Challenges of Teaching Organic Chemistry during COVID-19 Pandemic at a Primarily Undergraduate Institution

Rajesh Sunasee*  

ABSTRACT: With a sudden move to remote and online teaching due to COVID-19 pandemic, Organic Chemistry became more challenging for both students and educators with the emergence of new technological challenges and instructional strategies. The Organic Chemistry I class at SUNY Plattsburgh was shifted to an online learning model in an attempt to mimic face-to-face teaching as well as maintaining active learning. This communication highlights the instructor’s perspectives on the challenges and insights gained for teaching Organic Chemistry I (lecture component) for the Spring 2020 semester in the time of COVID-19. A combination of asynchronous and synchronous teaching methods was found to be effective for content delivery, active learning, and increasing student’s engagement. Synchronous class attendance was monitored and compared with typical face-to-face class attendance. Synchronous problem-solving exercises had an effect on student’s attendance rate and learning. An exit survey indicated about 64% of students had a preference for face-to-face teaching over online teaching of Organic Chemistry.

KEYWORDS: Second Year Undergraduate, Organic Chemistry, Distance Learning/Self-Instruction, Mechanism of Reactions, Synthesis, Testing/Assessment

UNY Plattsburgh is a primarily undergraduate 4 year institution located in a small city with an undergraduate enrollment of about 4870. This student-centered education university lays strong emphasis on small classroom teaching and experiential learning. Around mid-March 2020, the university announced the transition of classes from face-to-face to remote and online teaching due to the ongoing COVID-19 pandemic. With a sudden change to an alternative teaching model and an increasing pressure from the administration, a major challenge was to come up with an immediate lesson plan in a given short period of time in order to support students in achieving the required learning outcomes for the remaining weeks of the semester. While useful information about how to accomplish the transition and teach online started to rapidly pour out from the scientific communities and several educational sources, educators were still faced with various technological and instructional challenges. The exhaustive list of information, resources, and links were sometimes overwhelming, which rendered the starting phase for online teaching even harder. However, an inspirational message from the Flynn research group “keeping it simple and stick to the essential learning outcomes” was key for quickly transitioning to online classes. The instructor’s perspectives here reflected the 1 week preparation and the 7 weeks of online teaching of Organic Chemistry I (CHE241; 48 students; Spring term 2020) at SUNY Plattsburgh, focusing on essential learning outcomes. Technological and instructional challenges were highlighted as well as insights gained while teaching in the times of COVID-19.

SUNY Plattsburgh uses the course/student management system, Moodle, which supports online coordination between instructors and students. The Moodle online platform functions include organizing lesson materials, embedding videos, creating assignments, uploading assignments using drop-box tool, digital grading, and communicating with students in discussions.
The use of Zoom as a platform for online content delivery and real-time teaching was highly encouraged in order to mimic the face-to-face learning experiences. Using Zoom platform for synchronous teaching was initially a technological challenge for both the instructors and students to quickly adapt to the Zoom new learning environment. Furthermore, the synchronous Zoom instruction (video lecture real-time teaching that replaced the face-to-face lecture) during normal class schedules (11:00 am–12:15 pm on Tuesday and Thursday) would not work for all the students (class size \( n = 48 \)) in this unprecedented COVID-19 time. Some students definitely had challenges with access to technology, time constraints, working space, or privacy issues unique to their new learning environment. As such, an instructional strategy that combined both synchronous and asynchronous learning was implemented in an attempt to partly overcome the above student’s challenges. In the asynchronous learning, students watched the recorded lecture videos which mimicked the normal face-to-face lectures prior COVID-19. The synchronous instruction via Zoom was focused on summarizing the key points of the lecture videos and reinforcing the main concepts of the chapters through online live activities. This was achieved using the PowerPoint program and the “screen sharing” feature of Zoom. Moreover, the “pen” tool in PowerPoint allowed the instructor to draw structures of organic molecules or explain the mechanism of organic reactions in real-time (Figure 1). The “chat” and screen sharing functions of Zoom increased student’s engagement and participation for the online learning activities.

The Zoom synchronous lecture meetings were set up via the Moodle platform (called as “virtual classroom”) that allowed students registered in the class to easily join the scheduled meetings. Although students were highly encouraged to attend the Zoom lecture meetings, the sessions were not mandatory given the constantly changing challenges the students faced during the ongoing pandemic. The synchronous Zoom sessions were all recorded for those students who were unable to attend the scheduled sessions. The combination of asynchronous and synchronous learning for remote and online teaching is closely related to the “flipped classroom” or “inverted instruction” pedagogical approach. Nevertheless, an exit survey indicated that 96% of the class had no issue with the length of the lecture videos (Table 2; exit survey below). Videos were saved as M4V files and were directly embedded on the Moodle platform. However, a main technological problem arose for students with

Table 1. Comparison of Features between Face-to-Face Teaching versus Remote and Online Teaching for Organic Chemistry I, Spring Term 2020

<table>
<thead>
<tr>
<th>features</th>
<th>face-to-face, before COVID-19</th>
<th>remote and online, during COVID-19</th>
</tr>
</thead>
<tbody>
<tr>
<td>technology platform</td>
<td>Moodle</td>
<td>Moodle</td>
</tr>
<tr>
<td>teaching methods</td>
<td>in-class lectures</td>
<td>online Zoom lectures recorded videos</td>
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<td></td>
<td>textbook readings</td>
<td>textbook readings</td>
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<tr>
<td>learning activities and assessments</td>
<td>in-class activities</td>
<td>online activities</td>
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<td></td>
<td>in-class quizzes</td>
<td>online assignments</td>
</tr>
<tr>
<td></td>
<td>Moodle problem sets</td>
<td>Moodle problem sets</td>
</tr>
<tr>
<td></td>
<td>textbook questions</td>
<td>textbook questions</td>
</tr>
<tr>
<td></td>
<td>in-class closed-book exams</td>
<td>online open-book exams</td>
</tr>
<tr>
<td></td>
<td>final cumulative exam</td>
<td>no final exam</td>
</tr>
</tbody>
</table>

Figure 1. Zoom synchronous lecture depicting an example of how a synthesis question was discussed via screen sharing and using the pen function of PowerPoint.

Video recording was also a challenging and tiring task to ensure all lecture videos were available on time every week. The instructor’s efforts in video lecture recording changed from the first day of teaching in the new COVID-19 environment to alternative ways of video recording as time passed with new COVID-19 university mandates. Initially, the main goal was to mimic the classroom teaching experience by recording the lecture directly in the same classroom environment for face-to-face teaching (Figure 1a). Two lecture videos based on the chapter of nucleophilic substitution reactions \( \text{S}_2^\text{2} \) and \( \text{S}_2^\text{1} \) were accomplished in this format. However, with the New York Governor’s directive calling for all non-essential employees to stay and work at home, an alternative way of video recording at a home workstation was quickly adapted. Interestingly, with a simple laboratory equipment such as retort stand/clamp and a cell phone, the preparation of the video lectures was achieved in a timely manner (Figure 1b). The clamp allowed easy adjustment of the level of the cell phone for effective video recording. Although this method might not represent the ideal way of video recording, it did work in a stressful COVID-19 time where access to video recording facilities were unavailable. The use of an iPad and Apple pencil was found to be useful particularly for one main chapter (alkenes and alkyne) where written lecture notes (with incomplete sections) that would normally be used by students during face-to-face teaching (Figure 1c) were already available. The Apple pencil was more effective to draw organic molecule structures and arrow-pushing in comparison with the pen feature of PowerPoint. The videos were approximately 20 min long, on average, with the longest one being approximately 30 min. Ideally, the lecture videos should be kept to shorter length \( t_{\text{video}} \) Nevertheless, an exit survey indicated that 96% of the class had no issue with the length of the videos (Table 2; exit survey below). Videos were saved as M4V files and were directly embedded on the Moodle platform.
low Internet connectivity, as somehow it took longer times for accessing and viewing the videos on the Moodle platform. The issue was solved when all the recorded videos were shifted to YouTube platform, and the YouTube video links were then posted on Moodle or via email. The efficient organization of the video lectures for each chapter on Moodle was crucial for students to watch in the correct order as expected for each chapter. Overall, the insights gained through these video recording transitions were quite a learning experience for the instructor.

■ ATTENDANCE RATE AND STUDENT ENGAGEMENT

One of the benefits of synchronous instruction via Zoom is that it can provide socially isolated students a schedule and sense of community. It also allows instructors to feel the “whole-class” teaching experience and more effective communication for instructor—student engagement. Despite the fact that Zoom synchronous sessions were not mandatory, the attendance rate (class size, n = 48) for the weekly Zoom sessions were recorded for the 7 weeks of remote and online teaching (Figure 3).

Instead of the usual two weekly lecture sessions of 1:15 min (Tuesday and Thursday from 11:00 am to 12:15 pm) for face-to-face teaching, the instructor held only 1 weekly synchronous lecture session (typically on Thursday). About 65% of this Zoom live lecture session time was dedicated mainly to reinforce difficult concepts and a summary of the learning outcomes of the video lectures, while the remaining time was focused on problem-solving exercises with student participation. A lower synchronous Zoom class attendance (weeks 9–15, Figure 3) was observed when compared to the in-class attendance prior COVID-19 (weeks 1–7). However, a fairly high-class attendance (n = 40; 83%) was observed in the first week of synchronous online class (week 9), which could be due to student’s keen interest in knowing what the Zoom lecture session would entail and its effectiveness. About 50% drop in attendance rate (in comparison with week 9) was observed in weeks 10 (n = 22) and 11 (n = 19). Possible reasons for the decline in attendance rate could be attributed to the availability of recorded synchronous lecture videos, a change in the student learning, and home environment or any other reason caused by the ongoing COVID-19 pandemic. In an attempt to increase student’s attendance and engagement, the synchronous Zoom sessions were mainly focused on problem-solving exercises to enhance critical learning. Interestingly, the attendance rate slightly increased for weeks 12–14 (in comparison with weeks 10 and 11). During these weeks, the instructor was able to reinforce key learning objectives (alkenes and alkynes chemistry) such as predicting the product of a given reaction, mechanism, and ways to approach synthesis questions through various problem-solving exercises. A very low attendance rate was observed for the last week of online class, possibly due to increased student’s workload and final exams.

The teaching and learning environment fell short in one aspect regarding effective communication despite the best of intentions and with planned activities during the COVID-19 disruption. For instance, visual communication and the online class dynamic between the students and instructor were lost due to student’s unwillingness to keep video turning “on” feature active during the Zoom live sessions even though the majority of the students had access to both audio and video (webcam) features. Initially, about 30% of the class had the video on, but in the following couple online classes, it decreased and, finally, the last 4 week synchronous sessions were completely “video-off” Zoom style meeting. This made the synchronous Zoom sessions

Table 2. Distribution of Student Responses on Exit Survey for Online and Remote Teaching of Organic Chemistry 1

<table>
<thead>
<tr>
<th>survey statements</th>
<th>student responses by category, % (N = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>When I watched the recorded lectures, I also took notes</td>
<td>strongly disagree disagree neither agree nor disagree agree strongly agree</td>
</tr>
<tr>
<td>I was fine with the length of the videos</td>
<td>0 11 7 32 50</td>
</tr>
<tr>
<td>Listening to lectures at home at my own pace was more effective in my learning than if I had listened to a lecture during actual class time</td>
<td>18 43 11 14 14</td>
</tr>
<tr>
<td>After watching the recorded lectures, I felt that I could do problems on my own from the problem sets and assigned textbook questions</td>
<td>4 11 18 39 28</td>
</tr>
<tr>
<td>During the Zoom instructor weekly meetings, working on problems together increased my problem-solving comfort level</td>
<td>0 4 14 39 43</td>
</tr>
<tr>
<td>I found the graded assignments effective for learning and preparing for exam</td>
<td>0 7 3 36 54</td>
</tr>
<tr>
<td>Overall, I prefer the online remote teaching versus face-to-face teaching method</td>
<td>32 32 11 7 18</td>
</tr>
</tbody>
</table>

*Response rate was 58% of the 48 students in total in the course.
less effective as the student— instructor relationship was lost which is a vital component of a typical face-to-face teaching practice. In general, possible reasons for a nonvideo Zoom meeting could include the following: (i) circumstances in which the Zoom meetings were occurring like family members or kids present at home or the feeling of not being properly dressed for a video meeting; (ii) computers with no webcam; (iii) a behavior preference for being more comfortable with audio-voice only.

■ ASSESSMENT OF STUDENT LEARNING AND COURSE EVALUATION

Assessment of student learning during the COVID-19 pandemic displayed another challenge, and some changes were required in comparison to face-to-face teaching (Table 1). Although all types of assessment were crucial, formative assessment remained a fundamental tool during COVID-19 to understand the learning needs of students and to adjust the instruction accordingly. Formative assessment was administered both in synchronous and in asynchronous forms. In the synchronous form (Zoom lecture), the instructor and the students worked together on problem-solving activities and real-time feedback was provided to students. This is closely related to the actual “classroom real-time assessment” for a face-to-face teaching. In the asynchronous formative assessment, students were provided with online-graded assignments and bonus mark questions. The bonus marks were added to their chapter exams marks, which ultimately motivated them to attempt those questions. Both the online assignments and bonus mark questions were graded directly on Moodle platform, and feedback was provided accordingly (feedback box in Moodle). Figure 4 shows an example of an online assignment question for a formative assessment of student mechanistic knowledge (curved arrow-pushing) of organic reaction and also depicted how grading was achieved on the Moodle platform. About 52% of the class answered the mechanism correctly (or almost correctly), and this mechanism question was further explained in the next Zoom lecture session where common mistakes about arrow-pushing were highlighted.

Problem sets for each chapter, which contained a collective number of basic questions as well challenging questions, were assigned to help students think critically and familiarize with typical exam questions. By checking their answers with the instructor’s posted answers, students could verify if they had achieved the intended learning outcomes for that particular chapter. Answering student’s questions and explaining concepts via email (with attached pics of drawings or mechanisms) was another popular asynchronous form of assessing student learning during COVID-19. Summative assessment was carried via three online chapter exams (∼20% overall grade for each
exam), and questions were aligned with specific intended learning outcomes such as knowledge of electrophile/nucleophile mechanisms, acid/base chemistry, understanding organic reactions (predicting reagents and products), and planning a synthesis (via retrosynthetic analysis). The main goal was to ensure students having the required knowledge and skills to embark to Organic Chemistry II in the Fall 2020 semester despite the abrupt move to remote learning. The online chapter exam format was different compared to the normal face-to-face class exam, and the preparation of online "open-notes" exam questions in a time constraint situation was challenging. The online chapter exams were all set up in a Microsoft Word document and consisted of a mixture of multiple-choice-type questions and short-answer questions. Students answered directly on the word document by simply typing in their answers in the spaces provided. A key observation was an increase in student’s performance, with higher class averages for the online chapter exams in comparison with in-class chapter exams of previous semesters. However, a direct and effective assessment of both exam formats (online open-note vs closed-note in-class) results was difficult given the interplay of different variables. Nevertheless, an interesting observation was made in regard to student’s performance on questions related to the design of a synthesis of an organic molecule. Students who attended and participated in the synchronous Zoom sessions for synthesis problem-solving activities performed better than those students who did not attend and relied mainly on the recorded video sessions. Understanding the logic of organic synthesis is a challenging concept for many first semester organic chemistry students, and recently, card games and videos were useful tools for engaging students with organic synthesis materials to improve student learning. In the case of online remote teaching, synchronous problem-solving activity sessions were found to be effective to promote critical thinking skills and active learning for difficult concepts such as organic synthesis. In an attempt to gain more information about the online course evaluation and student’s opinion, an anonymous online exit survey was administered after the final week of the semester. The exit survey questionnaire was made up of 10 simple basic questions focusing on study habits, assessment methods, and student opinions. A five-point Likert scale was employed, which had five levels of responses ranging from strongly disagree to strongly agree. Table 2 illustrates examples of some of the survey questions and the results obtained based on a 58% response rate (28 students responded for a class size = 48).

For this class, a closed-ended question with "yes" or "no" option was also surveyed in regard to whether it was the student’s first experience with online and remote learning, and 68% indicated a "yes" response. About 61% (strongly disagree and disagree) preferred a typical lecture during class time rather than listening to video lectures at their own pace and time at home. The majority of the surveyed students (~82%) found that working on problems together with the instructor during the Zoom synchronous sessions increased their problem-solving comfort level. About 90% agreed that the online-graded assignments were effective for learning and exam preparation. When asked about a preference for remote and online teaching to face-face teaching method, ~64% still preferred face-to-face teaching.

CONCLUDING REMARKS

The COVID-19 crisis has created a big disruption in the educational system with unprecedented technological and instructional challenges. Teaching Organic Chemistry represented another level of its own challenges; however, with a crisis, new opportunities emerged. Changes were made to traditional teaching, and new online teaching platforms were adapted to continue providing meaningful and creative learning opportunities. A combination of synchronous and asynchronous teaching methods was found to be effective that could potentially be applied in the coming Fall term in the event classes would still be remote and online or a hybrid-based delivery teaching mode. The instructor’s guided synchronous problem-solving activities were crucial for increasing student’s engagement and effective learning during COVID-19 pandemic.

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Notes

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