JOURNAL OF CHEMICAL EDUCATION

pubs.acs.org/jchemeduc

Communication

Emergency Remote Instruction during the COVID-19 Pandemic Reshapes Collaborative Learning in General Chemistry

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Cite This: *J. Chem. Educ.* 2020, 97, 2884–2888

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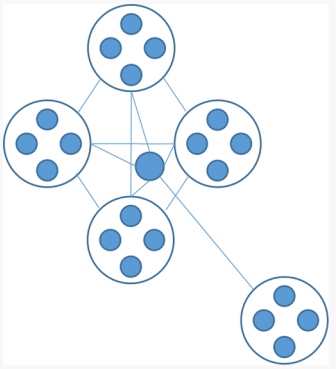
ABSTRACT: The spring of 2020 saw the spread of COVID-19 throughout the world, and in response many colleges and universities moved to emergency remote instruction. Herein is described how an introductory chemistry course that prioritizes active learning and collaboration was adapted for emergency remote learning. Instructors used both asynchronous and synchronous instruction and continued with revised group activities. A Distance Learning Pod allowed students in distant time zones to work collaboratively even when they could not participate in synchronous instruction. Rates of submitted work paralleled how heavily that work factored into the student's final grade. Equity, for example in access to technology and disparate student living conditions, remains a critical concern during the COVID-19 pandemic.



KEYWORDS: *First-Year Undergraduate/General, Collaborative/Cooperative Learning, Inquiry-Based/Discovery Learning, Student-Centered Learning, Distance Learning/Self Instruction*

INTRODUCTION

A person who pursues a career as a teacher–scholar is well-served by a certain amount of flexibility in thinking, willingness to learn new things, and ability to adapt. Events in the spring of 2020 highlighted the importance of these traits as the spread of COVID-19 led many colleges and universities to send residential students home and pivot to emergency remote instruction.[1] Instructors and students accustomed to face-to-face pedagogies shared the experience of learning new methods of teaching and learning during a time of personal upheaval, which posed an educational challenge that was unique in the lifetime of many in higher education.

Like many small residential colleges, Harvey Mudd College (HMC) is a close-knit community that prioritizes student–faculty interactions and collaboration. The introductory chemistry course at HMC, Chemistry in the Modern World, was recently revised to take advantage of these community features while offering a rigorous introduction to chemistry, as described in detail elsewhere.[2,3] In brief, the course relies on active learning and group work, teaches transferrable skills required for success in college such as collaboration and study skills, and presents chemical concepts alongside their societal applications. Instructors write course modules that cover a specific chemical concept in a societal context, and each module includes required preclass work, optional practice problems, and in-class POGIL exercises designed to be completed in groups of four students. In addition to the module, students complete weekly homework sets and a weekly low-stakes quiz. In the spring of 2020, a total of 220 students were enrolled in the six sections of the course. The course design assumes close physical proximity: proximity of students working together around a small table in class or in informal groups in the dorms, proximity of the instructor to work with students, and proximity to resources such as reliable internet, scanners, and printers. These proximities were disrupted when HMC sent students home in mid-March, right before spring break, and moved to emergency remote instruction in an effort to prevent COVID-19 from spreading on-campus.

RAPID REDESIGN

The three-person instructional team for Chemistry in the Modern World were unfamiliar with online teaching when HMC moved to emergency remote instruction. While strategies and best practices for online education[4−17] are well documented, the instructors had only a cursory knowledge of these practices as obtained through workshops and resources

Special Issue: Insights Gained While Teaching Chemistry in the Time of COVID-19

Received: June 16, 2020
Revised: July 16, 2020
Published: July 29, 2020

https://dx.doi.org/10.1021/acs.jchemed.0c00691
J. Chem. Educ. 2020, 97, 2884–2888

provided by the Claremont Colleges Center for Teaching and Learning in response to the COVID-19 pandemic.

The team began by identifying the key learning goals of each remaining instructional day. In the original course design, the primary learning goals were augmented by optional challenge material for advanced students. Instructors simplified the course by eliminating advanced material in favor of focusing on a smaller set of high-priority learning goals. For example, the first day of online instruction covered fuel cells. In the original course design, students learned about a variety of types of hydrogen fuel cells, including polymer electrolyte membrane fuel cells and solid oxide fuel cells. In the streamlined course, solid oxide membrane fuel cells were eliminated to help students focus on the primary learning goal of understanding the redox chemistry of a hydrogen fuel cell.

This effort to streamline the course also reflected concerns about student living arrangements and equity. HMC's Office of Institutional Research and Effectiveness conducted a survey of all students after they returned home to learn about their access to technology and the challenges students faced. This survey showed that not all students had ready access to technologies such as printers, scanners, and fast, stable internet. Some students went home to share space and broadband networks with siblings and parents who were working remotely, while a few lacked any broadband connectivity. Many students navigated increased familial responsibilities, such as caring for younger siblings while their parents worked or finding employment to replace student-work jobs. Students were concerned about completing rigorous coursework alone, without the benefit of collaborating with their peers. In a few cases the college provided cell phones and plans to facilitate student access to online learning. To accommodate a wide range of living situations, instructors used a blended instruction method that combined asynchronous and synchronous learning.

Asynchronous Work

The class relies on structured preclass work[2,3] that guides students through the day's reading and offers them a chance to practice key concepts and problem-solving skills. Since not all students would be able to participate in synchronous instruction, instructors expanded the preclass work to include activities that would normally be completed in-class. Instructors supported this work by providing the key for preclass work before class. In addition, the instructors provided short videos before class that explained concepts and walked students through the problems.[4,5] Videos were recorded using the Camtasia software package[18] on laptops or an iPad equipped with Explain EDU.[19] To accommodate disparate broadband access, data plans and learning styles, students could access the videos either by streaming videos through private YouTube channels or by downloading mp4 files from the class management system. With these modifications, students who were not able to participate in synchronous sessions were still able to engage fully with the class content. The team-teaching format made this work manageable, as each instructor took responsibility for a subset of the instructional days.

The class used Gradescope[20] for homework and quizzes, which requires students to upload files as a pdf or jpeg. Before the pandemic, instructors required students to submit high-quality scans made using campus scanners. When students moved home, however, they took photos with smart phones and used apps that convert a jpeg to a pdf file. Instructors did not penalize students for image quality or for hand-writing their answers on notebook paper. Instructors were prepared to mail coursework to students, complete with stamped return address envelopes, but this did not prove to be necessary, and all students were able to submit work electronically from home. It is noteworthy that disparate student circumstances pose equity concerns (see later).

HMC operates under a robust honor code. During their orientation, first-year students make a public commitment to the principles of academic and personal integrity outlined in the honor code. All quizzes and exams in this chemistry course were take-home prior to the disruption, and each of these assignments asked students to sign a statement indicating that they completed the work in accordance with the honor code. In this context, the COVID disruption did not offer a new opportunity for academic dishonesty. After the pivot to remote learning, instructors continued to rely on the honor code to govern the integrity of student work and did not observe evidence of academic dishonesty during the disruption.

Synchronous Instruction across Time Zones and the Distance Learning Pod

Close student−faculty interactions and collaborative group work (see later) are key features in this course, so instructors opted to retain an optional synchronous class meeting. Synchronous sessions let students ask questions in real time and engage in group work (see later). These sessions were recorded and posted on the class management system so that students who could not participate could watch at a later time. Students submitted questions via a chat box or verbally, depending on their comfort with being on-screen.

HMC is a global community, and some students returned home to distant time zones. Synchronous sessions were held at the standard class times of 10 and 11 am PDT, but participating in these sessions would be unduly burdensome for students in Asia. To accommodate this, instructors created a Distance Learning Pod (DLP). Instructors sent a survey to the class asking students to report their time zone and then reached out to students who were several hours removed from Pacific Daylight Time. Five students opted to participate in the DLP, leading to a remote group that was comparable in size to the typical four-member groups used throughout the course. These students leveraged the group-work skills they had learned earlier in the semester to self-organize and meet regularly via Zoom in student-led sessions to complete group tasks and homework as well as discuss the recorded class sessions. One of the instructors scheduled a late-night office hour in consultation with students in the DLP, and most students attended this office hour regularly. These students received a 24-h extension on coursework so they could view posted class material before submitting homework assignments and quizzes. After the course ended, one representative student wrote, "I'm rather missing the bi-weekly chemistry distance class and office hours. I wanted to let you know that the [chem profs'] distance-learning response was by far the most accommodating and actually helped me engage with the material *better* than before. So for that, and for your understanding, thanks so much."

Online Group Work

This course relies on active learning in the form of group work, and an important student learning outcome for the course is the ability to collaborate effectively in teams.[2,3] As such,

https://dx.doi.org/10.1021/acs.jchemed.0c00691
J. Chem. Educ. 2020, 97, 2884−2888

instructors continued using group work via Zoom's Breakout Room feature, in which a host can move participants into small groups. Overall, students reported that they appreciated the breakout rooms. They found it valuable to discuss class material with their peers. After the first class, one representative student wrote, "The breakout sessions were good. I like that we are going to be able to retain those small group work sessions."

These virtual groups differed from in-person collaborative learning in important ways. During face-to-face instruction, students worked in the same group for multiple days in order to build camaraderie with their team, and instructors were not able to duplicate these stable groups using Zoom. While Zoom participants can be manually assigned to breakout rooms in real time or through preselected groups, this process proved to be time-consuming and unreliable. For example, in one class activity students discussed different forms of renewable energy. Instructors designed a jigsaw activity such that each student in a small group served as the group's expert on a particular renewal energy source. But on the class day, the preassigned groups did not load properly in Zoom and instructors had to resort to random groupings. As a result, not all groups were able to discuss every technology, which required instructors to revise the final exam. Additional instructor practice may mitigate this issue.

Online group work required a level of structure that was not necessary in the classroom. In face-to-face instruction, an instructor could easily scan the room and quickly intervene when students were not communicating in their group. In contrast, moving between Breakout Rooms in Zoom was a slower process. In the first online class session, students reported that their online teammates were often hesitant to speak up. In subsequent classes, students were assigned to a specific role in their group. Before sending students into groups, instructors showed a slide that said, "the person with the first name closest to A is the team leader. The team leader will read the question out loud and check in with each group member." This greatly facilitated the group work. While group roles are well-established in the literature,[21,22] they had not been necessary in face-to-face instruction in this particular course prior to the COVID-19 disruption.

Managing class time posed a challenge during virtual group work. In face-to-face instruction, an instructor could easily gauge when most groups were finished with their work. After the first day of the online class, students reported that they quickly finished the assigned tasks and then "Breakout groups got awkward and quiet" while students waited to be called back to the main session. In subsequent classes, instructors asked students to use the "ask for help" feature to alert the instructor when they had finished the group work, and this practice helped instructors better manage class time.

■ ASSESSMENT

Students faced significant disruptions to their personal and academic lives in spring 2020, which means that considerable care must be used when comparing student performance in spring 2020 with other terms. For this reason, assessment in this work focuses on rates of student submissions rather than on student performance. Table 1 compares the percent of students who submitted the preclass work before and after spring break, as the pivot to emergency remote instruction corresponded with spring break in Spring 2020. There is a noticeable decrease from 87.9% to 82.1% of students who submitted the preclass work after the move to remote learning, though it is notable that the vast majority of students still submitted this work despite the disruption. For comparison, Table 1 shows submission rates for the previous year. In both terms, "Post-Disruption" includes the weeks after spring break, and the small decline in students who submit work in this period in 2019 likely corresponds to end of year fatigue. Students are required to submit a preclass assignment in advance of each class, which is graded on completion rather than accuracy, and this work accounts for 10% of the student's final grade.

Table 1. Percentage of Students Who Submitted the Preclass Work

Time Period[a]	Spring 2019 (n = 228)	Spring 2020 (n = 220)
Prespring break	90.6%	87.9%
Postspring break	89.5%	82.1%

Table 2 shows the percentage of students who submitted graded work after the disruption, which includes homework (20% of final grade) and quizzes (20% of final grade). Here there is no significant change in submission rates as compared to Spring 2019. It may be that students prioritized work that counted more heavily toward their final grade. Instructors see the preclass work as a critical learning opportunity, which suggests that it may be worthwhile to re-examine how work is weighted in the final grade if remote instruction continues. It may also be that longer preclass assignments that covered complex material also contributed to the decrease in submission rates.

Table 2. Percentage of Students Who Submitted Quizzes and Homework after Spring Break

Time Period[a]	Quiz 7	Quiz 8	Homework 7	Homework 8
Spring 2019 (n = 228)	92.5%	88.6%	97.4%	94.7%
Spring 2020 (n = 220)	90.5%	90.9%	96.4%	96.4%

■ LESSONS LEARNED

At the time of the COVID disruption, no member of the instructional team had taught an online course. The Claremont Colleges Center for Teaching and Learning served the community with aplomb, offering a training session and multiple resources about strategies and best practices. Nevertheless, the speed of the transition to emergency remote instruction prevented the instructors from taking full advantage of the rich resources available. Many of the challenges described herein are likely easily avoided by experienced online instructors. While the course was successful overall, a deeper knowledge of online instruction and greater facility with some technological tools could have aided both students and instructors.

Despite this lack of experience, instructors were fortunate to have some advantages in pivoting to remote learning. A collaborative teaching team that was able to divide the work of the class, such as revising the course modules and producing instructional videos, was a tremendous help. None of the instructors had small children at home, in contrast to many colleagues who were juggling childcare alongside the pivot to emergency remote instruction after local schools closed. All instructors were tenured faculty, and this combination of job

https://dx.doi.org/10.1021/acs.jchemed.0c00691
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security and ability to focus on teaching responsibilities represented unusual privilege during the COVID-19 pandemic.

The spring general chemistry course is a half-course that met twice a week for 11 weeks of the semester. The course was roughly two-thirds complete at the time of the disruption, so instructors had a manageable number of course meetings to conduct online. The instructors also benefited from institutional resources, such as an existing institutional license for the Gradescope[20] software that made it easy for students to submit work and for instructors to provide feedback, as well as continued institutional support for student graders and course tutors.

It was fortunate that the pivot to online instruction happened halfway through the second semester, when students were well-acquainted with the rhythms and format of the course. One of the course goals was to help acclimate students to college,[2,3] and this work paid off when the class moved online. The already strong emphasis on active learning and collaboration prior to the pivot meant that students were comfortable working on expanded preclass lessons by themselves and that a large fraction of the precious time available in synchronous contact after the pivot could be used to maximum effect in a collaborative environment. In hindsight, considerable effort and reimagined strategies would be required to teach these skills to a cohort of first-year students who did not have the benefit of several months together on campus. As of this writing, plans for Fall 2020 continue to evolve at HMC, which like many institutions is considering a variety of teaching modalities including but not limited to hybrid-flexible (hyflex)[23] and online synchronous and asynchronous instruction. The strategies used to build community and develop study skills will likely need to be adapted for introductory chemistry in Fall 2020 in order to build community and familiarize students with course and college norms in the absence of the grace of an introductory period of adjustment.

Instructors needed to keep in mind how the daily experience of students changed during remote instruction. The class relied on accessing multiple resources, including a module with content and questions, the corresponding answer key, and class slides. Many students did not have ready access to a printer and so they accessed all of these materials on their laptop screen. Students reported that it was often challenging during class to navigate between Zoom and the multiple pdf files they needed to consult.

Most importantly, issues of equity emerged in the pivot to online classes. Optional synchronous sessions were well-attended and beneficial to students, but not all students were able to participate. While no student lost attendance points and all students had opportunities to engage with problem-solving through the preclass work, there was a missed opportunity to ask questions and work collaboratively with peers. Homework assignments, quizzes, and the exam were distributed to students as pdf files and returned in the same format. Students with technological tools such as tablets that allow for rapid downloading, marking up, and uploading of pdf files could more easily submit work than those who had to rely on other means of completing and submitting work. While students face disparate challenges even on campus, these disparities were magnified when students left campus and the institution pivoted to online instruction (see previous). In particular, students with disabilities and low-socioeconomic status (SES) found that the disadvantages they encountered were magnified in the online modality. As instructors consider a fall term that is likely to include at least some remote instruction, issues of equity are essential in course design.

Technological tools, institutional and course culture, and instructor willingness to experiment allowed active learning and collaboration to help carry an introductory chemistry course through the transition to emergency remote learning. While the pivot was viewed as largely successful in terms of course goals and student learning outcomes, equity and, to a lesser degree, content suffered.

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Claremont Colleges Center for Teaching and Learning, the staff of which provided valuable and timely information about emergency remote instruction and best practices for online learning. The authors also thank Dr. Laura Palucki Blake and the staff in the Harvey Mudd College Office of Institutional Research and Effectiveness as well as Core Curriculum Director Professor Ben Wiedermann for coordinating a survey about student access to technology while away from campus. Their hard work made a big difference for the community.

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J. Chem. Educ. 2020, 97, 2884−2888