A Flipped Classroom Approach and Digital Learning in an Undergraduate Molecular Biology Course

By Andreas Kakarougkas and Reham Abdellatif

Teaching modalities such as Flipped Classroom Approach (FCA) are becoming increasingly popular in higher education. FCA requires that instructional content is completed outside the classroom, thus allowing active-learning activities to take place in class. In this article, we investigate the application of this approach to an undergraduate molecular biology course. The instructional content was delivered using the MITx 7.28x Molecular Biology Series MOOC via the edX platform. Discussions, activities, group problem-solving, and quizzes were carried out in the classroom based on the instructional content covered online. To gain student feedback on the teaching approach, we performed a mid-semester focus group and a post-semester survey. Student interaction with the instructional content was collected via the edX platform’s edX Insights feature. Completion of the instructional content and thorough class preparation are important prerequisites for FCA. Data from the edX platform showed a high completion rate of the instructional content, despite student feedback that completing the online content was too time consuming. Students indicated that the topics, materials, and instructor made the experience engaging, which motivated them to complete the assigned materials. Overall, our results indicate that this teaching modality engages students, promotes active learning, and aids information retention.

Over the past 2 decades, pedagogical research findings suggest that active-learning approaches are superior compared to traditional lecture formats for promoting student learning (Cattaneo, 2017; Misseyanni et al., 2018; Wright, 2015). Active learning is a broad term that encompasses a variety of teaching strategies aiming to provide high-quality, collaborative, engaging, and motivating education. One such strategy is the Flipped Classroom Approach (FCA), in which students engage with educational content in the form of videos or reading material outside the classroom, thus freeing up time for active learning in the classroom, such as group problem-solving and discussion (Leo & Puzio, 2016; Samuel, 2019).

In courses that adopt FCA, the educational content can be original content developed by the course instructor, or it can be existing online material such as YouTube videos; open educational resources (OERs); or videos, texts, and quizzes from MOOCs (Massive Open Online Courses; Carpenter et al., 2020). This study implemented FCA in a 400-level molecular biology credit-bearing course at the American University in Cairo (AUC). This study is part of a wider collaboration between the Abdulla Al Ghurair Foundation for Education and the Massachusetts Institute of Technology (MIT) Office of Digital Learning that aims to transform teaching and learning in the Arab region through online learning. The collaboration offers the AUC instructor the ability to enroll students in the course via the Edge platform (rather than the open edX, which MOOC participants use) so that students can take quizzes and the teacher can access the backend of the platform to set due dates, remove pages, view student performance on quizzes, and track students’ engagement with the platform.

Project objectives

Since 2013, AUC has been undertaking a digital learning initiative to improve the quality of education at AUC and integrate innovation into teaching. There are a number of courses at AUC that have adopted FCA, but this study looks at the first implementation of the approach in a course from the undergraduate biology major. The selected course is titled BIOL 411/4150—Molecular Biology of the Gene and is a 4-credit course (3 credits for lecture and 1 credit for lab). The instructional content was delivered as videos, text, and quizzes via a customized version of the MITx 7.28x Molecular Biology Series course. This course was selected because course alignment showed a high degree of overlap between the AUC and MIT course’s learning outcomes and content, and therefore its suitability in terms of content and complexity. The objectives of the study were to (a) pro-
provide students with the experience of FCA to develop their skills for lifelong learning and for the 21st-century global environment; (b) improve the quality of the content of the course; (c) accommodate different pacing for students, as they can choose to spend more time with content if needed; and (d) increase student engagement and provide students with high-quality, collaborative, engaging, and motivating education via an active-learning classroom environment.

The majority of students undertaking the biology major had used MOOCs related to their major to help them study or to learn about topics not covered in the major. However, this class was the first time they were exposed to FCA. Here, the online content was customized and guided by the professor according to the intended learning outcomes and directly linked to the classroom activities. To ensure the highest-quality content for the course, the MITx 7.28x Molecular Biology Series was used for delivery of the online material. The material includes videos and text created and delivered by MIT faculty who are respected experts in their field. Diagrams, animations, and detailed explanations were used to help students visualize and grasp complex biological concepts, while end-of-video questions and quizzes enabled the learner to monitor their learning.

The AUC faculty member delivering the course had previous experience using FCA. Prior to starting the course, the professor had attended a course-design workshop with MIT faculty on best use of the MITx course and edX platform with support from AUC’s Center for Learning and Teaching in course design and assessment. Following course alignment and prior to the semester starting, a custom course (CCX) was created that allowed the professor to manage and customize the content on edX while also monitoring how the students interacted with the content via the edX feature.

The 400-level course was open to both juniors and seniors in the biology major. Although all students had the same prerequisites before enrolling in the course, there were discrepancies in students’ preparation. Specifically, senior students appeared to be better prepared and more confident than junior students. This study assessed whether the availability of online materials helped alleviate these discrepancies, resulting in a more uniform student group, which is important for the application of active learning.

Course design and data collection

The number of students enrolled in the course (15) was well suited to active-learning activities, and student groups were created that contained both senior and junior students. At the start of the semester, students were invited to enroll in the CCX course on the edX website. Following registration and enrollment in the course, students could see the educational materials posted by the professor. The educational materials typically consisted of a learning sequence of between six and eight videos, each 5 to 10 minutes long. New sections were posted once or twice a week, 2 or 3 days before class. There were two 75-minute lectures per week. There were no software training sessions offered to students prior to course enrollment.

The MITx 7.28x course has “test yourself” questions interspersed between the video sections. However, in the CCX, these questions were frequently omitted and were used instead as the basis for in-class group activities and discussions. Students were encouraged to collaborate with their peers when solving the problems to promote peer-to-peer learning. Groups were frequently required to complete work on the board with their groups before presenting their answers to the class. Student preparedness (group and individual) was monitored by the professor prior to and after class via the edX insights feature. In addition to group work, a portion of class time was dedicated to “board work” by the professor, who covered and reinforced concepts from online educational content. Board work frequently included videos and screenshots from the online content, thus allowing students to ask unanswered questions and avoid falling behind. If any unanswered questions remained, students were encouraged to attend office hours and to watch the online materials for a second time.

Student performance in the course was monitored by a total of seven quizzes throughout the semester, which were designed to encourage students to keep up with the online content as well as apply the information in a way similar to what was done during class time. In addition, there were two midterm exams and a final exam.

The majority of the data (quantitative and qualitative) relating to this study was collected via a focus group done in the second half of the semester, data from the MITx platform, and a post-semester survey. Students were informed about the aims of the study and were required to sign consent forms if they chose to participate. The focus group was conducted by a senior officer of AUC’s Center for Learning and Teaching. The professor was not present during the focus groups, and all student responses were strictly anonymous. The post-semester survey was also anonymous and was distributed to students online. The findings of the focus group and post-semester survey are presented in the Results section. (The full list
of questions can be found at https://bit.ly/335NGbH.)

Results
Student preparedness
Student preparedness was assessed using the edX insights feature and is expressed as the percentage of students who watched at least one assigned video before attending class. The tabulated data are presented in Figure 1; the graph shows the average percentage of students who watched at least one of the assigned videos during the semester. These data do not include the amount of time spent watching the videos, the number of videos watched, or the completion rate. The data are based on the assumption that students watched the videos individually.

Student performance
Student performance was assessed by quizzes throughout the semester, two midterms, and one final exam. The summary of student performance is presented in Figure 2; the line graph shows average student performance on quizzes throughout the semester, while the bar chart shows the average student performance on the three exams.

Focus groups
Students were asked several questions to elicit their perceptions of the effect of the MITx materials as well as the professor’s facilitation of the FCA. (The full list of questions can be found at https://bit.ly/335NGbH.) Students were asked to explain what they liked about the flipped approach and what they would like to improve. Overall, students stated that they liked the MITx videos posted on the platform. One student elaborated by saying, “The professors in the videos are very professional and the content is presented in an engaging way.” Moreover, students mentioned that the course professor was able to answer all content questions. Students requested that online quizzes used in class be made available at all times, as they helped students study and test their understanding.

There was a small gap between senior and junior students in terms of dealing with the content. Senior students wanted the structure of watching the videos before coming to class and having the professor explaining through discussion and activities, while junior students found it difficult to grasp the content of the videos and wanted the course professor to explain the content first, then have the videos available to watch after the session. This difference in preference was taken into consideration by the course professor, who accommodated both sets of students by offering a short review of the assigned materials at the beginning of each class. The professor used the online quizzes on the edX platform to promote peer-to-peer learning and to test student understanding of the assigned materials. In the focus group, most students recognized the impact of the FCA (watching the videos before the session), explaining that it allowed them to independently try to figure out and read more on the topic presented before coming to class. The students who preferred that approach mentioned that this “allowed us to come up with questions, and this helps with [our] critical thinking.”

Evaluation of instruction
Students were encouraged on multiple occasions to submit their online evaluations. When completing the evaluations, students were asked questions about the course as well as the instructor. Finally, students were afforded the opportunity to leave comments and make recom-

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FIGURE 1
Completion rate of assigned online materials.
Post-semester survey

Approximately 6 months after completing the course, students were invited to complete a post-semester survey. Students were reminded on several occasions to complete the survey, but the completion rate was only 40%. The results of the survey are presented in Figures 4 through 6.

Discussion

In this study, we examined applying FCA to an undergraduate molecular biology course at AUC via a customized version of the MITx 7.28x Molecular Biology Series MOOC on the edX Edge platform. None of the enrolled students had previously taken a credit-bearing online course or a course adopting the FCA. The students did not receive any training in using the online platform before starting the course. None of the students reported any technical problems or difficulties with accessing and navigating the online materials, and they stated that the platform is very user-friendly and easy to navigate. The students really liked the edX feature of being able to speed up the videos to twice the normal speed as well as having a transcript of the videos available, as these features allowed them to speed up review of the sections with which they felt comfortable and ensure they had not misheard anything by checking the transcript. The course professor at AUC had previous experience with the FCA and had used the edX platform as well. The professor faced no difficulties with assigning materials or collecting analytical data from the platform. The professor indicated that the platform allowed for seamless integration of FCA by creating harmony between the assigned materials and the class activities. As the quizzes and activities used in class were directly linked to the online content, there was continuity between online learning and class activities. We conclude that the edX platform is an excellent choice for applying FCA, with no prior training required from students.

Comments from students in the evaluation of instruction and post-semester survey (Figures 4, 5, and 6) indicate that the students enjoyed FCA and would recommend online-enriched courses to other students. One of the goals of this project was to expose students at AUC to the highest-quality education via relevant and flexible online learning. The FCA requires that students complete educational content online before attending class (Francis et al., 2019; Leo & Puzio, 2016; Ojennus, 2015). Data from the online platform and insight from the course professor indicate that the completion rate of the assigned materials remained high throughout the semester. Student feedback indicated that there were a number of factors that led to the high completion rate of the online materials before attending class: (1) Students enrolled in the course were interested in the topic of molecular biology, so they found the assigned materials engaging. (2) Students were impressed by the quality and
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(3) The professors’ delivery of the materials, coupled with the diagrams and animations, allowed students to comprehend detailed biological processes and technologies without the use of additional resources. High student preparedness (due to the reasons listed earlier) meant the professor could carry out group work in class, in which students were divided into groups and completed problems related to the assigned materials.

Although the overall completion rate was high, there was fluctuation in the completion rate of the assigned materials throughout the semester. As expected, the highest completion rate was before scheduled quizzes or exams. Students indicated that a high workload and deadlines from other courses were the main reasons for the instances in which assigned materials were not completed. There was mixed feedback from students regarding completion of the materials and class preparedness (Figure 3). Some students indicated that not completing the materials prior to class was not an issue because the course professor provided a recap before initiating group activities; however, completing the materials ensured students were better prepared and able to participate in class activities. Other students suggested that a longer explanation (even prior to materials being posted) would have been beneficial so there was not as much reliance on the online materials for content delivery. Time management and a high workload were identified by the majority of students as the main limitation of the approach. Multiple concurrent deadlines and exams made completion of the online materials challenging.
For this reason, when asked if they would like to see more courses in their major adopt FCA, students indicated that they would, but that they would not want multiple courses adopting FCA in the same semester due to the high workload.

One of the advantages of FCA identified by the students and the instructor is the availability of the assigned online materials as an educational resource. Feedback from students showed that having the videos available at all times meant that students could spend as much time as they needed to understand the concepts using the online materials; this was important because having both juniors and seniors enrolled in the course could create problems with pacing. Students could also use the online materials to fill in possible gaps from previous courses and go back to the materials when studying for exams. The online materials also helped students understand the concepts before attending class, which increased the time for in-depth discussions and activities during class time.

Use of the FCA did not seem to affect student performance in terms of grades on quizzes and exams (Figure 2). The students felt the course outcomes were achieved and that their performance was not negatively affected by FCA despite this being their first experience with the approach. Interestingly, when asked to comment on information retention 5 or 6 months after completing the course, students indicated that they felt their information retention had improved because of FCA. This can be attributed to three factors: (1) Students take notes when watching the online videos. (2) If something is missed due to a lapse in concentration or a distraction, the students can immediately watch the video again. (3) The educational content is then applied in class in the form of...
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We conclude that information retention was improved by FCA and see this as another advantage of the approach. This was a pedagogical research study looking at the application of FCA in a molecular biology course taught at AUC. These circumstances provided several advantages that allowed us to ask questions about the effectiveness of the approach. For example, we learned that the approach can be applied to students who have little or no experience with FCA or online learning. In this case, the faculty member delivering the course had received training on FCA, which we believe contributed to the course running smoothly. The collaboration between the AUC and MIT allowed us to use the MITx materials on the edX platform. This meant we had the highest-quality online educational content at our disposal, as well as a content delivery platform that was easy to use and customizable. Finally, we were able to collect user data through the platform that provided insight into student online learning. Our study demonstrates how FCA can be used to promote active learning and make the highest-quality education accessible for all.

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**References**

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**FIGURE 6**

Student feedback for future courses adopting flipped classroom and digital learning.

Did having access to the online materials help you fill in “gaps” from previous courses or help you in other courses in your major? Please explain.

6 responses

1. Yes. It complemented the genetics course really well.
2. Yes as some concepts were mentioned in other courses like “Genetics” and
3. Yes
4. Absolutely. The course was focused on the logical design of assays. There were too many assays, but they all made sense. The best thing about the course is this logic element and the thinking style we gained throughout the process of discussing the design, advantages and disadvantages of the different assays.
5. It allowed for connections to be made from other biology courses. As they are all inter connected to some extent, so by understanding a portion of this course, it has allowed to connect/relate that specific topic to other topics relevant. So for example there was some overlap when taking this course and Developmental biology.
6. To an extent, I don’t really remember if it did.

Would you like to see other courses in your major adopt a similar format?

5 responses

1. Other molecular based courses yes, however I think that this method would not work in other major courses that rely more on practical work rather than mechanisms, etc.
2. Yes, however my only concern would be the high workload that would result because of taking several courses that would follow this same format.
3. I would see all the courses adopting the same format.
4. I think this type of learning would be applicable to the majority of the major courses. With the exception I think bioinformatics, laboratories (hands on experience is always ideal over videos in this regard.) If balanced correctly, I do believe it would be an effective means of education, whether as the primarily source of information or secondary as a means of solidifying concepts.
5. Yes

What suggestions do you have for improving this type of course in the future?

5 responses

1. the post video exercises were much easier than the midterms and ex exams. I would suggest increasing the level of these exercises or giving the students parts of the exams prior.
2. More in-class activities and take home assignments rather than quizzes as they are already offered online.
3. I would recommend more quizzes. Also, I would go for a weekly journal club activity.
4. If there is an ability to go into more depth on the lecture side of things. As the videos do a good job of explaining the basics, but the more in depth information tends to be more challenging yet far more engaging.
5. I think it would be better to get a feedback after the first midterm from the students, and see who is struggling and who is not and adjust to that.

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