Analytical and Bioanalytical Chemistry (2021) 413:1245–1250
https://doi.org/10.1007/s00216-020-03147-w

Implementing a flipped classroom approach in remote instruction

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Published online: 11 January 2021

Introduction

Prior to the onset of the COVID-19 pandemic, we had both implemented student-centered active learning into our courses. Students spent the majority of class time working in small groups on worksheets that developed topics under study. Findings by cognitive psychologists that knowledge is constructed in the mind of the learner, so students learn more by doing something rather than watching and listening, is one justification for the use of active learning [1–3]. Numerous studies also show the benefit of active learning over lectures at promoting student achievement and other important skills [4–18].

When faced with the prospect of teaching courses in the Fall of 2020 in a fully remote or hybrid format, we were both interested in maintaining a student-centered approach. Therefore, we decided to use a flipped classroom format. In a flipped format, students watch one or more videos prior to a class and then spend the class time working in small groups on worksheets. In our situations, the small-group sessions involved synchronous remote instruction.

Prior use of flipped classrooms has resulted in some best practices that can enhance the effectiveness for students and instructors (Table 1) [19, 20]. The use of familiar technology will facilitate the preparation of videos. Working with other instructors who teach the same course is a way to reduce the time each individual needs to spend preparing videos. Starting small by identifying one or a few topics to flip is advisable for someone unfamiliar with the use of small-group work in class. Videos should be kept short, with 10–13 min considered the ideal length. It is critical that students watch the videos before class, so pre-class assignments or other strategies that motivate students to prepare for class are important. Finally, since the flipped format may be unfamiliar to many students, it is important to describe the process that will occur and clearly articulate the expectations for students. Because we were already using small-group work throughout the entire courses, we converted the entire courses into a flipped format for remote instruction. Herein, we will describe our individual approaches to the development and delivery of flipped instructional methods for analytical and General Chemistry courses at St. Mary's University and King's College.

A flipped approach in a Quantitative Analytical course

The Analytical Chemistry course at St. Mary's University is a traditional quantitative analysis course required of all B.S. Chemistry, Biochemistry, and Biology majors. The class meets twice a week for 75 min each. I teach this course as a blended learning environment in which each class session consists of guided, group-learning activities. Lecture supplements the activities, occupying at most 25% of the class time. Approaching a fully online Fall 2020 semester, I wanted to maintain the active learning environment in the virtual space, while eliminating the lecture component of class time. To that end, I implemented a flipped classroom model. All lecture occurred as asynchronously viewed videos. Synchronous class time, 90 min per week, was devoted completely to active learning activities and discussion.

Enrollment at the beginning of the Fall 2020 semester was 40 students. All course materials were posted on the learning

This contribution is part of a series featuring teaching analytical science during the pandemic in order to support instructors in preparing their courses.

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Table 1 Best practices for flipped classrooms

- Use familiar technology when preparing videos.
- Share preparation work with other instructors who teach the same course.
- Start small—flip one or a few topics.
- Keep videos short—10–13 min is considered ideal.
- Develop pre-class assignments or other strategies that motivate students to prepare.
- Explain the class format and clearly articulate the expectations for students.

management system (Canvas). Course material was divided into modules, with each module being 1 or 2 weeks in duration. There were 3 types of activities for each module, as shown in Fig. 1. The synchronous component of the course was a weekly meeting during which students participated in group-based learning activities through Zoom. Assessments were due a few days after the module small-group meeting. Assessment also included three in-term exams and a final exam. The course structure was explained to the students on the syllabus, as well as through a video and infographic posted on the learning management system as part of a course introduction module. During the first synchronous meeting, I described the course structure and my motivation for using the flipped classroom model. The videos and small-group meetings were the most significant components of the flipped classroom modality. I will discuss these two components in more detail, and then provide some reflections on my experience.

Video components

For each module, I developed a series of videos that replaced all synchronous lectures. The videos were prepared in PowerPoint and recorded using Kaltura Capture, which allowed for easy embedding directly into the learning management system. The modules had between 3 and 10 videos each, for a total of 46 videos. The videos ranged in duration from 5 to 24 min, with an average duration of 14 min. The total duration of videos for each module was less than or equal to one 75-min class period per week, with one exception. I did not provide the students with the PowerPoint slides for the videos.

In addition to the content-based videos, I also recorded example videos. The number of these example videos ranged from 1 to 14 for each module. In some example videos, I demonstrated skills in Microsoft Excel such as calculating and plotting a standard addition curve, or performing an F test and t test. I also recorded videos working through sample calculations using the whiteboard of a Microsoft Surface device and a stylus. During an in-person version of the class, I do not work example problems for the students, as I feel students are prone to memorizing steps rather than developing problem-solving skills. However, I felt it was necessary to include sample calculations for an online version of the course. I was concerned about the feasibility of students tackling difficult calculations as a group in a virtual space, and wanted to devote more of the synchronous time to concept development.

Students reported liking the ability to watch the videos multiple times and revisit them as needed. I am not able to monitor whether or not students watched the videos, but am able to determine if students viewed the page containing the video. At the end of the semester, 89% of the video pages were viewed by $\geq 94\%$ of students. The videos were on average viewed four times per student. Anecdotally, students would ask questions directly referencing the videos and refer to the videos frequently during synchronous discussions, office hours, and email correspondence.

Preparation of the videos was very time-consuming. In preparing the videos, I was careful to adhere to the student learning outcomes and not veer off topic or include extraneous information. Students commented that they liked that the videos broke down the information into digestible chunks. I was also conscientious to use best practices in preparing the slides, including using large font sizes and limiting the information on each slide. I imagined what the viewing experience would be like on a small screen like a phone and proceeded accordingly. Each video began with an introduction orienting the students to where we were in the module and ended with a Take-Home Messages slide.

Fig. 1 Summary of course components for each module

Small-group meetings

As I was preparing for the semester and deciding on the course format, I struggled with the idea of managing 40 students at a single Zoom meeting. I was concerned with my ability to manage a virtual discussion with a class that size and monitor what was happening in all the groups. To that end, I divided the class into subsets of students. The laboratory portion of the course was completely online and asynchronous. Therefore, I was able to use the lab time to meet with the students for lecture purposes rather than the designated lecture time. I divided each 4-h lab into two 90-min sessions for the small-group meetings. I assigned students to a time slot on their registered lab day. Each group was between 9 and 11 students, which were then randomly split into Zoom Breakout Rooms of 3–4 students each. The entire 90 min was devoted to active learning activities, with no presentation of new material. Students received a participation grade for the small-group meetings, which was 6% of their overall course grade.

The activities were a mixture of concept-based short answer questions and calculations, leaning heavily towards concept-based questions. Students had 5–15 min to complete a series of questions. I would rotate through the groups to observe the discussions and answer any questions. After time expired, we reconvened as a large group and discussed the questions. There was ample time for students to ask questions.

An important aspect of the small-group meetings is that I did not review any material from the readings or videos. I expected the students to have completed the readings and watch all videos prior to attending. This expectation was articulated to the students through the syllabus, a course introduction video and infographic, and an email sent to the students prior to the first meeting. The students also had to submit a pre-meeting assignment based on material from the readings and videos. I looked through the submissions prior to each meeting and could address common errors at the beginning of the meeting. After an opportunity for questions, we then jumped right into the activity. The students quickly learned that if they were not prepared for the meetings, they would be lost the entire time.

Attendance at small-group meetings was very high, with only two unexcused absences the entire semester from students who finished the semester. Attendance was significantly higher than prior in-person versions of the class. Students reported that they found the small-group activities to be highly beneficial to their learning in the class, as it was their opportunity to apply the knowledge gained from the videos, explore the subtleties, and clear up any uncertainties. When I dropped in on the breakout rooms, students were engaged and on task.

I did not record the small-group meetings. One of the students was international and attended the class from her home country. She was in a similar time zone, so the distance did not create a significant barrier to attendance. After the first exam, I asked the class if they would like to switch up time slots, and received unanimous feedback that they did not want to change. I took that feedback to mean that students were satisfied with the schedule and/or had developed a rapport with the other students in their small group.

Reflection

My experience with a flipped online Analytical Chemistry course was positive. Because presentation of new material was removed from the synchronous portion of class time, the entire class period could be used for group-based active learning. I had excellent attendance and participation during the synchronous meetings. Students came prepared, which resulted in a deeper conversation than I typically experience in the in-person environment where preparation was minimal.

Course grades were higher than previous semesters, with students demonstrating competence in both conceptual and computational aspects of the material. I doubt the increase in course grades can be completely attributed to implementation of a flipped online classroom, but it likely contributed. In the flipped classroom model, I increased the lecture component, albeit in the form of asynchronous videos. Perhaps the increased lecture component provided more structure and context to the course material. In addition, with increased student preparation, more higher-order learning activities were designed for the synchronous meetings.

The largest challenge in implementing the online flipped classroom model was the large time commitment required to prepare the videos. I was able to prepare the majority of the videos over the summer, prior to the start of the semester. If you already use a significant amount of lecture in your class, generating the videos may not be as significant of a time commitment. I easily adapted the active learning exercises I was using already for the small-group activities. Because the hard work of preparing the videos is already complete, I will to continue to use the flipped classroom model in future semesters.

A flipped approach in General and Analytical Chemistry courses

A flipped classroom style was used to facilitate in-person and remote instruction in two undergraduate courses at King's College during Fall 2020. General Chemistry had a course enrollment of 27 predominantly first-year students in a variety of STEM disciplines. Analytical Chemistry had 6 upper-level students enrolled, each pursuing a chemistry major or minor. Both courses were initially taught in a "hybrid" format, with approximately half of the class meetings held in-person, the other half remote. Remote classes were synchronous and hosted via Zoom. All classes were remote for the last 4 weeks of the semester due to pandemic concerns. I had been teaching Analytical Chemistry with an active learning approach for a few years; however, this was the first time I had flipped my General Chemistry classroom.

Flipping General Chemistry involved a collaboration with two King's College colleagues, Dr. Anne Szklarski and Dr. Jillian McCue. In past semesters, we had shared PowerPoint slides and problem-solving worksheets with each other, so we knew our teaching styles were complimentary. We decided that a flipped classroom approach would be an ideal option to allow for in-person teaching or a speedy transition to remote learning. Since creating an entire semester of flipped classroom materials would be extremely time-consuming and exhausting, we joined forces and each created one-third of the course material according to our areas of expertise. I recorded videos, created in-class activities, and wrote assessments for material that laid the foundation for Analytical Chemistry (titrations, redox, thermochemistry, etc.). A colleague who is an organic chemist created the modules for resonance structures and hybridization. I particularly enjoyed seeing how my colleagues explained concepts differently than I do, and students had the opportunity to learn multiple approaches to solve the same problem. Preparing for classes was easy; I could simply listen to a few short videos prepared by my colleagues and review the problem-solving answer key. Our shared set of flipped classroom materials proved useful in various learning environments, one taught in-person, one hybrid, one remote. We saved immense amounts of time and sanity by working together.

To flip our class, we separated material into multiple modules for each chapter. Each module consisted of several video lectures, accompanying notes, problem-solving worksheets, and fully worked answer keys, all of which were integrated into our learning management system (Moodle) prior to the start of the semester. We easily adapted course materials from previous semesters and kept our use of unfamiliar technology to a minimum. Video lectures were created using Panopto software, which we had all previously used in Spring 2020 during the unexpected transition to remote learning. We recorded our voice over PowerPoint slides which we already had prepared from previous semesters. The videos were intentionally kept short (10–15 min); often, a concept would be introduced in one video, and an example problem worked through in another. Students were expected to watch all videos for a module before attending a class session. During the class meeting, students worked through the problem-solving worksheets with the assistance of their peers and the instructor. Answer keys were timed to become available on our learning management system after the class discussion. Worksheets and answer keys for each module were easily adapted from longer worksheets we had each previously created to accompany the end of each chapter.

Short videos for General Chemistry worked better for students and myself than the longer 30+-min videos I had recorded in the past for Analytical Chemistry. I did not read from a script when recording the videos, but just spoke as if I was teaching the topic to a live classroom of students. Sometimes I misspoke a word and just corrected myself or I erased a mistake when solving a practice problem. When I asked a question, I intentionally paused to give students a moment to think on their own. There were moments when I laughed at my own awful jokes. I never edited any of these "imperfections" out, feeling that they showed my personality as if we were in a live classroom.

I also recorded short videos of myself to allow students to get to know me aside from a disembodied voice in a lecture. A 2-min welcome video let students see who I was behind a mask and safety glasses prior to the first day of class. My collaborators also recorded short videos so that students could "meet" all of us before listening to our voices. I sent video announcements sporadically with reminders about important due dates, course registration, or just words of encouragement. Students received so many emails daily that video messages were a welcome change.

The expectations for both courses including how to prepare for class meetings and the benefits of an active learning environment were clearly explained in the syllabi. We also spoke at length during the first class meetings about the format of the course and advantages of a flipped classroom for student learning. Ideally, students would be self-motivated and watch all videos, take notes, and try a practice problem before coming to class. Of course, this is not always the case. To encourage preparedness, I did not do any concept review at the beginning of class. We immediately started solving problems and working in small groups. This style of teaching inherently required advance preparation and was an adjustment, especially for first-year General Chemistry students. Students quickly learned that without watching the lecture material before class, the problem-solving sessions would not be particularly helpful. Panopto and Moodle also made it possible for me to monitor student engagement with the videos, thus I awarded a small number of points per video towards participation and graded these soon after each class meeting. Though very low-stakes assignments, the shock of earning a zero in their gradebook motivated many students to watch the lectures and prepare for class.

In Analytical Chemistry, upper-level students were generally accountable and prepared on their own accord. Especially for these students, working with peers who were ready to solve a problem was enough motivation to prepare themselves. When student motivation started to decline, I assigned part of the in-class problem-solving worksheet to be attempted before class. I emphasized that the solution did not have to be perfect, but I required a complete attempt at the problem.

During class time, students shared their final answer. When students had varying answers, which occurred often, they compared strategies and were able to work collaboratively towards the correct solution. As students' comfort level making mistakes and working together increased, I would assign different parts of a problem to each student. For example, each student would be assigned a different volume of titrant in a particular problem, but together as an entire class we could construct a full titration curve. Each student would explain their work, and while they spoke I would capture their ideas on a common document using a Microsoft Surface device and a stylus. This document was either screen shared in Zoom or projected on whiteboard in-person. When students were confused or made an error, the entire class could discuss a solution with my guidance. These strategies worked particularly well for my small class but could be used in a larger setting with multiple small groups of students.

Remote teaching in a flipped classroom was not without challenges and did require adaptability. My initial remote teaching sessions were question-and-answer style. Students posted questions to an online forum prior to class, and during the session I was able to work out a solution with the student for the entire class. However, this only engaged the student who asked the question, and the rest of the class left their cameras and microphones off. Quickly, I changed to a problem-solving style using Zoom breakout rooms to mirror my in-person flipped classroom. While General Chemistry students were hesitant to turn on cameras and microphones in the entire class of 27 students, they were more willing to use video and voice in a smaller group of 3–5 peers. Like my approach in Analytical Chemistry, I would assign each breakout room a different portion of a multi-part question. I visited each breakout room to check in with groups, set the tone for students to turn on their cameras and microphones, work with each other, and engage in problem solving. After a short period of time, often 5–15 min, the entire class reconvened to report on their solutions. A small number of students being responsible for each part of a problem increased participation and engagement.

I intend to continue flipping my classroom post-pandemic. The flipped classroom materials are flexible for students who miss occasional classes and worked both in-person and online. The time investment in creating course materials was worthwhile as I have video lectures, worksheets, and answer keys already prepared for next year. Most importantly, the individual attention I could give to students while solving problems was so much more than I could give during a traditional lecture. Remote or in-person, students in my flipped classroom were much more engaged. Students did the "easy" work of familiarizing themselves with basic concepts on their own time, but the "hard" part of solving problems happened during class with a support system of myself and their peers.

Concluding comments

We were both extremely satisfied using a flipped format in remote instruction. We adapted best practices for flipped classrooms to help overcome some perceived obstacles in remote teaching (Table 2). Students were required to watch one or more short videos prior to each class session. To encourage student preparation for class, each of us awarded participation credit to students for watching the videos and completing a pre-class assignment. We did not review video content in the synchronous, small-group sessions and instead immediately began group work. It was apparent in the small-group activities if a student had not prepared for class by watching the videos. We observed high levels of student preparedness in General Chemistry and upper-level Analytical Chemistry courses.

Table 2 Obstacles and strategies for success in remote flipped classrooms

Obstacle	Strategies for success
Student preparation for class	Clearly communicate expectations at the beginning of the course
	Assign participation points for videos or pre-class assignments
	Begin group work without reviewing new material
Large class size makes group interaction difficult	Utilize Zoom breakout rooms
	Break large class into smaller group meetings
Time management of course content	Use pre-class assignments as preparation for class activities
	Divide longer problems between groups and share solutions
New technology	Use familiar tools or software
	Use tools that easily integrate into the course learning management system
Time commitment to creating content	Prepare videos between semesters
	Adapt existing course materials
	Collaborate with colleagues who teach the same course

When students worked in small groups on the worksheets, we rotated through the groups to provide guidance and feedback. After some appropriate amount of time on small-group work, the entire class was brought back together. Groups were asked to report out on their answers and the entire class discussed the questions and identified the expected answers. Students then went back into their small groups and the process was repeated for the next set of questions on the worksheet. We observed high levels of student engagement in the small-group work and students reported that they preferred such an approach over other formats of remote instruction.

Creating the videos needed for a flipped classroom is a time-intensive activity. For courses with multiple sections and instructors, the time needed to create videos can be reduced by having several instructors split up the topics. Once the videos are prepared, subsequent offerings of the course are much less labor-intensive. Both of us intend to continue the use of a flipped course format when we return to in-person instruction.

Funding We received support from the US National Science Foundation through grant numbers 1624898 and 1624956.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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