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Article

Impact of the Emergency Transition to Remote Teaching on Student Engagement in a Non-STEM Undergraduate Chemistry Course in the Time of COVID-19

Ethan A. Perets, Daniel Chabeda, Angela Z. Gong, Xin Huang, Tat Sang Fung, Ka Yi Ng, Meghan Bathgate,* and Elsa C. Y. Yan*

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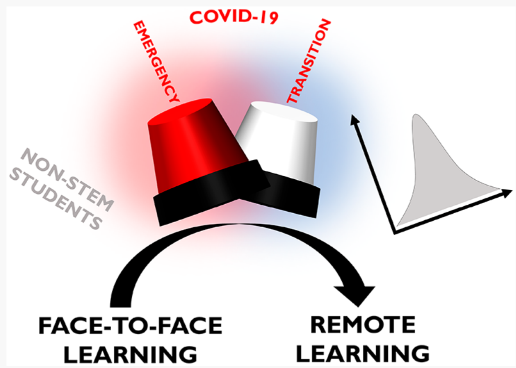
ABSTRACT: In Spring 2020, we began a study focused on the development of inclusive teaching practices in an undergraduate chemistry lecture course for non-STEM students. In the wake of the COVID-19 pandemic and ensuing educational disruptions, we changed the design of our study to focus on the learning and teaching experiences of students and instructors. Here, we conducted student surveys before and after the emergency transition to remote teaching and analyzed data on student participation in the online setting. We observed that student engagement was likely negatively impacted by the emergency transition. We also found that lectures engaged students less after the transition. By contrast, course activities that did not heavily rely on a physical classroom, such as students blogging about their research of chemistry literature and crafting an independent research paper about a chemical question, were more effective in retaining student engagement after the transition. We also analyze student utilization of synchronous and asynchronous learning opportunities (for example, recorded lectures). We contextualize student engagement in the course relative to policies adopted by the educational institution, notably a mandatory universal pass/fail grading policy. Finally, we communicate thematic reflections from students, undergraduate peer tutors, graduate student teaching fellows, and the course instructor about learning chemistry and teaching non-STEM undergraduates in the time of COVID-19. On the basis of these studies, we recommend seven instructional strategies for teaching chemistry during sustained educational disruptions.



KEYWORDS: *First-Year Undergraduate/General, Distance Learning/Self Instruction, Nonmajor Courses*

■ INTRODUCTION

The COVID-19 pandemic plunged universities, educators, and students worldwide into unprecedented educational scenarios.[1] Seemingly overnight, students across the world transitioned to remote learning through a virtual setting. Educators were forced to adapt course activities to accommodate online learning. Recent work has reflected on the challenges of abrupt teaching transitions in times of disruption.[2,3] The ubiquitous educational disruption due to COVID-19 has made the need for these lessons, and their extension, more relevant than ever before.

The Chemistry of Food and Cooking is a lecture course in the Department of Chemistry at Yale University that was taught during the spring 2020 semester (January−May) and suffered disruptions due to COVID-19. The course was designed to help non-STEM students appreciate the relevance of chemical structures and chemistry concepts to everyday life, and to apply fundamental knowledge in chemistry to explain cooking processes. Enrollment was limited to undergraduate, non-STEM majors who had not taken Advanced Placement or International Baccalaureate chemistry examinations, or a college-level chemistry course. Teaching the connections between chemistry and cooking has proven to be a popular theme to make chemistry accessible and to engage non-STEM students; Dabrowski and McManamy recently pointed out the growing body of literature that exists about the design of food chemistry courses for nonchemistry majors.[4]

Before the Spring 2020 semester began, an educational research project was designed in support of a grant funded by the National Science Foundation exploring effective pedagogical strategies for inclusive teaching of chemistry to non-STEM majors. Our research centered on exploring students' relationship with chemistry and their class community

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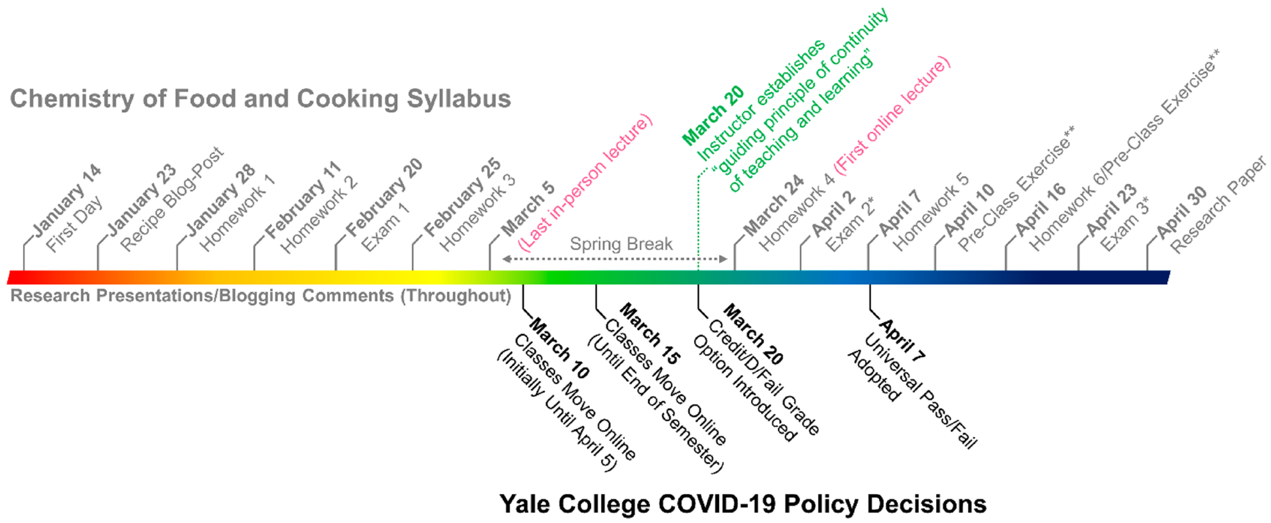

Figure 1. Timeline of course syllabus and COVID-19 policy decisions during Spring 2020. Timeline of syllabus by assessment due dates (gray). The "guiding principle of continuity of teaching and learning" (green) retained the original syllabus, except exams 2 and 3 (marked with *) were conducted online and open-book, and in-class quizzes were changed to preclass exercises (marked with **). Timeline of Yale College COVID-19 policy announcements (black).

throughout the semester. Before the U.S. onset of COVID-19, we designed the precourse, midcourse, and postcourse survey, and we conducted the precourse survey in January 2020. With the onset of COVID-19, we reduced the number and length of data requests to students during this time of increased stress. We eliminated the midcourse survey and heavily revised the postcourse survey. We adjusted our research questions and survey items in the postcourse survey to focus on the impact of COVID-19 on students' class experience, using the data collected by the presemester survey as an appropriate baseline. Here, we present data from our pre- and postcourse surveys that relate to these revised research questions. The full presurvey data is not presented here, as it no longer aligns with these revisions.

We wish to understand how abrupt transitions to emergency remote teaching may impact the teaching of chemistry to non-STEM majors. In this paper, we use survey data gathered before and after the emergency transition to remote teaching to describe students' learning experiences in a non-STEM undergraduate chemistry lecture course. Although we reduced the length of our surveys in the postcourse survey in the hope of increasing the student response rate, the sample size is small. For the class of 52 students, 15 students participated in the precourse survey, 15 students participated in the postcourse survey, and 9 students completed both the pre- and postcourse surveys. However, we conducted the precourse survey without anticipating the disruption due to COVID-19. Hence, the availability of the precourse survey data allows direct comparisons with some of the postcourse survey data, thus providing a rare glimpse of the impacts due to the COVID-19 pandemic. Although the small sample size does not support rigorous statistical analysis for standard education research, we present the survey data in a factual and observational manner to document this impact of the once-in-a-lifetime global pandemic in a chemistry course for non-STEM majors. To supplement and contextualize our data set, we also collect thematic reflections on the course experience from students, undergraduate peer tutors (D. Chabeda and A. Z. Gong), chemistry graduate student teaching fellows (E. A. Perets and X. Huang), and the instructor (E. C. Y. Yan). We respond to the call for papers[5] with an analysis of the COVID-19 emergency transition to remote teaching, within the unique context of a chemistry lecture course for non-STEM majors.

COURSE DESCRIPTION

Instruction

The one-semester course Chemistry of Food and Cooking was divided into six modules on the following themes: (i) atoms and molecules, (ii) carbohydrates, (iii) fats, (iv) proteins, (v) kinetics, and (vi) thermodynamics. For each module, the instructor delivered three or four 75 min lectures (see Supporting Information, section A, for course syllabus). Two chemistry graduate student teaching fellows each conducted 50 min discussion sections two times per week and a 60 min office hour once per week. The instructor recruited two advanced undergraduate chemistry majors, recommended by Yale chemistry faculty, to act as peer tutors. Previous research has shown that peer tutors can remove or invert the traditional performance gaps between majority and underrepresented minority students.[6,7] The two peer tutors each conducted a 60 min tutoring section two times per week. Student attendance was optional for instruction sessions offered by teaching fellows or peer tutors.

Timeline of Instruction

The course was conducted with 13 weeks of instruction and a 2 week spring break. Prior to the spring break (January 14–March 5), all instructional activities, including class lectures, teaching fellow and peer tutor sessions, and office hours, were conducted in person. After the spring break, all these instructional activities were offered in a remote setting until the end of the semester.

Assessment

Student performance was evaluated on the basis of four assessment categories: (a) in-class quizzes (10%), (b) problem sets (30%), (c) examinations (30%), and (d) an individual project (30%) (see Supporting Information, section A). Figure 1 (gray) presents the course structure. Students completed one problem set per module (assigned 2 weeks in advance of due

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date), and one noncumulative exam every two modules. Completion of the individual project took place progressively over the course of the semester and was broken down into manageable elements. The students were required to choose a favorite recipe, post on the class blog a chemical question relevant to the recipe (5%), research the scientific answer to their question, deliver a 5 min presentation on their research to the class (5%), post comments on the class blog (5%), and produce a 1000 word final paper to report their research findings that address the chemical question that they chose (15%).

Assessment Modifications

Following the onset of the COVID-19 pandemic and the learning transition, the instructor established "the guiding principle of continuity of teaching and learning" for the course (Figure 1, green). Namely, the original course syllabus schedule of homework, final paper, exams, lectures, discussion sections, office hours, and peer tutoring sections was retained (see Supporting Information, section B). However, some assessments were modified. In-class quizzes were converted to preclass exercises because the technological burden of administering in-class quizzes in a virtual setting was judged to be too high, and because some students could not attend lectures synchronously. To accommodate asynchronous learners, preclass exercises were made available to students at least 2 days before the exercise was due. Also, whereas exam 1 was closed-book, exams 2 and 3 were open-book. Exams 2 and 3 were released to students at the original date and time and submitted by students electronically within an allotted time window. To receive a grade on exams 2 and 3, students were required to sign and submit an "Honor Code" contract with each exam. Additionally, prior to the online transition, all student presentations took place during face-to-face lectures. Following the online transition, presentations were mostly conducted synchronously with class lectures. However, at least one student living outside of the United States recorded their presentation asynchronously. The recording was later shown during a live lecture.

Evolution of Grading Policy

The students were graded on an absolute grading scale out of 100 points total for the semester. Each assessment and assessment category constituted a well-defined percentage of the total grade (Table S1). An absolute grading scale, independent of class distribution, encourages collaboration rather than competition and fosters active learning.[8] Student grades were regularly updated after each assessment due date (Figure 1) using "Post'Em" in the Canvas learning management system (see Technology section below). This feature allows students to view only their own grades, giving students the ability to track their individual progress in the course.

During the spring break period, the university evaluated its grading policies. On March 20, Yale College adopted an optional credit/D/fail grading system (Figure 1). Under this policy, students could choose either to receive a letter grade or a credit/D/fail grade for any or all of their classes for the Spring 2020 term. The latter option meant that course grades C− and above would be recorded as "CR" on student transcripts and still count toward student degree requirements, whereas grades of D+ and below would be recorded on student transcripts with a letter grade. In subsequent weeks, however, Yale College students and faculty voted to switch to a mandatory universal pass/fail grading system. Yale College announced this change of grading systems on April 7 (Figure 1). Despite the university policy change, the course retained the absolute grading scale, and student grades were continually updated in Canvas through the end of the course, allowing students to receive regular feedback on their learning progress (see Reflections section). To conform with Yale College's universal pass/fail policy, final grades were reported on student transcripts according to the pass/fail scale.

Technology

Students interfaced with the course using the Canvas learning management system. Students blogged about their individual project topics using CanvasPress. Prior to transitioning to online teaching, in-class quizzes were conducted using PollEverywhere and accessed through a computer or mobile device. After the emergency transition to remote teaching, all lectures, discussion sections, office hours, and peer tutor sections were hosted on Zoom. Live lectures were delivered for synchronous learning. The lectures were recorded and made available to students immediately after the live lecture to support asynchronous learners.

■ DATA COLLECTION

Participants

The course enrolled 52 students, along with two teaching fellows and two peer tutors. The pre- and postcourse surveys were each completed by 15 students (some partial responses). Nine students completed both the initial and postcourse surveys and content tests. Of those who elected to provide gender data, 12 students identified as female, eight students as male, and one student identified as nonbinary. The research project was deemed exempt by Yale's Institutional Review Board (Protocol ID: 2000027124).

Student Precourse Survey

An email to an online survey was distributed in the second week of the course. Consent was requested at the start of the survey, and students were informed participation would not affect their grade or standing in the course. All student data was anonymized by a coauthor (M. Bathgate) unaffiliated with the instruction of the course to reduce bias and encourage students to share their candid responses. Data collected in the precourse survey consisted of students' motivations and expectations for taking the course, sense of belonging, and perceived competence in scientific literacy (see Supporting Information, section C, for survey questions).

Student Postcourse Survey

Run during the final weeks of the semester, the postcourse survey assessed students' experience with course activities and structure. To gather data specific to the transition to online learning, some postcourse survey questions asked about student experiences "prior to the transition to a virtual setting" and "after the transition to a virtual setting" (see Supporting Information, section D, for survey questions).

Additional Student Data

Records of student attendance of synchronous course lectures and teaching fellow and peer tutor sessions, as well as utilization of lecture slides and recordings for asynchronous learning, are presented. Three students provided reflections on the learning experience through a one-to-one semiformal interview with the teaching fellow (E. A. Perets) conducted in early June 2020. The purpose of the interviews was to gauge

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student impressions immediately after the emergency transition to remote learning ("What first came to mind when you learned that all classes would be delivered remotely?"), to understand what course policies contributed either negatively or positively to students' learning experiences after the transition, and to inquire what changes students would have made to the course to aid their learning experiences after the transition.

Instructional Perspectives

Teaching fellows and peer tutors were surveyed twice: once in the second week of the semester, focusing on their goals and expectations for serving in their course role, and again at the close of the course (see Supporting Information, sections E and F, for survey questions). The peer tutors, teaching fellows, and instructor, who are coauthors, provided reflections on their teaching experiences during the transition to remote instruction.

■ RESULTS

Scope of Data

In this Results section, we present the data collected for the non-STEM major course, Chemistry of Food and Cooking, offered at Yale University during spring 2020. The survey data focus on the students' assessment of how the transition to emergency remote learning impacted (1) their motivations, and expectations; (2) their feeling of being comfortable, committed, and supported in the course; and (3) the effectiveness of various course activities in maintaining their engagement. The data also include activities of synchronous and asynchronous learning tracked by the online course platforms (Canvas and Zoom). As indicated earlier, the small data set does not permit rigorous statistical analyses. Thus, we present the data in its original form in the hope of capturing the impact of this unprecedented COVID-19 pandemic on chemical education. While we do not intend to draw direct conclusion from the data using the standard chemical education research methods, we discuss what the data reflect about the impact of the emergency transition to remote learning for the chemistry course targeting non-STEM majors in the Discussion section.

Motivation and Expectation

The first set of survey data is related to student motivation and expectation. Of the 15 students who completed the precourse survey, 13 said they would not characterize themselves as a "chemistry person". This was expected as the course was only offered to non-STEM majors with little exposure to chemistry (see Introduction). At the conclusion of the course, 11 of 15 students who completed the postcourse survey agreed that they now understand the science of chemistry. Respondents' initial motivations for taking the course fell into two major categories: to gain a required science credit for obtaining their degree and to learn how chemistry applies to cooking. Following the conclusion of the course, 14 of the 15 respondents of the postcourse survey reflected that the course met their expectations. Moreover, 12 of the 15 respondents disagreed that the transition to a virtual setting had impacted the course meeting their expectations.

Class Belonging

The second set of survey data comes from the judgment of how students felt in their level of commitment, comfort, and support in the course before and after the transition. Figure 2

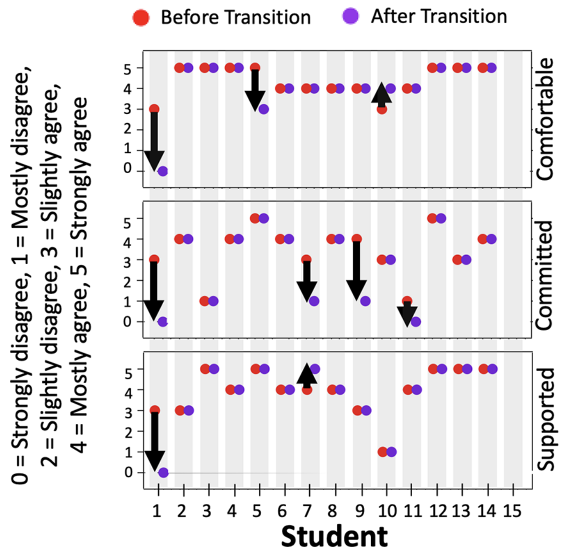

Figure 2. How students felt the level of support, commitment, and comfort before and after the emergency transition to remote learning. Students were asked to indicate their level of agreement in feeling supported, committed, and comfortable in the course before and after the transition. Arrows indicate the direction and magnitude of change in respondents' answers. One respondent (student 15) did not answer this set of questions.

shows the response of 14 students. Among the level of comfort, commitment, and support, the level of commitment shows the biggest negative change. Indeed, nearly half of the respondents noted the biggest challenge after the transition to a virtual setting was struggling to remain motivated and engaged in the course (Table S2). Of the 42 (= 3 × 14) entries by the 14 respondents, only 9 entries encompass changes (9 arrows in Figure 2) while 33 out of 42 entries remain the same, suggesting a majority of the students did not feel the impact of the transition. If these changes are quantified using an arbitrary scale (0−5), Figure 2 reveals that the overall net change (−15 units) is contributed predominantly by a single respondent (i.e., −9 units for student 1).

Class Activities

The third set of data capture the individuals' responses to how much they agreed that a particular course activity helped them engage in learning before and after the transition (Figure 3). These activities include lecture, course blogging, quiz, student presentation, and research paper. Lectures are the only course activity with a universal decreased response from all respondents while student presentation shows the largest changes in both directions. Moreover, on the arbitrary scale of 0−5, the other activities show small net changes: research papers (0), quizzes (−2), and blogging (0). Also worth noting is that the research paper scores relatively high in the effectiveness of engaging students in learning regardless of the transition.

Synchronous/Asynchronous Learning

We also tracked the number of students who engaged with the live (red) or recorded (black) lectures over time. Figure 4a shows the total student attendance in live Zoom lectures (red) and number of students who watched recorded lectures (black). Figure 4b illustrates the number of times lecture slides (red) and recorded lectures (black) were viewed by students through the semester. These figures also indicate the points for

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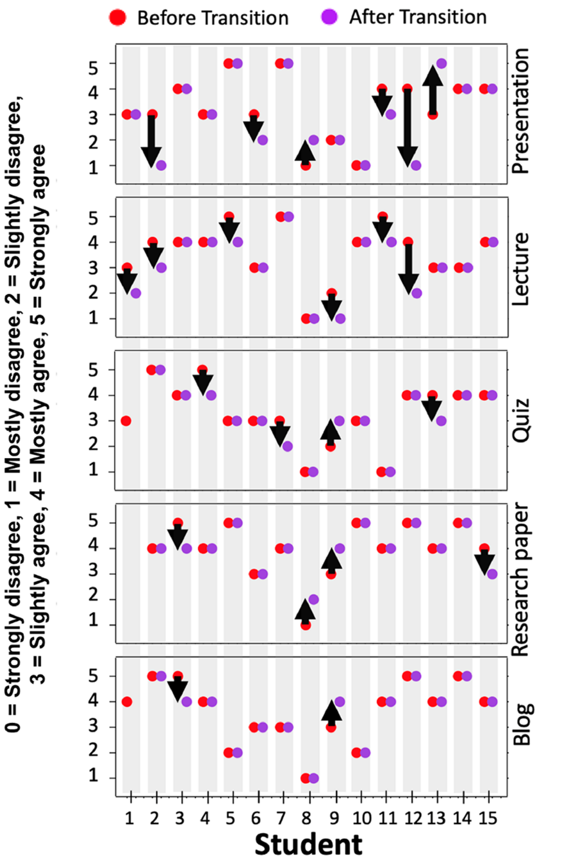

Figure 3. How course activities and assessments helped students to engage in learning before and after the emergency transition to remote learning. Students were asked to indicate their level of agreement that a particular course activity or assessment helped them to engage in learning before and after the transition. Arrows indicate the direction and magnitude of change in respondents' answers. One respondent (student 1) partly answered the questions.

the transition to emergency remote learning (blue lines) and Yale College adopting the universal pass/fail grading policy (gray line). Figure 4c presents the attendance of students in teaching fellow and peer tutor sections before (red) and after (blue) the transition.

■ DISCUSSION

Students' Assessments

Although the sample size of the survey is small ($n = 15$), the survey data still capture several observations that could reflect the impacts of COVID-19 on non-STEM majors learning chemistry. First, the course appeared to meet the respondents' expectation despite the emergency transition. A majority of the respondents agreed that the course helped them understand the science of chemistry and that the transition to a remote setting had not impacted the course meeting their expectations. Second, students were asked to judge their level of commitment, comfort, and support in the course before and after the transition (Figure 2). A majority of the students did not feel the impact of the transition to their feeling of belonging. Nonetheless, among the 14 respondents, one student (e.g., student 1 in Figure 2) gave a predominantly negative response in all aspects of commitment, comfort, and support in the course. It would be the instructor's concern and challenge to identify individual students who may be disproportionally impacted by the transition and thereby provide timely assistance. This is particularly important for inclusive teaching because feelings of community and inclusiveness are positively correlated with student learning outcomes in a virtual education setting,[9−12] and the importance of fostering student engagement in online learning environments is well-documented.[13] These sentiments may become critical during a transition to emergency remote teaching. Finally, the students evaluated the effectiveness of each class activity in engaging them in learning during the transition. Among all the activities, the impact of the transition in lectures is the most negative. This may not be surprising because lectures traditionally take place in a face-to-face setting. The student presentation data shows both positive and negative changes. Although it is difficult to pinpoint the reason for this observation, we speculate that it may be related to whether the respondents had delivered the presentations before or after the transition. The other activities, including research papers, quizzes, and blogging, individually do not show significant changes. Quizzes and blogging were mostly already completed by students prior to the transition to virtual education and, also, by their nature include a significant digital component, while the research paper was a report of an individual's work performed outside the classroom setting. One observation stands out: The research paper was identified by the respondents as an effective activity to engage them in learning chemistry regardless of the transition. This is potentially due to the fact that non-STEM majors in the arts, humanities, and social sciences have greater familiarity with being evaluated through writing essays and research papers. This finding provides insight into the further development of pedagogical strategies to engage non-STEM majors in learning chemistry.

Engagement in Synchronous/Asynchronous Learning

To look at the synchronous/asynchronous data, we focus on two time points: (1) the beginning of the transition of remote teaching and learning and (2) Yale College's adoption of the universal pass/fail grading system. First, the adoption of the pass/fail grading system on April 7 corresponded to a significant drop in the number of students who attended the Zoom lecture (Figure 4a). Attendance levels at lectures remained low for the remainder of the semester. Interestingly, students accessed the lecture recordings (black) in higher numbers immediately after April 7. However, this route of asynchronous engagement was not maintained, and numbers fell shortly thereafter. This suggests students explored asynchronous engagement with the course after adoption of the universal pass/fail grading policy but did not sustain the migration to asynchronous learning. Second, lecture slides were also made available throughout the semester for students to view and download after each lecture. Students accessed the lecture slides (Figure 4b) on Canvas at a higher rate before the online education transition. Following the remote learning transition, students viewed the lecture slides less over time. During this period (March 24−April 21), the most significant drop corresponded to April 7, when Yale College adopted the universal pass/fail grading policy (Figure 1). Views of Zoom lecture recordings (black) also spiked after April 7 and fell sharply thereafter. Overall, student engagement through Zoom and Canvas was demonstrably lower after April 7. Finally, postcourse survey respondents ($n = 15$) reported that their synchronous participation in teaching fellow and peer tutor

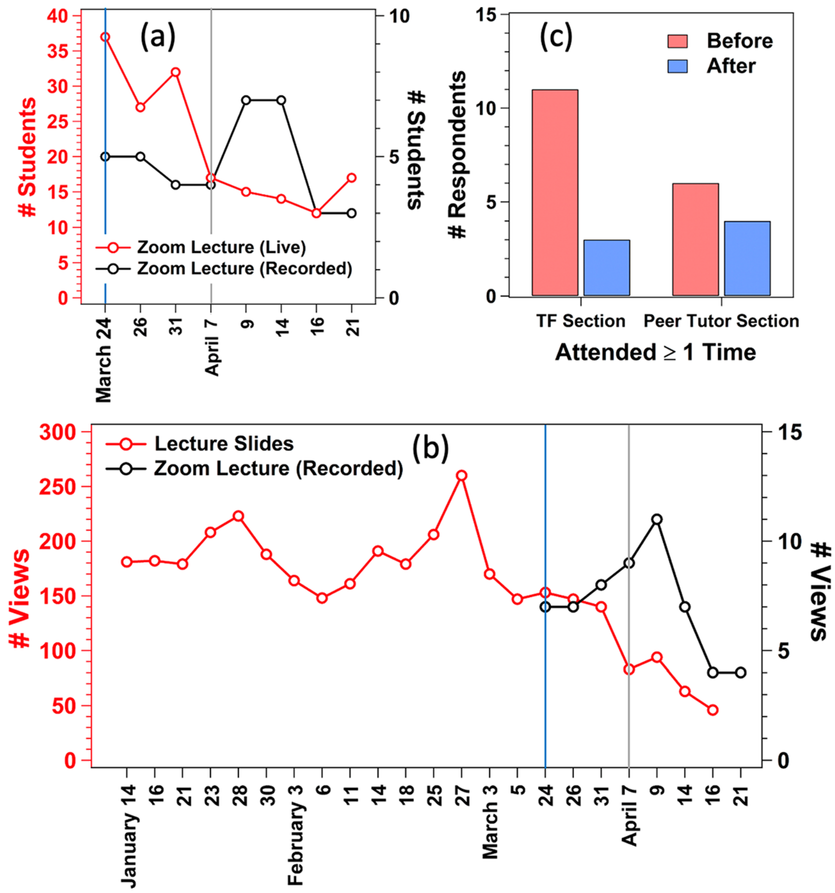

Figure 4. (a) Total student attendance in live Zoom lectures (red) and number of unique students who watched recorded lectures (black) after the transition to emergency remote learning (blue line indicates first lecture after the transition; gray line indicates date Yale College adopted universal pass/fail grading policy). (b) Number of times lecture slides (red) and recorded lectures (black) were viewed by students through the semester. No slides were posted for the lecture on April 21 because the instructor did not give a lecture; instead, roughly 10 students gave presentations on their research findings. (c) Respondent reports (n = 15) of their attendance in teaching fellow and peer tutor sections before (red) and after (blue) the transition.

sections also declined substantially after the transition to emergency remote instruction (Figure 4c). Altogether, students engaged with course instruction less after the transition to emergency remote learning, and Yale College's adoption of the universal pass/fail grading policy on April 7 had a perceptible, negative effect on the number of students who sought out course instruction.

■ REFLECTIONS

Students

All student interviewees noted that their primary challenge before the remote learning transition was to learn the course content. After the transition, the biggest challenge became maintaining engagement in the online learning experience. Interviewees also noted the importance of the students around them demonstrating engagement: If student attendance or engagement in the course fell, then so did their own motivation. This point merits further study. At least one report has concluded that students perceive instructor engagement to be more important than peer engagement.[14]

Student interviewees recounted their experiences with course policies that retained student engagement. They mentioned methods implemented in this course, such as student research presentations and discussions during teaching fellow and peer tutor sections. Interviewees noted the importance of more interaction between the instructor and students after the transition to a virtual setting. Students suggested that greater frequency of feedback on assessments (implemented in this course through frequent updating of grades on the Canvas website) could substitute for the feedback of a face-to-face setting. Student interviewees desired more group work through the use of Zoom "breakout rooms".

The "guiding principle of continuity of teaching and learning" (see Assessment Modifications section) was received positively by all interviewees. They especially appreciated the promptness of the instructor establishing this principle soon after learning that classes would move online (within 5 days, Figure 1). One interviewee noted that maintaining the structure of the class despite the transition to remote learning was important to maintaining "the feeling" of a classroom learning experience. However, another interviewee noted that absolute continuity in the face of an abrupt learning transition could fail to acknowledge the context in which learning occurs, missing an opportunity to impress upon students the real-world significance of the course matter.

All interviewees demonstrated concern that, in general, course policies designed in response to an emergency transition to remote teaching should recognize the potential inequities of student access to learning resources during a crisis.

Peer Tutors

Both peer tutors noted that their most significant instructional challenge was a lack of agility with virtual learning tools (e.g., Zoom "breakout rooms", screen sharing, recording, audio/visual, raising hands, and the digital whiteboard). Soon after Yale College announced that classes would transition to remote teaching (Figure 1), the Poorvu Center for Teaching and Learning at Yale offered teaching fellows and course instructors an in-person information session (March 13) on using Zoom, as well as virtual sessions on Zoom and Canvas in the weeks following this announcement. These offerings were not advertised to the peer tutors. The peer tutors found that the lack of training for the emergency transition negatively impacted their ability to teach chemistry concepts effectively and to engage non-STEM students. Thus, all persons responsible for course instruction (e.g., principal instructors, teaching fellows, as well as peer tutors) should be included in trainings for teaching in a virtual setting.

Even though both peer tutors were equipped with digital pen and tablet devices to utilize Zoom functionalities, incorporating these tools into instruction during the emergency remote teaching transition still proved difficult. The challenge of virtually drawing chemical structures compared to a physical chalkboard significantly detracted from the peer tutors' ability to teach effectively. Both peer tutors emphasize the potential advantages of chemistry-specific training modules for online teaching beyond generic Zoom training. Such training modules should be offered to all persons responsible for instructions of chemistry courses.

Before the transition to remote teaching, discussions during peer tutor sections could easily develop from a focus on course material to explorations of a related branch of chemistry or biology as students led discussions by their questions. For example, curiosity about functional groups in organic chemistry resulted in talks on the importance of reactivity in both chemistry and biology. A practice problem on stoichiometry once developed into an animated discussion on the history, uniqueness, and necessity of Avogadro's number and the mole. After the transition, peer tutor sections consisted almost entirely of direct responses to problem sets or practice exam questions.

Teaching Fellows

Both teaching fellows identify low student attendance in the optional sections as a principal challenge. This difficulty existed before COVID-19 but was exacerbated by the emergency transition to remote teaching (Figure 4 and Figure S1). Moreover, a unique challenge of this course was its target of non-STEM majors. Of the 15 precourse survey respondents, 12 disagreed that chemistry would help them in their future careers. The "low stakes" of optional teaching fellow and peer tutor sections likely contributed to poor attendance, especially after the transition.

To improve student engagement and outcomes after a transition to remote teaching, students should be strongly encouraged to attend teaching fellow sections (noting that equitable treatment of students who are unable to attend will be a priority). This suggestion is consonant with research by Eddy and Hogan that increased course structure aids student learning.[15]

The in-person, emergency training with Zoom (March 13) offered by the Poorvu Center for Teaching and Learning at Yale was critical, since neither teaching fellow had used the Zoom platform before. The training provided early opportunities to practice using Zoom for teaching and gave the teaching fellows confidence about the transition to online instruction.

Instructor

The instructor felt that it was very important to give students a sense of certainty in light of the very uncertain situation. Days before the start of online teaching, the instructor announced the "guiding principle of continuity of teaching and learning" (see Supporting Information, section B): the class would follow the schedule and grading system as outlined in the syllabus with the unchanged timeline for homework submission, final paper, exams, as well as all lectures, discussion sections, office hours, and peer tutoring sections. This announcement set the overall expectations for the course, important not only to the students but also the teaching fellows and peer tutors.

Preparing the open-book exams, the instructor invested many hours in designing the logistics and writing instructions (see Supporting Information, section G). The instructor prepared a document to specify time constraints, methods for downloading the exams and obtaining a time stamp for submission, rules of asking questions during exam, and an honor code. The students received this document days prior to the exam and took the exams following the instructions without any issue.

Before the transition, the instructor incorporated several live demonstrations to illustrate chemical concepts, e.g., combustion by igniting vodka in a hot pan and amphiphilicity by preparing salad dressing. After the transition, the instructor replaced live demonstrations by YouTube videos. These videos were effective in illustrating chemical concepts but fell short in engaging students.

The instructor believed that two elements in the original course design had helped ease the stress of students. First, the final grade was based on many class activities instead of solely examinations. Second, the course used an absolute grading system (e.g., 85−100% for A/A−, 75−85% for B+/B, etc.). At the time of the transition, an online grade-disclosure system (Post'Em) was already in place, by which the students could see their accumulated scores after finishing each class activity.

The universal pass/fail grading system impacted class participation. Right after the announcement (Figure 4), the attendance of live lectures dropped by half. This drastic drop negatively impacted the instructor's enthusiasm in preparing and delivering lectures. The instructor feels that it is important to further research and document the pros and cons of the pass/fail grading system in the emergency transition to online teaching due to COVID-19.

Yale's Poorvu Center of Teaching and Learning provided excellent technical support to faculty. The instructor participated in training sections, which helped the instructor conduct online classes without any technical issues. In retrospect, the instructor could have implemented the polling and breakout-room functions in Zoom to better engage students, and the random multiple-choice feature in Canvas to widen the topics covered in examinations.

Yale's student body has become more diverse with increasing numbers of low-income students, first-generation college students, and minority students. The emergency transition to online teaching provided the instructor with experience in knowing the additional challenges faced by these

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groups of students. The need for improving inclusive instruction continues beyond the COVID-19 pandemic.

CONCLUDING REMARKS AND RECOMMENDATIONS

The COVID-19 pandemic disrupted education worldwide in 2020. Some aspects of this disruption were temporary, whereas others promise to leave lasting and transformative impacts across all areas of education. In this report, we document how the COVID-19 disruption affected student engagement in a non-STEM undergraduate lecture course on the Chemistry of Food and Cooking.

We acknowledge the difficulties of generalizing our observations too broadly, given our sample size and the uniqueness of educating during an emergency transition to remote instruction due to a pandemic. We aim to assess our observations by analyzing additional student data to be gathered in the coming years. Despite these constraints, our survey data capture a snapshot of the student learning experience during the COVID-19 pandemic. Students noted their difficulties staying committed to the course after the emergency transition to remote teaching (see Reflections section). Although students' sense of belonging in the course's learning community was not significantly affected by the transition, some individuals might be impacted much more heavily by the education disruption (Figure 2). Lectures and student presentations were less effective at retaining student engagement compared to individual student research projects (Figure 3). Students utilized all synchronous learning opportunities less after the transition, especially after the universal pass/fail grading policy was adopted (Figure 4). Concurrently, a brief rise in student engagement with asynchronous learning was not sustained (Figure 4).

In response to our observations and reflections, seven educational strategies can be recommended:

- Focus on raising student engagement (e.g., increased use of "breakout rooms" and group work) and increasing the frequency of feedback given to students.
- Prioritize class activities and assessments that better tolerate the absence of a physical classroom (e.g., research projects).
- Recognize that a universal pass/fail grading system can negatively impact student engagement.
- Recognize that the creation of opportunities for asynchronous learning (e.g., posting recordings of lectures) does not guarantee such resources will be heavily utilized, although their availability may be essential to students unable to attend synchronously.
- Implement a semimandatory attendance policy for lectures, teaching fellow, and peer tutor sections to increase course structure and retain student engagement, while practicing empathetic instruction for individual student situations.
- Establish a "guiding principle of continuity of teaching and learning" as soon as possible.
- Provide specialized training in online chemistry instruction to all instructors, including peer tutors.

Even in the absence of significant disruptions, STEM education, including chemistry education, carries its own set of challenges compared to the teaching of other disciplines.[16,17] STEM classes for non-STEM students pose additional unique challenges (and rewards) for educators, including attending to the teaching of scientific literacy.[18,19] Abrupt transitions to emergency remote teaching could compound these challenges. Despite the COVID-19 disruption and transition to emergency remote teaching, the Chemistry of Food and Cooking course generally met the students' expectation in teaching chemical concepts and had positive impact in improving scientific literacy (Figure S2) for the non-STEM undergraduates.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.0c00879.

> Course syllabus, message on "guiding principle of continuity of teaching and learning", survey questions, instructions on open-book exams, course grading table, student respondent narrative answers about challenges before and after the transition to emergency remote teaching, teaching fellow and peer tutor section attendance, and scientific literacy data (PDF)

AUTHOR INFORMATION

Corresponding Authors

Meghan Bathgate − *Poorvu Center for Teaching and Learning, Yale University, New Haven, Connecticut 06511, United States*; Email: meghan.bathgate@yale.edu

Elsa C. Y. Yan − *Department of Chemistry, Yale University, New Haven, Connecticut 06511, United States*; orcid.org/0000-0002-3583-1627; Email: elsa.yan@yale.edu

Authors

Ethan A. Perets − *Department of Chemistry, Yale University, New Haven, Connecticut 06511, United States*; orcid.org/0000-0001-9554-776X

Daniel Chabeda − *Yale College, Yale University, New Haven, Connecticut 06511, United States*

Angela Z. Gong − *Yale College, Yale University, New Haven, Connecticut 06511, United States*

Xin Huang − *Department of Chemistry, Yale University, New Haven, Connecticut 06511, United States*

Tat Sang Fung − *Department of Mathematics, Columbia University, New York, New York 10027, United States*

Ka Yi Ng − *Department of Mathematics, Columbia University, New York, New York 10027, United States*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.0c00879

Notes

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