students and other minoritized groups often receive their precollege education in resource-poor districts and thus are less prepared for college, likely contributing to their decrease in skills engagement. Relatedly, they often come from homes and neighborhoods with less internet and education resources available, making it more difficult to adapt to emergency remote online instruction when they are stripped of the resources previously available to them at the university. Regardless of the precise reasons, which are likely many and complex, these survey results indicated that the engagement of URPOC students was more adversely affected by the COVID-19 pandemic, indicating that special attention needs to be paid to URPOC students during future periods of emergency remote online instruction, to ensure that the performance gap does not widen further.

The essay responses provide further insight into students’ perceptions of the sudden instructional change. Many students mentioned a decrease in motivation in their essay responses (see Figure 3), which in the context of expectancy-value theory suggests that many students experienced a decrease in task value (attainment value and intrinsic value) as a result of the traumatic and encompassing global events of COVID-19. In the context of student engagement, these most prevalent themes indicate that many students experienced decreases in skills engagement and emotion engagement following the pandemic, which both made it more difficult to maintain regular study habits and to feel that what they were learning is important and relevant. That said, responses related to student work habits and their preference for in-person or emergency remote online instruction were more mixed. From these responses, it seems like the effect of the pandemic on students’ skills engagement depends somewhat on their home environment and the habits they had built prior to COVID-19. There were also a number of responses mentioning that it was more difficult to interact with the instructor and fellow students after the pandemic, leading us to conclude that the sudden switch to emergency remote online instruction decreased social aspects of learning for most students, and that they were unable to seek help from the instructor or study with classmates to the same extent they did before the pandemic.

The results in this study largely corroborate many of the findings in previous works devoted to tracking the effects of COVID-19 emergency remote online instruction on chemistry education. Similar to the work of Perets et al., this study makes it apparent that students had difficulty remaining engaged after the switch to emergency remote online instruction, born out in both the quantitative results and in many of the essay responses. Also, in the same vein as some of Petillon and McNeil’s study, the essay responses in this work show that increased stress and anxiety were a factor for many students following the onset of COVID. Our essay responses also corroborate Jeffery and Bauer’s observation that many students experienced a decrease in peer interactions, though the effects on student learning were not investigated in this work. However, there were some notable differences between the results of this work and these previous efforts. Miltiadous, Callahan, and Schultz found a distinct preference for in-person learning among their students, but in our essay responses the tone was more mixed, with some students expressing a preference for remote instruction, and many students noting that the adjustment was simple since so many of the course materials were online already. This observation perhaps indicates that, in courses with a nominally face-to-face format, the adjustment to remote instruction was easier if students were already accustomed to having and using a lot of online resources. Finally, in a study by Wester et al. across a few science courses, they found that emergency remote online instruction caused a decrease in emotional engagement, but such a decrease was not readily apparent from our quantitative analysis, and none of our demographic factors predicted emotion engagement.

CONCLUSION

This study provides insights into the effects of the COVID-19 pandemic on college student learning, from the standpoint of motivation, student engagement, and self-regulation. A 19-item Pandemic Online Student Engagement (POSE) scale was developed to measure students’ self-reported changes in behaviors and attitudes following the sudden switch to emergency remote online instruction at the onset of the pandemic. The survey results indicate student engagement decreased in three of the four components during emergency remote online instruction, skills engagement, emotion engagement, and participation engagement, albeit with a range of outcomes among the population of students surveyed. Qualitative analysis of an open-ended essay response corroborates these findings and provides additional insight. Taken together, the mixed-methods approach suggests that many students experienced a decrease in motivation and self-regulation, because the historic pandemic event made it more difficult to focus on studies, and because being in their home environment was not conducive to self-regulated learning. Underrepresented people of color (URPOC) students reported significantly greater decreases in three of four engagement components: skills engagement, participation engagement, and performance engagement. Insights from the essay responses...
indicate that the student’s home environment and circumstances play a significant role in their adaptation to emergency remote online instruction, with students who live in large family environments and/or are financial providers for their family facing the largest hurdles to maintaining their engagement. The challenges for college administrators and instructors are readily apparent, with the pandemic making it even more difficult to engage students from all backgrounds and reduce performance gaps. Instructors need to be mindful that the pandemic and emergency remote online instruction can have differential effects on students and need to strive to design classes that allow students to maintain a sense of connectedness to the instructors, their classmates, and the course materials. As one of the essay responses indicated “I do not believe online instruction is just the fault of online schooling. It’s hard to focus when I witnessed my mother having breakdowns due to losing her brother, someone whom she loved very much, to COVID-19, along with seeing both my parents get laid off. This leads me to stress about other things, instead of school, which leads it to not be just the fault of online schooling.”

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.1c00665.

Tables with POSE survey items, descriptive statistics, principal component analysis, and essay responses, and figures summarizing essay responses as a function of demographics (PDF)

■ AUTHOR INFORMATION

Corresponding Author

Fan Wu — Office of the Provost, University of Houston, Houston, Texas 77204, United States; Email: fwu7@uh.edu

Author

Thomas S. Teets — Department of Chemistry, University of Houston, Houston, Texas 77204, United States; orcid.org/0000-0002-7471-8467

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.1c00665

Notes

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