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Remote Versus In-Class Active Learning Exercises for an Undergraduate Course in Fluid Mechanics

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Abstract:

Fluid Mechanics is a fundamental core course in mechanical engineering curricula that covers the motion of fluids (liquids and gases), internal flows (flows in pipes/ducts), external flows (flow around vehicles and aircraft, river flow, etc.), and flow vector fields which require higherorder math skills to master. We have taught the undergraduate fluid mechanics course in hybrid modality with active in-class learning before the COVID-19 pandemic. Once the COVID-19 pandemic required the instruction to move to the remote format in the middle of the Spring2020 semester, we have started a new open Courseware website and a new YouTube channel and hosted 200+ lecture videos totaling 45 hours of undergraduate fluid mechanics class and prerequisite differential equations content and continued the active learning exercises via synchronous remote sessions. This paper discusses how the transition was accomplished and how the synchronous remote sessions were handled for continued active learning exercises for 100+ students enrolled in the class in spring 2020 and beyond. We also distributed a survey on students and inquired about how the student perception and learning effectiveness of active remote learning exercises vs. active in-class exercises. The students overall appreciated the availability of lecture videos and preferred to watch the lecture videos directly from YouTube as opposed to the Learning Management system. The majority of students found the effort to be more for remote instruction, as they found more responsibility has been placed on them. As a result, around 80% of students either preferred in-class active learning or were not sure for the Spring2020 semester. The percentage of students preferring online instruction increased for the Summer 2020 and Fall2020 semesters. As an example, just slightly over 50 percent of the students preferred in-class instruction as of the Fall2020 semester.

Keywords: Active learning, In-class exercises, Fluid mechanics, Online learning exercises,

1. Introduction

Fluid mechanics is a core course for many, if not all, mechanical, civil, and environmental engineering undergraduate curriculums throughout the world. However, previous studies indicated that the students typically view the undergraduate Fluid Mechanics course(s) as challenging, resulting in low student performance, discouragement, and low engagement during the class sessions [1, 2].

Fluid mechanics or any other STEM (Science, Technology, Engineering, and Math) course can be taught in either traditional or flipped teaching modalities. In the traditional classroom modality, faculty lectures on a particular topic of the day according to the syllabus while students listen and take notes. Depending on the content, the faculty assigns homework and/or quizzes to ensure students are studying and learning the concepts covered. However, multiple studies [3-5] have shown that this passive learning of STEM courses may be ineffective and may foster low engagement. The instructor needs to introduce new concepts, motivate the students on the need to cover that concept, perhaps derive the fundamental equations; there is hardly any time left for students to work on example problems for higher-order learning. The second is the flipped classroom modality, in which the students review the lecture material via assigned multiple short and focused lecture videos and reading the textbook before coming to class. This frees up class time, allowing the application of the fundamentals to higher-engagement experiential learning activities while the faculty and teaching assistants answer student questions and provide 1-on-1 assistance to students [6-10].

In traditional lecturing, actual self-assessment takes place when the students are working on an assignment [11]. One fundamental problem with this passive mode is that by the time students develop mastery of the topic via working on practice problems, the instructor has already progressed to a more advanced topic, typically assuming students' full comprehension of the prior topic. Previous evidence-based research [12] conducted on over 60 courses and 6,500 students has illustrated that active learning is associated with substantial improvement in conceptual understanding of the topics covered and problem-solving skills when compared to passive learning. Additionally, a meta-study of over 150 studies for undergraduate STEM courses states that "…students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning…." [4].

Aligned with these findings, we incorporated significant active learning exercises into the undergraduate fluid mechanics class, beginning with the summer 2019 offering to address the low student engagement and discouragement reported in the literature. To alleviate that limitation of the traditional classroom pedagogy, we employed hybrid and flipped teaching pedagogies before COVID-19 and exclusively flipped teaching pedagogy when the COVID-19 pandemic required remote instruction. Students reviewed lecture videos and read the textbook before coming to class [13]. During class time, the students applied the fundamentals via higherorder active learning exercises for both in-class and remote learning formats.

When the COVID-19 pandemic required to move the instruction to remote format within a matter of days, the authors, similar to the majority of faculty all around the world, scrambled to move all of the lectures to an online format. We continued recording lecture videos and uploading them to the Learning Management System (LMS) of the course page. However, LMS took significant time to process the lecture videos. Hence, we started a new open Courseware website (www.collegefluidmechanics.com) and a YouTube Channel and made lecture videos freely available to everyone in these tense, hard, and unpredictable times. Currently, there are over 200 lecture videos (totaling 45 hours of content) composed of derivations, discussion, and real-life examples of various fundamental fluid mechanics and prerequisite differential equations content [14, 15].

2 Methods

We have divided the undergraduate core fluid mechanics class into 12 distinct modules (see Table 1). For a typical 16-week semester with a total of 37.5 contact hours available, each module is reserved for 2.5 to 3.75 contact hours, depending on the complexity of the content covered. Each of the 12 modules listed in Table 1 has its student learning outcomes, comprehensive lecture videos, and reading assignments from the required textbook, as well as the assessment of student learning outcomes (weekly homework and weekly quizzes). Also, each module has focused discussion boards, where students get feedback from their classmates (reciprocal teaching), teaching assistants, and the instructor. Figure 1 illustrates the composition of each of the modules.

Table 1: Detailed information on each of the modules, including the topic name and number of lecture videos available for students to watch before coming to the class sessions

Module #	Topic	# of Lecture Videos
1	Introductory Concepts and Viscosity	14
2	Fluid Statics – Manometry	8
3	Fluid Statics – Forces on Submerged Surfaces	15
4	Fluid Kinematics	9
5	Finite Control Volume Analysis: Conservation of Mass	8
6	Finite Control Volume Analysis: Conservation of Momentum	9
7	Finite Control Volume Analysis: Conservation of Energy and Bernoulli's Equation	9
8	Differential Analysis of Fluid Flow: Conservation of Mass	8
9	Differential Analysis of Fluid Flow: Conservation of Momentum	7
10	Dimensional Analysis and Similitude	9
11	Viscous Flows in Pipes	17
12	Navier-Stokes Equation	8

In addition to the 12 technical modules, to assimilate the students with the course content, format, and expectations, we have an introductory module titled "module 0 – Getting Started," the detailed contents of which are illustrated in Figure 2. Module 0 also includes a video titled "what are the Fluids? Why study the Fluids?" which motivates the students on why they are taking this course, how it fits into their career progression upon graduation, as well as discuss the prerequisite course contents. We also include a section on "What you can expect from me" and "What I expect from you"; as well as detailed information on the Online Learning Integrity Software, Proctorio, that is used in all the exams and tests, where we proctor the students, the websites they visit, as well as verify their state-issued ID before making the exams available to them.

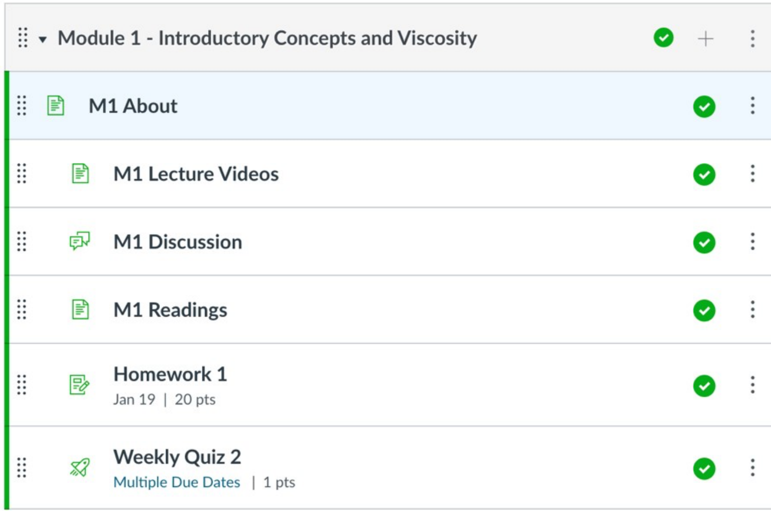

Figure 1: Representative example of the composition of each module

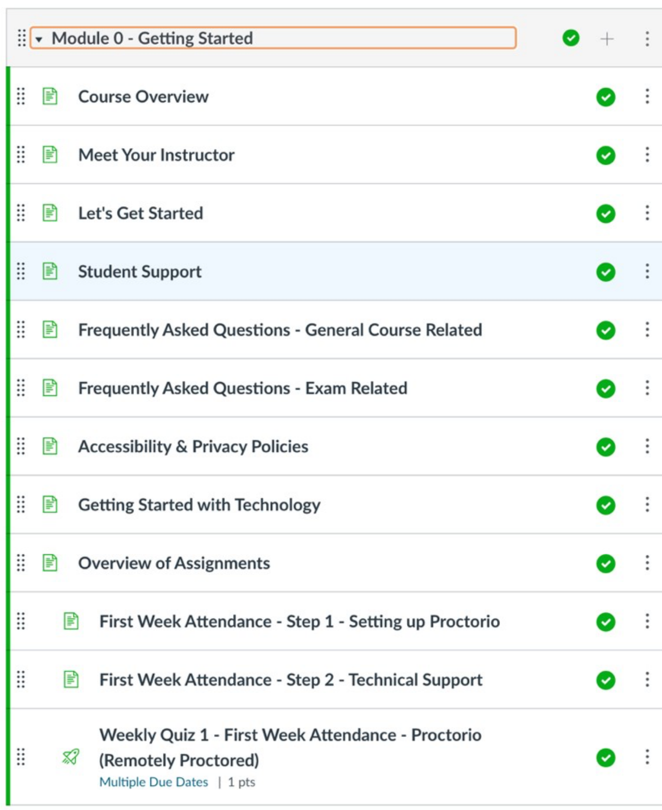

Figure 2: Detailed Contents of the Module 0 - Getting Started

For the available 2.5 to 3.75 available contact hours for each of the 12 modules, we have successfully replaced the in-class active learning sessions with online synchronous live sessions during the assigned class times through Blackboard Collaborate Ultra. During the COVID-19 remote and online instruction period, the students were required to watch the short and focused lecture videos before joining the live sessions. The students had the option of watching the lecture videos directly through YouTube, or video links were also embedded in the LMS to give students flexibility. The advantage of the YouTube platform is that it is a very familiar platform for the students. According to Alexa Internet Inc., it is the 2nd most visited website globally after Google [16], with 70% of the millennials visiting YouTube at least once daily [17]. Also, whether students are accessing the lecture videos on a large computer screen or a smartphone with any operating system, it automatically scales the lecture videos and adjusts the resolution depending on the speed of the internet connection.

Students are also assigned reading assignments from the required textbook of the course that must be read before joining the live sessions. It is worth noting that students also had any time access to Canvas messages and discussion boards for each of the modules at the LMS for peer, instructor, and teaching assistant feedback. We observed that students used these communication channels available to them heavily after transitioning to online remote instruction during the pandemic. In order to ensure that students are watching the lecture videos, reading the textbook, and learning the concepts, we have implemented auto-graded online multiple-choice quizzes that test lower-order learning for all 12 modules.

During the 75 minute twice-weekly synchronous live sessions during assigned class periods, approximately 20 to 25% of the class time was reserved for traditional lecturing - including derivation, discussions, real-life examples - and clarifying the difficult topics of the particular topics discussed. The feedback on identifying the difficult topic was received via quizzes/homework/discussion board/individual communication with the instructor and the teaching assistants. Depending on the response from the students, approximately another 20 to 25% of the class time is reserved for answering student questions, going over the quizzes and homework questions.

The remaining 50 to 60% of the class time is reserved for active learning exercises, including *think-pair-share* activities, while the instructor and teaching assistants support the students on an individual and group basis. As part of the *think-pair-share* activities, the active learning exercise sessions started with students working on the handout of the day on an individual basis (Figure 3). Then the students were arbitrarily grouped into 3 to 4 students using the breakout group functionality of the Blackboard Collaborate Ultra. The instructor and the teaching assistants were available to assist students both in the individual exercise time and group work time. After the group work, the students returned to the main room of the Blackboard Collaborate Ultra, where the instructor went over the procedure on how to solve the question posed in the flipped classroom session of the day.

Flipped Class Module 1:

Question: The boundary layer velocity profile of a Newtonian fluid flowing over a fixed surface can be approximated by

$$u(y) = U.sin(\frac{\pi}{2h}y)$$

where u is the variable velocity within the boundary layer, U is a constant number (free flow velocity), h is the thickness of the boundary layer (constant), while y is pointing up from the fixed surface, please see the figure below.

As a function of h, U and the fluid viscosity (μ)

a) Find the shear stress in the fluid at y = h (4pts)

   Answer: 0

b) Find the shear stress in the fluid at y= h/2 (3pts)

   Answer: 1.11 U.μ/h

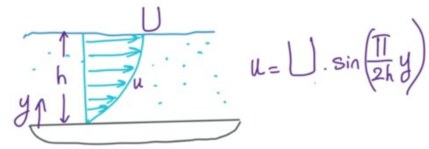

Figure 3: A representative handout shared with the students for the synchronous live flipped class sessions.

4 Results and Discussion

The results and discussion are presented in the subsequent sections. First, each semester is analyzed on its own then a comparison is made between the semesters and their responses. Surveys were blind to the instructor teaching the course and the administration of the surveys was conducted by a separate researcher. The surveys indicate a general trend in the acceptance (easing of tensions with students) of COVID-19 related online-instruction. Despite efforts to detail a correlation in behavior among students and grades, no statistically significant trends were found in this regard.

Table 2 summarizes some general information regarding the student responses and enrollment quantities for the three separate semesters. It is worth noting that the student survey response rate varied by semester: in the Spring 2020 semester, 77 of 101 students filled out the survey (75%); in the Summer 2020 semester, 26 out of 33 students filled out the survey (79%); and in the Fall 2020 semester, 101 out of 119 students filled out the survey (85%). This indicates a general trend of an increasing number of students completing surveys. This may be an indication that students are more concerned with expressing their opinions, as the remote and online instruction due to the COVID-19 pandemic continues.

Two other important notes are that student support and enrollment between the semesters differ. There were two teaching assistants available to assist the students over the Fall and Spring semesters, but only one teaching assistant was assigned for the Summer semester due to lower enrollment. When there are two teaching assistants, one is dedicated to assisting students outside the classroom through Microsoft Teams or other communication platforms. If there is only one teaching assistant, this assistant both grades and assists students, so he/she was less available to aid students. Also, it is noteworthy to compare the enrollment by semester. Summer semesters typically only have one-third of the enrollment of Spring or Fall semesters.

Table 2: The enrollment, respondent quantities, and respondent percentage are expressed as well as the quantity of TAs available for each session of the course.

Semester	Student Enrollment	# of Respondents	% of Respondents	Available TAs
Spring 2020	101	77	75%	2
Summer 2020	33	26	79%	1
Fall 2020	119	101	85%	2

4.1: Individual Semester Analysis:

As the instructional change due to the COVID-19 pandemic occurred in the middle of the Spring 2020 semester, this presented a unique opportunity to study active in-class vs. active remote learning with the same subjects between the control and treatment groups for a fairer comparison. We have collected student satisfaction surveys to analyze student perception and learning effectiveness. Out of 101 registered students, 77 gave consent and took the survey. According to the student survey results, 57% of students exclusively watched the lecture videos posted, vs. 43% of students used a combination of videos and read the required textbook (Figure 4). It should be noted that the students did not take advantage of the required textbook of the course as much as the instructor wished students to use.

In addition, it can be observed from Figure 5 that students highly appreciated the availability of lecture videos as they can revisit them anytime, including right before the exams, quizzes, and homework, for better knowledge retention. They also preferred to watch the lecture videos directly from YouTube over the LMS (Figure 6). When they are asked about the effort required and responsibility put on them remote vs. in-class learning, the majority of the students found the effort to be more (Figure 7), and they perceived more responsibility had been placed on them (Figure 8). As a result, more than 80% of students either preferred in-class instruction or were not sure (Figure 9). However, it should be highlighted that among other factors, learning is impacted by the environment [18], and the environment changed significantly for our students, including job layoffs, health issues, financial difficulties, job, and internship offer rescindments. These circumstances should be taken into account when discussing the comparison.

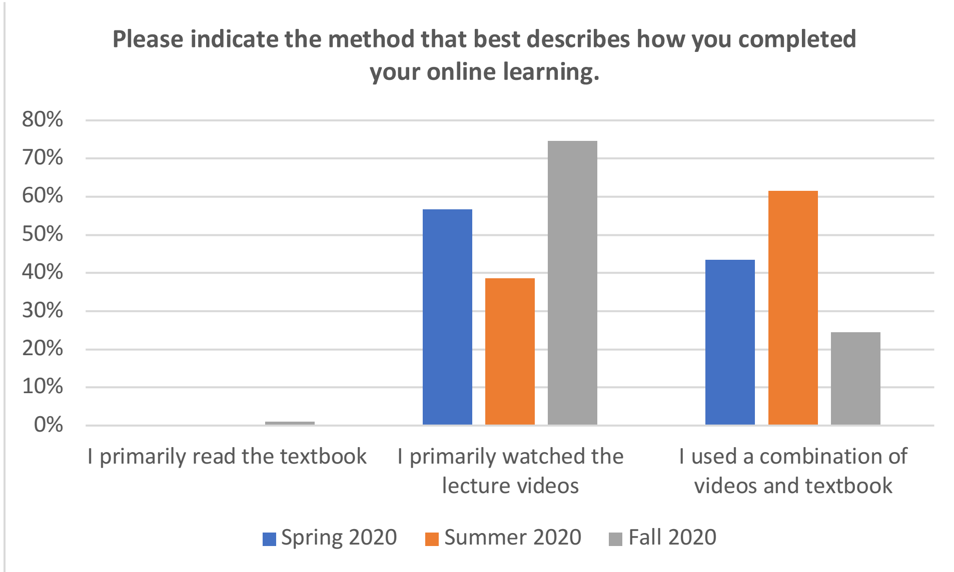

Figure 4: Student responses for the survey question on the method they have employed for online learning for Spring2020 through Fall2020 semesters

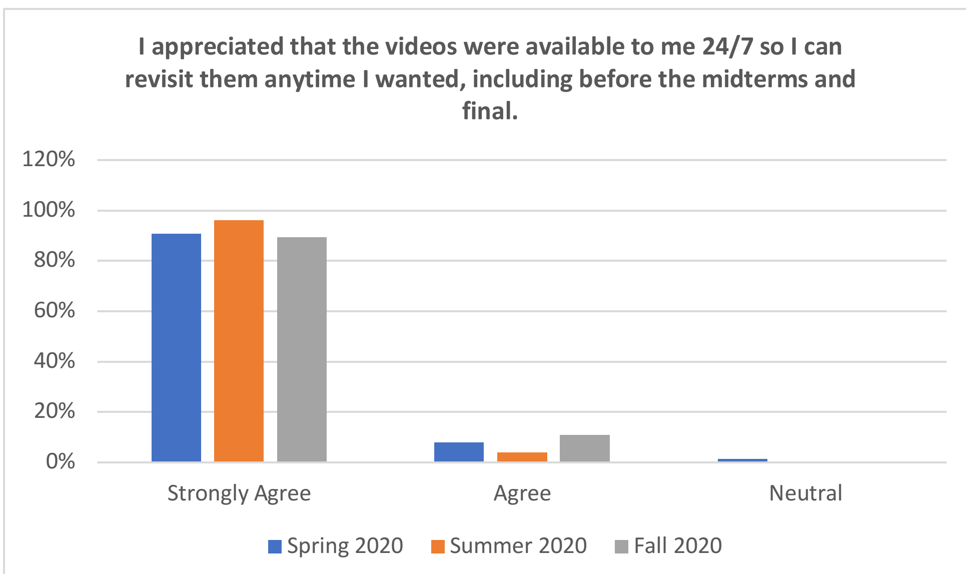

Figure 5: Student responses for the survey question on whether they appreciated the availability of lecture videos for Spring2020 through Fall2020 semesters

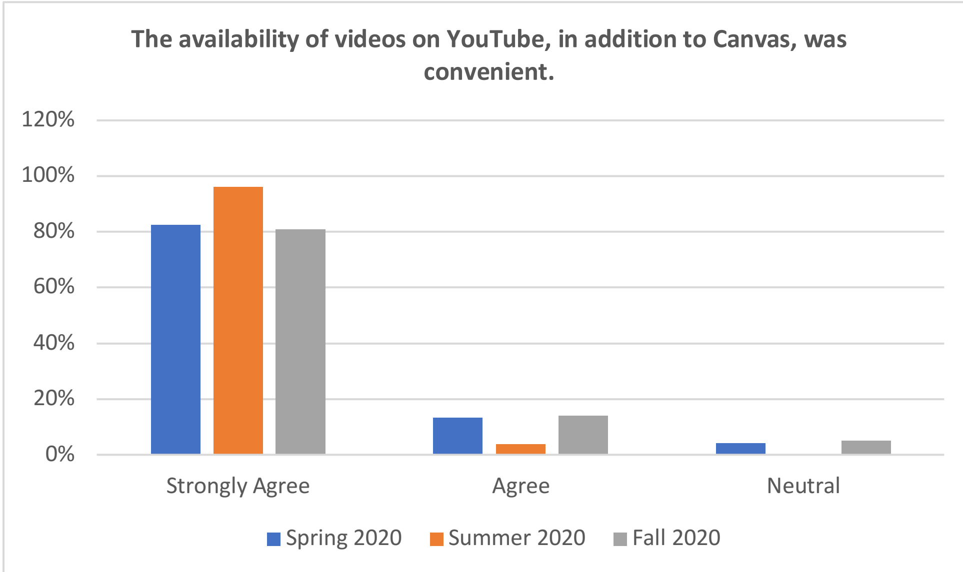

Figure 6: Student responses for the survey question on whether they appreciated the availability of lecture videos on YouTube for Spring2020 through Fall2020 semesters

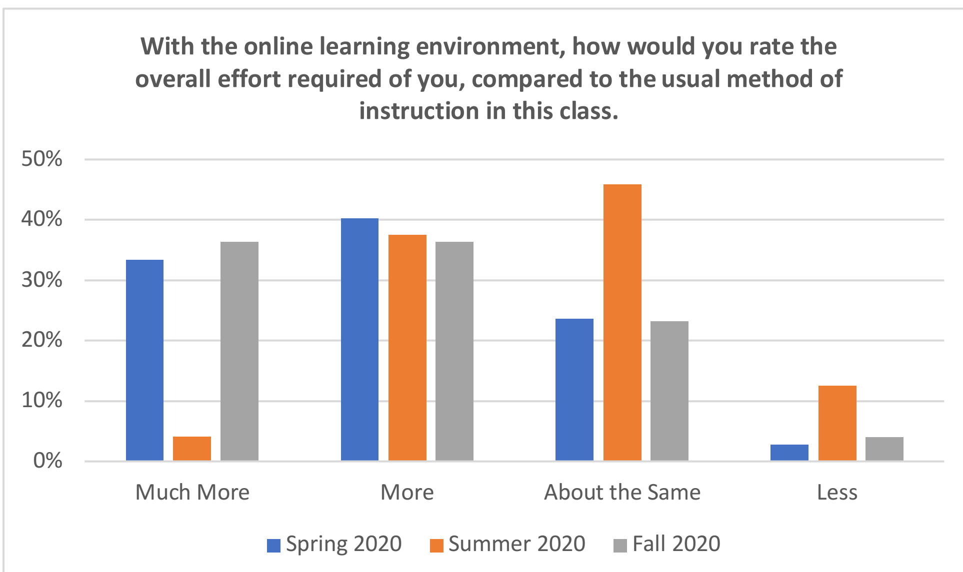

Figure 7: Student responses for the survey question on whether they had to put in more effort for Spring2020 through Fall2020 semesters

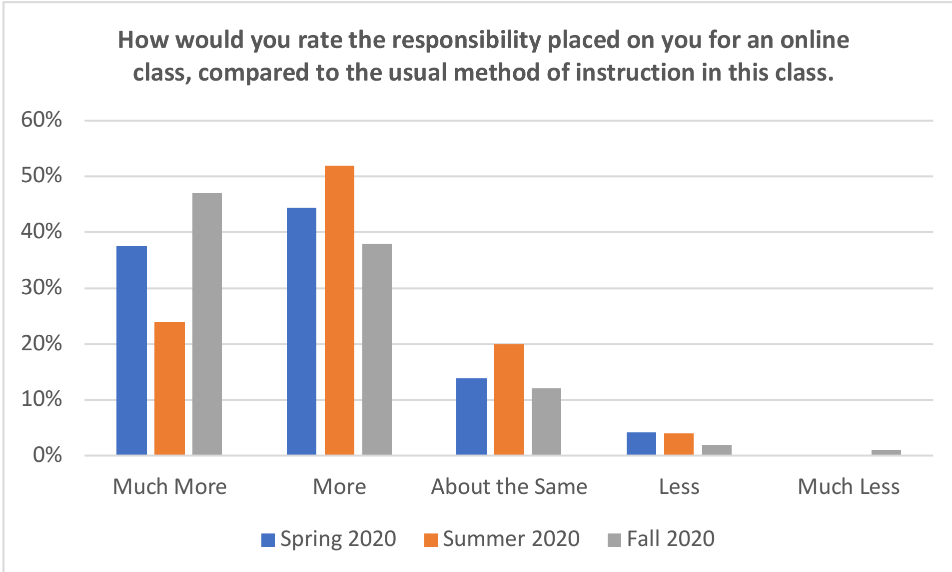

Figure 8: Student responses for the survey question on whether more responsibility has been placed on them for Spring2020 through Fall2020 semesters

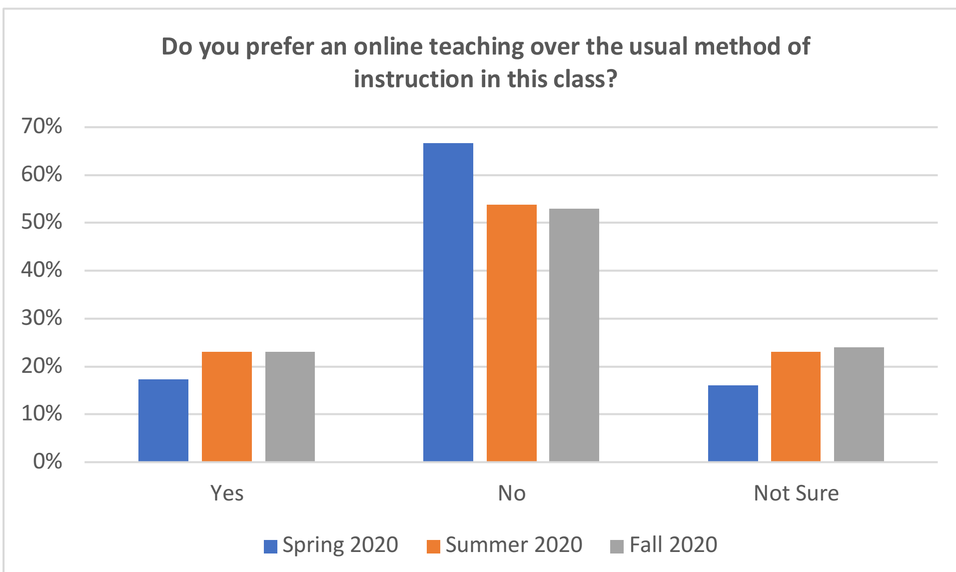

Figure 9: Student responses for the survey question on the preference of online versus in-class instruction for Spring2020 through Fall2020 semesters

The Summer 2020 semester presents a view that suggests that students are beginning to accept some of the differences with online learning. For instance, students continued to respond positively to the fact that lectures available online can be viewed repeatedly and before examinations (Figure 5). Student desire for online learning, however, is still far below half of the students preferring online teaching. One can observe from Figure 9 that 25% preferred online over in-class in the Summer 2020 semester, which is higher than the Spring2020 semester.

Students continued to consider the effort required and responsibility placed on them was greater with online coursework (Figures 7 and 8). However, these interesting findings must be viewed from the understanding that the students that typically take Summer courses may not be representative of the students that take courses during the Fall and Spring semesters. For instance, student aid is not typically provided over the Summer semester, and many students opt to take internships or breaks from school over Summer semesters. Accordingly, our findings suggest that the tendencies of the students that take Summer coursework may differ slightly from students that take courses over the Fall and Spring semesters.

The Fall 2020 semester features student responses similar to those of the Summer 2020 semester. In general, students continued to prefer in-class learning over online learning. However, it should be highlighted that only slightly above 50% of students preferred in-class teaching versus online learning. Grades over the Fall 2020 semester are slightly improved over the Spring 2020 semester (Figure 10). As before, the availability of lecture videos being online and easy to access is seen as a benefit among students (Figure 5). Also, the effort required and responsibility placed on the students were perceived by the students as being greater than when compared with in-class learning, which is similar to the feedback received from Spring2020 and Summer2020 cohorts (Figures 7 and 8).

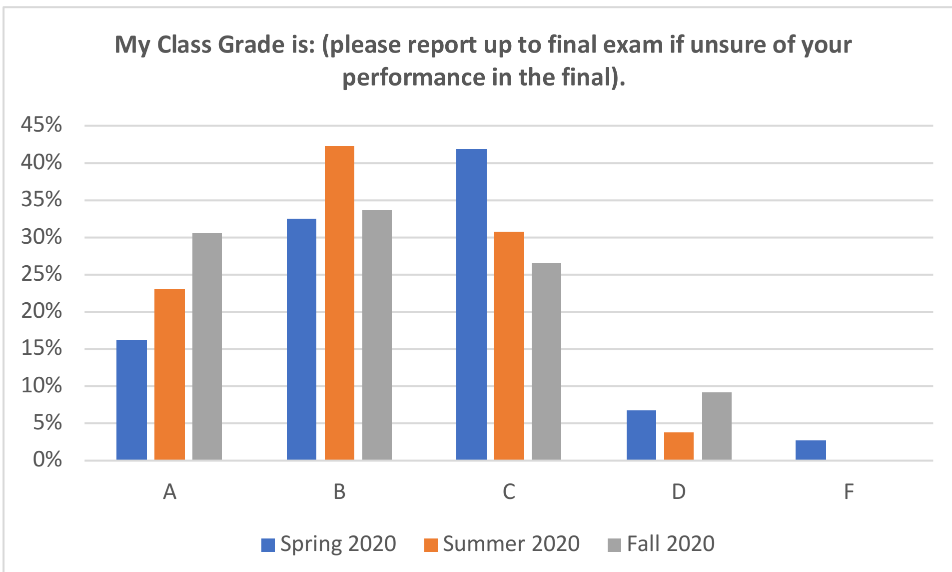

Figure 10: Student responses for the survey question on their class grades for Spring2020 through Fall2020 semesters

4.2 Comparative Analysis Among Semesters

Some interesting but relatively insignificant statistical findings can be seen in the student responses between the different semesters. As an example, Figure 9 indicates the general attitude of students towards online learning. Students responded more favorably, on a percentage basis, over the Summer and Fall semesters when compared to the responses for the Spring 2020 semester. This may indicate that students are getting used to online learning, also perhaps the teaching team is also more experienced with online teaching after a full semester of teaching exclusively online.

As can be concluded from Figure 4, students have had an increased tendency to exclusively watch lecture videos as opposed to a combination of textbook and video studying, which is not ideal. While conclusions can be suggested for this, such as potential word-of-mouth spreading from previous students indicating that the lecture videos are sufficient for studying, these conclusions are conjectural.

Figures 6 and 7 show that regardless of the semester, students highly prefer coursework being readily available online. Figures 7 and 8 provide intriguing responses in that students feel more responsibility has been placed on them, and the effort that they need to spend on courses are more for all three semesters investigated. However, the students over the Summer 2020 semester indicated, on average, more often that the effort was "About the Same" than they did over the Spring and Fall 2020 semesters. This suggests that students in the Summer semester had a less negative view of the effort required of them. It should be noted that literature typically reports increased effort and responsibility placed on students for flipped instructions. However, our comparison is for flipped learning for both in-class and online environments.

Figure 8, however, strongly indicates that students feel a greater burden of responsibility, regardless of semester. There is a slight easing of responses over the Summer 2020 semester, but the results still indicate a negative view of the responsibility borne by students. Figure 10 indicates the grades of students between the three separate semesters analyzed. Student grades have generally been improving over time. The exact factors as to why cannot be determined from the survey as there are far too many variables to consider concluding why the grades have improved.

5. Conclusions

Several conclusions can be drawn regarding the student responses. Students tend to not prefer online instruction as opposed to in-class instruction; however, students seem to be getting more used to online instruction, as indicated by the increase in the percentage of students preferring online instruction over the three semesters investigated. However, the availability of lectures online is a great benefit to the students, with a growing number of students exclusively studying using the lectures online as time progresses. The burden of responsibility perceived by students, however, is a growing concern, and the effort felt by students is seen as a negative among them. Despite the issues perceived, student grades have improved over the course of the COVID-19 pandemic (as determined by the student's self-reported grades). Future work will correlate student responses with standardized tests. While further analyses were attempted as part of this paper, such as analyses by grade, no statistically relevant occurrences were found beyond the trends noted that have occurred as the semesters have progressed. For instance, there is no clear indication that students with a particular mode of study produce superior grades.

The existence of all the class lecture videos on a platform readily available to all the students benefits the instructor and students significantly. Once the COVID-19 pandemic passes, the instructor will continue to offer his in-class courses in a flipped pedagogy, where students will be assigned to watch short lecture videos and read related content from the textbook before coming to class sessions. A discussion board hosted through the LMS will continue to be employed for peer, instructor, and teaching assistant feedback for outside the class assignments. During the inclass sessions, mini-lectures will be employed as needed. Clicker quizzes will be employed, assessing technical content covered for that class session. In addition to active learning exercises testing higher-order learning, we are highly interested in incorporating metacognitive exercises into our class session to ensure that the students develop life-long learning skills needed to navigate the professional workplace throughout their careers.

In this study, we have analyzed the survey results distributed to the students. In the near future, we will analyze the raw student data available at the LMS and study the multiple potential correlations, such as grades vs. student engagement. Additionally, we would like to note that while these initial surveys in our extended study have not included demographic information of students, future studies will include this information.

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