

MODERNIZING INTRO BIO AT UCR:
HOW HYBRID COURSES MIGHT HELP STUDENTS LEARN MORE.

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Abstract

Large introductory science classes typically experience high failure rates and low student engagement. Efforts at improving learning outcomes have centered on methods such as active learning, flipped classroom modes, and engagement through primary research. The first course for students in a Life Sciences Major at UCR is Biology 5A, Introductory Cell and Molecular Biology. Traditionally, the classroom portion of this course has been taught by lectures, supplemented by PowerPoint slides and/or notes, and a weekly 1-hour discussion section run by a Graduate Teaching Assistant. Recently, Professor Maduro at UCR has developed both Hybrid and Online versions of Bio 5A, which ran concurrently for the first time at UCR in Spring of 2019. In these versions of the course, the primary content delivery is through online videos that have questions in them. The difference between the Online and Hybrid versions is that the Discussions and Exams take place in the online environment rather than face to face. Because the replacement of the lectures with videos is a dramatic shift in how course content is delivered, I wished to measure how the Hybrid, Online and Traditional classes are perceived by students, and how the different versions of the course might affect their learning. I worked with Prof. Maduro to measure these outcomes for a subset of students in the Online and Hybrid courses. Recent studies (e.g. Gavassa et al. 2019, *CBE—Life Sciences Education* • 18:ar8, 1–10) suggest that hybrid classes may be superior to traditional classes for today’s students. Our results suggest that in introductory Biology, a hybrid or online class is at least as good, and may possibly be better, than a traditional lecture-based class. With the recent forced adoption of fully online courses by all major educational institutions due to the COVID-19 pandemic, an understanding of the effectiveness of designed online courses is that much more relevant.

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Introduction

Undergraduate Education is changing with the availability of new technologies and the way 21st-century students learn. Today, a bachelor's degree is a minimum requirement for most jobs in the knowledge economy. Therefore, improvements to access to higher education requires robust solutions that remove structural barriers and provide critical support [5]. One way through which access to quality education has been feasible is Digital media. Now it is relatively easy for anyone with a smartphone to record a high-quality video, edit it, and share it online with a worldwide audience via posting it on a YouTube channel [2]. Additionally, many websites have also contributed in providing professional higher education content such as Khan Academy, Coursera, and edX. To ensure students do not just memorize facts from these sources and count that as learning, many instructors have been changing the way they teach to address such problems [8]. Compared to a traditional method of teaching where a professor stands behind a lectern, holding forth to auditoriums of usually sleep-deprived students, many instructors now have added a component of active learning to engage students with the material [8]. Some of these methods include quizzing students after every few slides with questions using technology such as clickers, Kahoot! Top Hat, etc. Other educators use methods of flipped classrooms where students are asked to learn at home using notes, slides, videos, and additional documents provided, while during class time they are *required* to come in and participate in group activities to practice what they learned.

A Hybrid course in Introductory Biology was developed by Professor Maduro in which the *entirety* of the main course instruction is relegated to a set of 75 short online videos of average length 8½ minutes and embedded with multiple-choice questions to keep engagement and interest. Students are given access to these videos along with supplementary materials, and

they have the option of attending class on non-exam days and utilize that time period as a kind of office hours. Discussion is still held in person and run by a Teaching Assistant. In this work, I will study student reactions to the hybrid class structure compared with traditional methods. This will tell us about the students' experience with the hybrid style of teaching, which can ultimately inform campuses whether having more STEM Hybrid courses could improve learning outcomes, and ultimately, student success rates. These results are especially relevant given the sudden shift to online learning as a result of the COVID-19 pandemic.

Why Biol 5A

Biology 5A is an introductory intensive course for life science majors, the first course designed to prepare students for upper-division courses in cell and molecular biology. This course covers biochemical, structural, metabolic, and genetic aspects of cells. I took Biol 5A after successfully completing calculus and part of general chemistry, but this class was the first most challenging course for me at UCR. I struggled partly because I came into UCR without taking AP Biology in High School, but mainly because the introductory course was too fast paced for me. In every lecture, I would misunderstand a key information on the first few slides and then the rest of the concepts would not connect. In order to obtain participation points, I began to either ask friends or guess on the Kahoot questions my professor asked. Like many of my peers, I chose to never raise my hands during the lecture because public speaking is a little scary and asking questions seems to only slow down the pace for the rest of the class.

I overcame these challenges by spending a lot of time watching and taking notes from various different YouTube channels including "Amoeba sisters" and "Khan Academy" to learn the concepts. Furthermore, I utilized TA office hours, learning Assistants, and SI sessions to understand anything I couldn't clarify from videos. Lastly, I did many additional practice

problems using the past exams written by professor Maduro, provided on iLearn by my professor. Overall, I spent so much additional time trying to learn material from the outside resources rather than understanding concepts directly from the professor that I was only able to obtain a grade of B+ and not the A I worked for. The next year, I became a learning assistant for Biol 5A and I met several more students struggling just like I had. A few even gave up because they couldn't keep up with the material. I felt there needs to be a better method to teach such a difficult introductory class.

A year later at an Honors faculty mixer event, I met Professor Maduro who briefly mentioned that the last quarter was the first time he taught Biol 5A in a hybrid fashion. He said he made videos to teach the concepts while the lecture time is available for any additional help. This grabbed my attention right away because not only the professor is making the videos so students could learn at their own pace without missing out on any key information, but he has made lecture an option for students to go in and clarify concepts directly by asking the professor! What's even more convenient is that lecture time is already assigned as part of the student's weekly schedule, so students who are unable to attend the office hours can simply go during lecture hour and get help. I later discovered that he uses PlayPosit to add questions within the videos as a check for understanding and allows students to comment if they need to share anything regarding the video. For all these reasons, I believe hybrid teaching methods that utilize technology effectively can potentially be a very interactive method of teaching capable of replacing much of the large lecture experience and could perhaps even be more effective. Therefore, I hypothesize that Professor Maduro's hybrid class is at least as good and possibly better than the traditional lecture mode, especially for intensive introductory courses like Biol 5A. Through this research project, I hope to determine whether this hypothesis is supported by

the results of student interviews and their learning outcomes, and if so, encourage other professors to utilize hybrid courses, or at least make videos for very difficult topics.

Research Done in 2017: Outcomes for a pilot Hybrid version (by Prof. Maduro only)

Previous research Results: When conducting his first hybrid Biol 5A course in the Summer 2017 quarter, Professor Maduro did a study to understand the outcomes of the modified course structure [4]. In this study, he first described the features of the redesigned course, and then showed what were the outcomes. He found that compliance rate of completing the videos by due date was $\geq 95\%$, while in comparison, attendance of the summer classes normally is typically 50-60% of registration by mid-course. Additionally, PlayPosit questions average scores over the entire course ranged from 60-70%, while in the past, clicker questions generally scored correct an average of 50% of the time. Next, the Performance in the midterms was somewhat higher with an overall mean of 66%, while in prior offerings the midterms averaged approximately 61% which he hypothesized may be due to having 3 midterms covering slightly less material, compared to densely packed 2 midterms. Overall grades in this quarter were now in more of B range compared to that of C range. Lastly, on iEVAL, past students gave the instructor a higher rating on average than in prior offerings. Based on these outcomes, he concluded the following statements: 1) Students work more with the course material when given the opportunity to learn at their own pace. 2) When learning through videos students learn the same or slightly more as in a traditional instruction format [4].

In this capstone project, professor Maduro and I took a step further to learn about the students' experience in the hybrid course, while continuing to understand how overall learning is impacted in this format. More importantly, we now have additional data as the hybrid Biol 5A

course has now been offered a total of 5 times, giving us a larger base of students to draw our conclusions upon.

Methods and Materials:

Surveys

The Qualtrics survey tool (www.qualtrics.com) was used to create a brief online survey and the link was sent by email to all the students taking the Bio 5A hybrid course in that quarter. In these pre-course surveys we asked questions that could help us analyze how much prior knowledge of biology is the student coming in with, and what do they anticipate regarding how they will do in the class after learning they are enrolled in hybrid format instead of traditional lecture course.

For the end of quarter survey, we administered a paper survey at the final exam, using a Likert scale for students to rate their opinions on various aspects of the course, as its overall structure, the videos, the optional lecture, the discussion format, and whether they used the supplemental resources provided. The Likert scale ranged from strongly Disagree, Disagree, Neutral, Agree, Strongly agree.

iEVAL

Unlike surveys where students only had the option to select one of 5 choices available, Faculty instruction evaluation provided us with student thoughts and opinions on Professor Maduro's hybrid teaching format for those students who chose to respond. Evaluations were collected to see student opinions, both positive and negative, regarding how is hybrid format compared to traditional lecture format. It is recognized that this is a non-random sample and is likely to select for the strong-opinioned students, however the nature of the comments and not their frequency are what are important here.

Focus Groups

During the Fall 2019 quarter, I held a focus group session to understand the experience of students who took Hybrid Biol 5A with Dr. Maduro in the past quarters. This session was mainly held to get additional feedback not already obtained from surveys and the evaluations. Dr. Maduro was not present in the focus group, so students were able to freely express their opinion. In order to make sure we had enough participation in the focus group, we provided pizza lunch and a \$10 amazon gift card to students as incentives.

I used Google forms to create the invitation to the focus group. In the invitation students were asked to state which quarter they took the Biol 5A course in (Between spring 2018-Summer 2019). Dr. Maduro then used Microsoft Excel to randomly select an equal number of students from the different quarters in which the hybrid course was offered in. By using an emailing system he wrote in the Python programming language, Professor Maduro then emailed personalized invitations to those 120 students. The first 12 students who RSVP'd were invited. Nine of twelve randomly chosen students came to the focus group, while one student gave his responses via a questionnaire because he couldn't make it that day (N=10). The focus group was held on November 8, 2019 in Rivera Library at UCR.

Grades

I will compare the grades from Dr. Maduro traditional lectures to the hybrid lectures and see the difference between which format allows students to have better grades. The data will be anonymous.

RESULTS

Table 1: Survey Results from Spring 2019: (Dark shade of blue represents larger percentages)

Question Number	Questions	Total	% Responding				
			SD	D	N	A	SA
question 1	I was initially worried about taking a course with videos	122	18.03	19.67	10.66	38.52	13.11
question 2	I liked having videos instead of lectures	124	1.61	3.23	8.06	20.16	66.94
question 3	I liked the flexibility of not having to attend class in person	124	0.00	1.61	7.26	19.35	71.77
question 4	I liked being able to watch the videos whenever I wanted	124	0.00	0.81	0.81	17.74	80.65
question 5	I learned more because the course had videos rather than lectures	124	2.42	4.03	20.16	22.58	50.81
question 6	the PlayPosit questions were useful for my learning	124	0.00	2.42	15.32	38.71	43.55
question 7	the videos were overall of good quality	123	0.00	0.00	1.63	23.58	74.80
question 8	I regularly read Prof. Maduro's notes	124	4.03	7.26	20.97	34.68	33.06
question 9	I regularly used the Campbell Biology textbook	124	50.81	37.90	7.26	0.81	3.23
question 10	I regularly used the free OpenStax textbook	124	50.00	29.84	8.87	6.45	4.84
question 11	I regularly studied using the past exams	124	1.61	6.45	9.68	33.87	48.39
question 12	I liked the format of the Discussions	124	2.42	12.10	12.90	33.06	39.52
question 13	the Discussions helped me learn the material better	124	0.00	6.45	20.16	36.29	37.10
question 14	I tended to complete the PlayPosit videos on the day they were due	124	4.84	20.16	24.19	32.26	18.55
question 15	I re-watched videos as part of my studying	124	2.42	5.65	7.26	31.45	53.23
question 16	I did the videos by myself	124	0.81	2.42	8.06	26.61	62.10
question 17	I did the videos as part of a group of students working together	124	41.13	27.42	13.71	12.90	4.84
question 18	the weekly overview videos were useful	124	0.81	2.42	12.90	41.94	41.94
question 19	I watched the YouTube streaming office hours live	124	9.68	23.39	14.52	20.97	31.45
question 20	I watched the recordings of the streamed office hours	124	6.45	14.52	12.90	31.45	34.68
question 21	I liked getting my exam results back right away	124	0.00	1.61	7.26	10.48	80.65

question 22	I attended the optional class regularly	124	31.45	25.81	20.16	9.68	12.90
question 23	it would be fine if there was no in-person class at all	123	17.07	17.89	25.20	19.51	20.33
question 24	I liked getting personalized emails from the professor	124	0.81	0.00	7.26	32.26	59.68
question 25	I liked having clearly defined expectations for grading	124	0.00	0.00	3.23	18.55	78.23
question 26	overall, the course was a good experience	124	0.00	0.00	3.23	22.58	74.19
question 27	I would like it if more of my courses were formatted like this	124	1.61	3.23	8.06	14.52	72.58

Table 2: Survey Results from Summer 2019 ((Dark shade of blue represents larger percentages). Here the class size was smaller as this was a summer course.

Question Number	Questions	Total	%Responding				
			SD	D	N	A	SA
question 1	I was initially worried about taking a course with videos	83	19.28	24.10	19.28	28.92	8.43
question 2	I liked having videos instead of lectures	82	3.66	4.88	13.41	34.15	43.90
question 3	I liked the flexibility of not having to attend class in person	83	1.20	1.20	8.43	24.10	65.06
question 4	I liked being able to watch the videos whenever I wanted	83	0.00	0.00	4.82	25.30	69.88
question 5	I learned more because the course had videos rather than lectures	84	2.38	5.95	17.86	20.24	53.57
question 6	the PlayPosit questions were useful for my learning	84	1.19	2.38	8.33	42.86	45.24
question 7	the videos were overall of good quality	83	0.00	0.00	3.61	22.89	73.49
question 8	I regularly read Prof. Maduro's notes	84	0.00	13.10	15.48	30.95	40.48
question 9	I regularly used the Campbell Biology textbook	84	59.52	22.62	11.90	2.38	3.57
question 10	I regularly used the free OpenStax textbook	84	52.38	19.05	13.10	9.52	5.95
question 11	I regularly studied using the past exams	84	2.38	5.95	17.86	34.52	39.29
question 12	I liked the format of the Discussions	84	2.38	5.95	20.24	44.05	27.38
question 13	the Discussions helped me learn the material better	84	2.38	10.71	20.24	40.48	26.19
question 14	I tended to complete the PlayPosit videos on the day they were due	84	4.76	11.90	16.67	41.67	25.00

question 15	I re-watched videos as part of my studying	84	2.38	4.76	4.76	36.90	51.19
question 16	I did the videos by myself	84	0.00	0.00	1.19	20.24	78.57
question 17	I did the videos as part of a group of students working together	83	67.47	22.89	4.82	2.41	2.41
question 18	the weekly overview videos were useful	84	2.38	7.14	26.19	35.71	28.57
question 19	I watched the YouTube streaming office hours live	84	21.43	21.43	21.43	23.81	11.90
question 20	I watched the recordings of the streamed office hours	84	17.86	20.24	19.05	34.52	8.33
question 21	I liked getting my exam results back right away	84	0.00	0.00	7.14	21.43	71.43
question 22	I attended the optional class regularly	83	40.96	24.10	19.28	3.61	12.05
question 23	it would be fine if there was no in-person class at all	84	7.14	13.10	30.95	29.76	19.05
question 24	I liked getting personalized emails from the professor	84	0.00	2.38	16.67	39.29	41.67
question 25	I liked having clearly defined expectations for grading	84	0.00	0.00	3.57	29.76	66.67
question 26	overall, the course was a good experience	84	0.00	3.57	3.57	30.95	61.90
question 27	I would like it if more of my courses were formatted like this	84	2.38	3.57	13.10	22.62	58.33

Table 3: iEVAL results

Hybrid Bio 5A Course IEVAL response
<p>“The overall course was more helpful than a traditional class. I agree with the professor's input that students will look up videos in order to understand concepts. So, having the class taught in video formats was helpful because of the visual connection with the material.”</p>
<p>"I felt like taking this course online was actually better for me than taking the in-person course. I felt like I was going at my own pace and I really liked that."</p>
<p>"The sheer flexibility of the video format is an amazing benefit to students due to the freedom it grants in both studying and scheduling, and while there is a significant up-front investment in time and effort required, I believe the results speak for themselves. I've discussed this class with several of my peers over the course of the quarter, and we all agree that this is one of the most effective and engaging classes we've had the pleasure of taking here"</p>
<p>"The distillation of the course content from two dozen or so lectures to a few highly condensed videos saved me a ton of time, kept me from having to rent an expensive textbook that I would only use for one class/quarter"</p>

"I found this structure to be beneficial for learning. Professor Maduro also provides the most practice tests ever and I really liked preparing myself for the tests and going into a test feeling confident that I know what to expect."
"I liked the professor's enthusiasm in making the course accessible to everyone as well as his drive to encourage everyone to do better without setting up the class for competition. I felt that he was doing an awesome job putting all the hard to understand material in good sizable chunks that could be digested every week and I feel that the application could work in other science classes as well as labs."
"I thought it was really cool that before every exam the professor would do an online YouTube review/office hours."
"Even though I personally had a difficult time with the professor's exams, I greatly enjoyed the course due to this professor's enthusiasm and effort in creating a unique experience. His modern techniques of teaching are highly effective. I wish everyone could experience it!"
"His teachings were easier because of the hybrid course. The lessons were easier because I was able to rewind them and rewatch them to refresh before tests."

Table 4: iEVAL critiques

Hybrid Biology 5A iEVAL response (criticisms)
"I found it really difficult to keep up with all of the information provided in the short amount of time."
"One suggestion is if the PlayPosit practice exams could also be uploaded as pdfs so they can be printed out."
"I took the online course. It wasn't ideal but it was the only thing open. Of course, it's a more difficult learning environment. Learning about things in 5-15 minute videos weren't exactly the easiest thing. I almost wish we had longer videos or more videos explaining some of the concepts further. Some questions were a little difficult because they appeared to be something we haven't really gone over."
"Probably the best online course I've taken so far. The only problem I had with the videos was that, for each question, I couldn't see why other answers were wrong. This might just be me, but I learn best from understanding why other options would not work in reality."
"Teaching was limited to prepared videos."
"Most of the time the questions don't correlate with the info given in the videos causing students to get the wrong answer"

Table 5: Focus Group Responses-These responses are from 10 randomly chosen students who took the hybrid Bio 5A course between Spring 2018-Summer 2019

Focus Group Questions	Student Responses
What motivates you to learn in a hybrid course?	"Well for me I didn't know I was entering a hybrid at first but when I found out I was taking a hybrid course, it put a little bit of relief to me only because I commute from LA..."
	"I feel like we always had time for the office hours. L.his office hours were during lecture time, so if I wanted to go I knew I have time to go."
	The hybrid class is really easy to like learn and videos are very helpful because, like, a lot of the times I find myself dozing off in lecture, if I missed one point I feel like I'm completely lost, but now I can go back and rewatch it and I can pause
	"... Because for me, it's just, it doesn't feel like I have to be there, it feels like I am there because I want to be there."
When you used to be confused about a topic after watching the videos, what did you do to better understand the concept?	"when I didn't understand the concept, I would actually read the material and then watch the video."
	"I feel like I'm like a more of a visual learner so the captions help[ed] me"
	"He explains it in a way that like you don't feel like he's dumbing it down you feel like you're getting the right amount of information that you need, that's where you don't need to find any other [sources] of information."

Focus Group Questions	Student Responses
Did the professor's level of enthusiasm in the videos affect your ability to pay attention? If so, then in what way(s)?	Yeah! it positively affected my ability to pay attention. The level of enthusiasm allowed me to feel as if it mattered that I put in the effort to succeed in the course
	"He had some amazing examples that will kind of relate to what we're learning. And, and every video will be so different. It's like difficult material but I mean, in terms of like, he would always say something new where I would be like, "Oh, I didn't think of it that way."
Did anyone watch other YouTube videos/ used other sources after watching the Professor's videos?	"For certain topics, but most of the time I felt like I didn't need to because he said everything that we needed in the video."
	"I used the supplements like two to three times, it's not as good as the videos."
	"I like the textbook, but he is really good at convincing what you need to know, like cutting out all the extra components that are not important to understand."
what if a student says 'what's the point in looking at the past exams if he is going to change the questions anyways'?	"I thought past exams were really helpful because I use it to see if I can actually answer the question and see if I got it right. And if I didn't, if I couldn't answer correctly, I went back and studied the area that I got wrong."
	"We used them as references in our group studies"
	"I really use the pass exams to figure out how ready I was for the exam to study....very great diagnostic"

Focus Group Questions	Student Responses
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<p>What if we switched from hybrid to completely online, so no face to face lecture after the videos, how do you think that would impact your learning?</p>	<p>" I feel like completely online, I'll just- I won't have commitment to be doing all my classes."</p>
	<p>"If it's online it keeps me on track a little bit, but then going to lecture it's like everything that I kind of like slacked off on. Okay, like recap."</p>
	<p>" I'm actually taking two online classes right now. One of them is actually no videos, no audio, it's just reading lectures and honestly really boring....and the other online class I'm taking actually the lectures online so we meet face to face online. I feel like it's so much better because you're actually paying attention they make you interact at the same time</p>

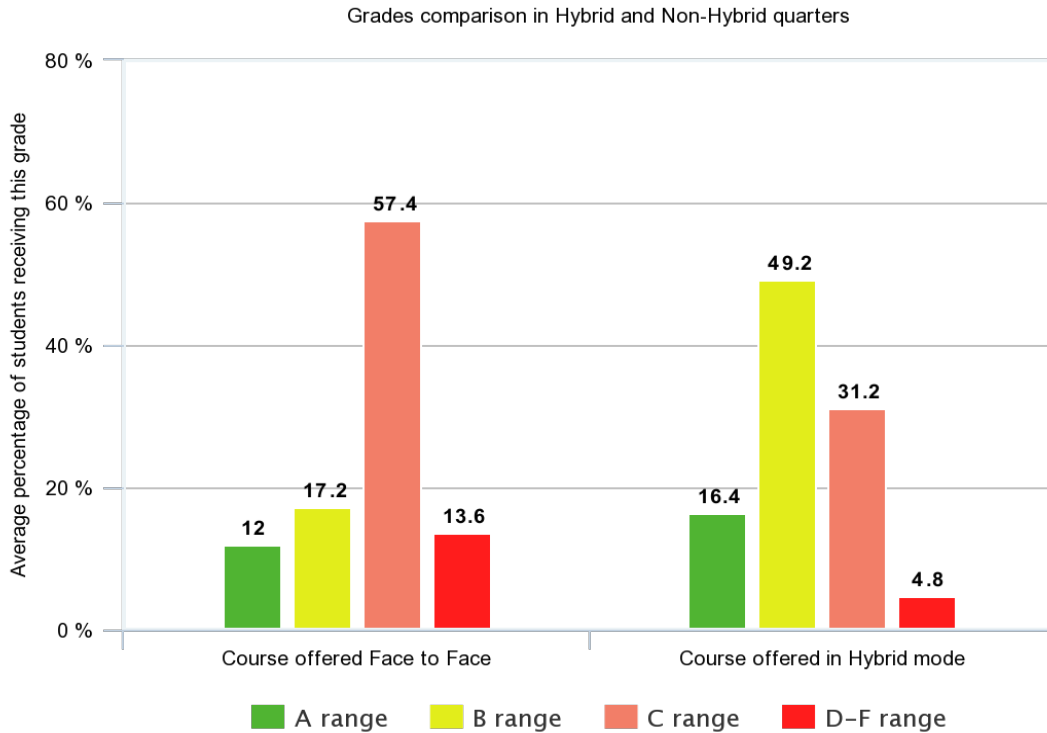
<p>Do you think other instructors at UCR would be capable of effectively conducting hybrid courses? Why or why not?</p>	<p>"Not Really, some professors are monotone."</p>
	<p>Yes. Saves the professor time and the method is highly effective in my opinion.</p>
	<p>"Subject matters"</p>
	<p>"I love the videos, but I don't think it was as effective, especially with o chem, because there wouldn't be any feedback and then you would want to go ask the questions, but you can't really"</p>

Table 6: Grades

Term	Fraction of students receiving:			
	A+/A/A-	B+/B/B-	C+/C/C-	D or F
Summer 2014	10/80 (13%)	13/80 (16%)	51/80 (64%)	6/80 (8%)
Summer 2015	5/61 (8%)	13/61 (21%)	37/61 (61%)	6/61 (10%)
Summer 2016	9/46 (20%)	8/46 (17%)	26/46 (57%)	3/46 (7%)
Summer 2017	9/57 (16%)	32/57 (56%)	16/57 (28%)	0/57 (0%)
Summer 2018	17/76 (22%)	35/76 (46%)	19/76 (25%)	5/76 (7%)
Summer 2019	12/86 (14%)	37/86 (43%)	37/86 (43%)	0/86 (9%)
Fall 2015	15/186 (8%)	32/186 (17%)	105/186 (56%)	34/186 (18%)
Fall 2016	22/193 (11%)	29/193 (15%)	94/193 (49%)	48/193 (25%)
Spring 2018	51/291 (18%)	159/291 (55%)	71/291 (24%)	10/291 (3%)
Spring 2019	35/296 (12%)	137/296 (46%)	108/296 (36%)	16/296 (5%)

Table 6: White represents the quarters when the course was offered face to face and Gray represents the quarters when the course was offered in Hybrid mode.

Figure 1: Grade Comparison Chart



meta-chart.com

Discussion

Surveys (Table 1 and 2)

Based on the survey data, the majority of the students in both spring and summer 19 quarters were initially worried about their learning in a hybrid course structure. As the course progressed, over 70% of students in both quarters agreed or strongly agreed that they learned more because the course had videos in it rather than lecture, while only 6-7% of students disagreed with this statement. According to student opinion provided in the instructor evaluation, many students reported that videos and the play posit questions embedded in the videos were very helpful for their learning. Additionally, the past exams were a perfect way for them to study and know exactly what to expect for the test. Some aspects of the course that students appreciated include having the visual connection as the professor draws or illustrates example, the extra office hours with the professor, the ability to rewind and pause the lecture to take notes, and the flexible schedule for commuters and even non commuters that comes with having no lecture.

Focus group (Table 5)

Through focus group sessions, many students emphasized that professor maduro's enthusiasm about the subject and his willingness to teach it in a way that made sense played a huge role in their learning as well. For this reason, they unanimously agreed that the professor personality also plays a major factor in designing a successful hybrid course. Additionally, students expressed that there are many aspects of hybrid courses that motivates them to learn but going completely online seems less of a preference. Most importantly, students expressed that they needed to utilize fewer outside resources (i.e. other YouTube videos) in the hybrid course because the professor's videos contained most of the necessary information to perform well.

iEVAL Criticisms (Table 4)

Some students provided suggestions about improving the design of the course. One student suggested if the PlayPosit questions and practice exams could be uploaded as PDF files so they can be printed out. It is possible that this student was unaware that there were already dozens of other exams available as PDF files.

Some students felt that PlayPosit questions needed to give an explanation as to why the other choices are wrong, likely because they felt that learning this would be an additional source of helping to clear up confusion. According to Higher ED Teaching Strategies (Magna Publications), since wrong answers on multiple choice can provide misinformation that could influence subsequent thinking about the content, it is the students job to do the legwork where they talk with each other, check notes, look things up in the text, and then explain why the option is incorrect. The instructor could highlight questions with incorrect answer options regularly selected and allow time in class to facilitate the process [7].

One student commented that they would have preferred longer videos rather than short ones. This student response suggests that there is a small minority of students that feel that longer blocks of learning time work better for them. However, current best practices on educational videos suggest that having many short videos is much more successful than longer ones, as this helps minimize extraneous cognitive load and optimize germane cognitive load of memory [1].

Grades (Table 6+ Figure 1)

The end-of-quarter grades show students' overall performance outcome based on the instruction method. In a study that only used end-of-term grades to evaluate the effectiveness of hybrid learning against traditional classroom instruction in an introductory management course, they

found that the final grades for the students in the hybrid situation were significantly greater than those earned in the traditional format, while all other aspects of the course remained the same [6]. The results of this study show that once the hybrid course replaced the traditional method, most students received a grade in the B range rather than in C range. We do not see much difference in the “A” range, suggesting that students in the very top will work hard on their own to earn the desired grade despite which method the course is taught in. We do observe the failure rates being lowered in the hybrid teaching style as well. However, it must be noted that a contributor to the higher scores in a hybrid format is the allocation of points to discussion attendance and the PlayPosit videos which bring averages up (worth 25% total). Another potential contributor might be that the hybrid course consists of three midterms instead of two, allowing students to be tested on less material each time which helps improve the concepts retention.

Finally, in light of the recent COVID-19 pandemic, academic institutions in the United States changed to online instruction for the latter part of the 2019-2020 academic year. The sudden transition for most instructors meant that they had to design online courses with little time, often just by giving the same lectures by Zoom or pre-recording them and changing to online exams. This has created new problems, such as the complete displacement of students from UCR and their isolation from their friends, colleagues and the stimulation of the learning environment of lecture halls, libraries and study areas. Although the Spring, 2020 version of Bio 5A is now completely online, it is unknown how students will feel when *all* of their classes are now in this instructional mode. It is possible that the success of the Hybrid/Online versions of Bio 5A from 2017-2019 resulted in part from the fact that for most students, this was the only course that they were taking in this mode. When all classes are online, it is likely that there have

been shifts in how students prioritize their time and learn compared to the typical on-campus experience.

Conclusion

Higher education courses require students to learn critical concepts in depth, and the way a course is taught impacts how well the student performs in the class. Stepping aside from the traditional mode of teaching with a lecture hall filled with over 100 students, the hybrid method is a new approach to teaching, and the results of this study based on multiple offerings of the course to over 500 students that a hybrid class is at least as good, and possibly better, than traditional lecture for student learning and course satisfaction. With the results of this study, and the experience gained by teaching solely online due to COVID-19, more instructors can now consider redesigning their course in a hybrid format post pandemic, especially if they believe students can benefit from such a format.

Future Directions

The results of this study were mostly based on students reporting their thoughts and opinions on the hybrid format of the course, which helped us better capture students' overall experience in a STEM hybrid course. Now, I would like to encourage further research where there could be direct comparison of grades of traditional face to face courses and the hybrid course running concurrently together with all other aspects of course same to further understand the overall learning outcomes.

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