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Comparison of Online and In-Class Instruction in Introductory Fluid Mechanics*

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An introductory course in fluid mechanics has been delivered with the lecture component in online and traditional face-to-face (F2F) modes. Online and in-class lectures were delivered by the same instructor and the student learning assessments were identical. Students were surveyed at the beginning of the course to assess differences in the online and F2F cohorts, and near the end of the course to gather feedback. This paper reports a comparison of the main student outcomes and feedback for both modes. A statistical analysis of the course grades shows that the students' program had the most influence on academic performance. The effect of the mode of lecture instruction on student performance was mixed and depended upon the students' program: mechanical engineering students performed better with the F2F lectures, while industrial engineering students had superior performance with online lectures.

Keywords: online learning; blended learning; hybrid course; course effectiveness; engineering; fluid mechanics

1. Introduction

Many engineering programs are seeking to leverage information technology to improve the efficiency, flexibility and effectiveness of instruction. Some engineering courses, and even entire programs [1], have been converted to be fully online. However, blended learning, which combines online content with traditional classroom instruction, is the most common approach. One way to blend online content into the curriculum is the "flipped classroom" [2–5]. In this format, students learn some of the main concepts outside of the classroom via online resources. Face-to-face (F2F) instructional time is then spent on hands-on practice, group design projects, problem solving and discussion. Another common format is the hybrid course, involving the conversion of one or more instructional component for online delivery [6–8]. The online course in the current study takes a hybrid approach, with lecture material delivered by asynchronous streaming videos combined with traditional F2F laboratory instruction.

A significant body of literature has developed over the past two decades on the effectiveness of online instruction, covering a wide range of fields. Despite extensive investigation, a definitive consensus has not emerged. Some studies favor fully online or hybrid-online learning. For example, a six-year study (involving 670 students) of an undergraduate biology course [9] showed that a hybrid method (online lectures with in-class laboratories) was superior to the standard lecture mode. A meta-analysis by Shachar and Neumann [10] also demonstrated that students in distance education generally outperformed their counterparts receiving traditional lecture instruction. In contrast, Bergstrand and Savage [11] report that online sociology classes are rated by undergraduates as less effective when compared to in-class instruction. Several investigators reach more neutral conclusions: McCutcheon et al. [12] report that online lectures for teaching clinical skills in nursing are no less effective than traditional modes. Closer to the field of the current investigation, recent studies of an engineering mathematics course [13] and an electrical engineering course [14] found no statistical difference among the grades of students taught by online and traditional lectures.

The lack of consensus in the literature on the relative effectiveness of online versus F2F instruction is not surprising, as many competing factors and complex interactions are at play. A critical factor, which is difficult to assess in the educational literature, is the quality of the instructional materials and their presentation. Also, it has been suggested that some disciplines, such as those involving mainly mathematics, may be harder to deliver successfully in an online mode [14]. Whether or not students are given a free choice (as in the present study) or are required to take an online course may further influence the level of student satisfaction and the effectiveness of instruction. As will be highlighted in the current work, the student's level of interest, which varies with both the course subject and the student's degree program, also

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influences academic performance across different modes of instruction.

In the fall term of 2018, an undergraduate course in introductory fluid mechanics (*MEC516*) was taught with online and traditional lectures. A key feature of the current study is that the online and F2F students were taught by a single instructor in the same semester, with identical lecture content. Furthermore, identical quizzes, midterms and final examinations were written at the same time by all students, which were marked with a common marking scheme by the instructor. For reasons involving faculty workload and course scheduling, this arrangement presented an uncommon opportunity to study the relative effectiveness of online versus F2F teaching. The current study largely eliminates the variability attributed to different course instructors (lecture style and clarity, marking standard, etc.) and the year-to-year variability in the examination difficulty and the student cohorts. The results of this study are relevant for instructors and administrators, particularly in engineering, who are considering the full or partial conversion of a traditional lecture course to an online format.

2. Description of the Online and Face-to-Face Courses

MEC516 Fluid Mechanics I is an introductory course in undergraduate fluid mechanics. It is textbook-centred and covers the first five chapters of the book by White [15]. Fluid mechanics is fundamentally a combination of applied physics (mechanics) and mathematics. In traditional F2F mode, the course has three fifty-minute lecture hours per week for thirteen weeks, plus four two-hour hardware labs. In the fall term of 2018, the course was offered to approximately 235 students in three undergraduate programs: mechanical engineering, biomedical engineering and industrial engineering. *MEC516* is a required course in the first semester of third year in all three accredited programs. The course had two instructors. One instructor taught in only the traditional F2F lecture mode, and one instructor (Professor Naylor) taught in both online and F2F lecture modes. The performance comparisons in this study are restricted to the students taught by Professor Naylor.

Table 1 shows a breakdown of the number of students in each program. Only the mechanical engineering (ME) and industrial engineering (IE) students could enrol in the online course. These students were given the free choice to select either traditional or online lectures. Biomedical engineering (BME) students were not permitted to take the online course.

The online version of *MEC516* is a hybrid course, involving a combination of online and F2F components. The course had three main online components: (i) lectures offered entirely by asynchronous streaming video, (ii) five online quizzes completed using the Desire2Learn (D2L) course management system, and (iii) technical counselling on assigned problem sets via e-mail. The online students were required to be on campus for four F2F hardware labs and other courses. For this reason, two hours per week of office counselling was provided, in addition to asynchronous counselling by e-mail.

The video lectures were created using screen capture software (*Camtasia Studio 8*). This software simultaneously captures the computer screen activity, an audio track and the output from a webcam. The edited capture sessions were exported as MP4 video files and uploaded to a dedicated *YouTube* channel for the course.

One of the advantages of video lectures is the ability to divide the course material into smaller modules, rather than forcing content into a fifty-minute lecture. Theory and simple numerical examples were presented using *Microsoft PowerPoint*. These recordings were enhanced with links to supplemental video material showing industrial applications and physical demonstrations by the instructor. A touch screen laptop computer with a stylus was used to capture the hand-written solution of several problems. All presentations were made available to students in pdf format for study and note-taking purposes.

The course had five auto-graded online quizzes delivered using D2L (worth 5%), which were completed by both the online and F2F students. Students were required to answer ten multiple choice questions, randomly selected from a bank of questions. Approximately one half of the quiz questions required a short numerical calculation. The numerical values for these problems were changed randomly (within a specified range), so that the correct numerical answer was different for each student. The question selection, order and multiple-choice answers were also randomized to improve the academic integrity of the quizzes.

Table 1. Number of students by program in the online and F2F courses (Prof. Naylor's students only)

	Mechanical Eng. (ME)	Industrial Eng. (IE)	Biomedical Eng. (BME)	Total
Online Lecture Course	62 (79.5%)	16 (20.58)	0 (0%)	78
F2F Lecture Course	52 (55.9%)	9 (9.7%)	32 (34.4%)	93

The video lectures for the entire course were posted at the start of the term. This allowed the online students to work at their own pace and complete the chapter quizzes any time prior to the deadline. (In contrast, the F2F students were required to wait until all the relevant material was covered in lecture prior to completing each chapter quiz.) The main purpose of the quizzes was to set a minimum study pace for the online students and motivate these students to stay up to date with the video lectures. The overall participation rate in the quizzes was 89% for the online students and 94% for the F2F students.

For the F2F course, lectures were delivered using a combination of a whiteboard and *PowerPoint*. Typically, a *PowerPoint* slide presentation was used to introduce the concepts and basic theory. Then, detailed numerical problems were solved on a whiteboard. The *PowerPoint* slides used in the F2F mode were the same as for the online videos but abridged to allow for some hand-written delivery on the whiteboard, particularly problem solving. Also, in the F2F mode, in-class demonstrations replaced video demonstrations. Thus, the primary difference between the learning environments of the online and F2F students was live lectures versus asynchronous streaming video lectures.

3. Pre-Course Survey

The students were asked to fill out a questionnaire at the start of the course, mainly to assess any differences in the student cohorts that could influence student learning outcomes. Students were also asked about their motivation for selecting either the online or F2F lecture course, which was a free choice for the ME and IE students. This survey was conducted in the first three weeks of the term, during the first hardware lab.

The pre-course survey asked about the students' total course load, hours of employment, time spent on extra-curricular activities, and commute time to campus. These variables were submitted to a one-way ANOVA test with course format (i.e., online vs. F2F) as the between-subject factors. None of these factors showed any significant difference between the online and F2F format ($ps \geq 0.255$). Since only ME and IE students could choose the online course, a second analysis was carried out only on students from these two programs. A two-way ANOVA test was conducted on these dependent variables, with course format (i.e., online vs. F2F) and student program (i.e., ME vs. IE) as the two between-subject independent factors. The main effect of course format remained non-significant for all the variables ($ps \geq 0.265$). Most of the factors did not reveal significant difference between ME and IE students ($ps \geq 0.0237$), except for extracurricular activities where ME students reported to engage in more hours in extracurricular activities per week than the IE students ($p = 0.032$). Overall, these factors can be largely discounted when considering differences in student grades.

The pre-course survey also asked whether the student had previously taken an online course. This factor showed a marginally significant difference ($p = 0.055$). Specifically, 21 out of 78 students in the online course had taken an online course, while 15 out of 105 students from the F2F course had taken an online course. Students who had experience with online courses were more likely to elect for this mode of instruction.

In addition, one question asked for the students' opinions on "which course format is more effective at delivering knowledge and skills". A Chi-square test showed significant differences in the student response distribution between students from the two course formats, X^2 (2, N = 183) = 67.02, $p < 0.001$. Among the online students, 45.6% believe that the online format is more effective, 10.1% believe the F2F format is more effective, and 44.3% believe that they are equally effective; whereas for the F2F students, only 5.8% believe that the online format is more effective, 65.4% believe that the F2F is more effective, and 28.8% believe they are equally effective.

The last part of the survey asks students to indicate how much they agree or disagree with several statements regarding study habits such as "I usually get lab reports done ahead of time", which was adapted from Driscoll et al. [16]. The mean responses from the pre-course survey of student attitudes is shown in Table 2. The BME student data was removed from this comparison since these students were not allowed to enroll in the online course. These results provide some insight into the students' motivations and reflect the freedom of choice in selecting their instructional mode. The students who selected the F2F course felt more strongly that being part of the class was important. The F2F students also valued classroom discussions more than the online students. It is interesting that the F2F students indicate that they are significantly more comfortable participating in these discussions, with the online students being more reticent. As might be expected, the F2F students also felt that frequent interactions with their professor were more important for performing well.

4. Video Lecture Viewing Data

The daily viewing statistics (available from the course *YouTube* Channel) are shown in Fig. 1 for

Table 2. Mean responses from the pre-course survey of student attitudes (based on a Likert scale of 1 to 5, with 5 being strongly agree and 1 being strongly disagree)

Question	Online (n = 79)	F2F (ME & IE only) (n = 104[§])
1. I usually get lab reports done ahead of time.	3.86	3.83
2. Feeling like I am part of a class is important to me.	3.15	3.47*
3. Classroom or online discussion is helpful to me.	3.63	3.96*
4. I feel comfortable taking part in discussions in an actual classroom setting.	3.21	3.58*
5. I prefer figuring out the instructions for lab reports or problem sets on my own without the instructor explaining them to me.	2.58	2.55
6. I always read all the assigned readings.	3.35	3.14
7. I enjoy working with other classmates on projects or in study groups.	3.66	3.62
8. I usually participate in study groups when they are available.	2.99	3.03
9. Part of doing well in a course involves frequent interactions with the instructor.	3.29	3.75*
10. I usually read the online readings on the computer rather than printing them out.	4.34	3.86**

* Significant statistical difference at p = 0.05 level in a t-test.
** Significant statistical difference at p = 0.01 level in a t-test.
[§] Included the other F2F instructor's students who elected not to take the online course.

a single lecture video. This video (Chapter 2, Part 1) covered the topic "Introduction to Fluid Statics", which was taught in traditional lectures in week 2 of the fall term (Sept. 17). The deadline for the online quiz for Chapter 2 is also marked on the timeline (Oct. 4). This data shows the large variation in student work habits. Several keen students watched at least part of this video in early September, well before the material was covered in lecture. However, many students waited until a few days before the deadline to watch (or possibly re-watch) the video. There is another peak in the access rate of this video prior to the midterm (Oct. 16) and prior to the final exam (Dec. 4), indicating that some students re-watched part of this video for study purposes.

In total, this 40-minute video was accessed 362 times over the entire term, with a total watch time of 80.4 hours. For the 89 students enrolled in the online course, this represents the time-equivalent of 1.4 views of the entire video. *YouTube* also tracks the device type via a media query that determines the screen resolution of the student's device: 95% of the total watch time was on a computer or tablet and 5% was on a mobile phone. Thus, students mostly followed the instructor's recommendation to watch the videos on a high-resolution screen.

To access the videos, students clicked on a hyperlink on the course website. The *YouTube* videos were not posted publicly, and the course website was password protected. Nevertheless, it is likely that some of the F2F students will have had access to the videos through password sharing. However, Fig. 1 suggests that a relatively small

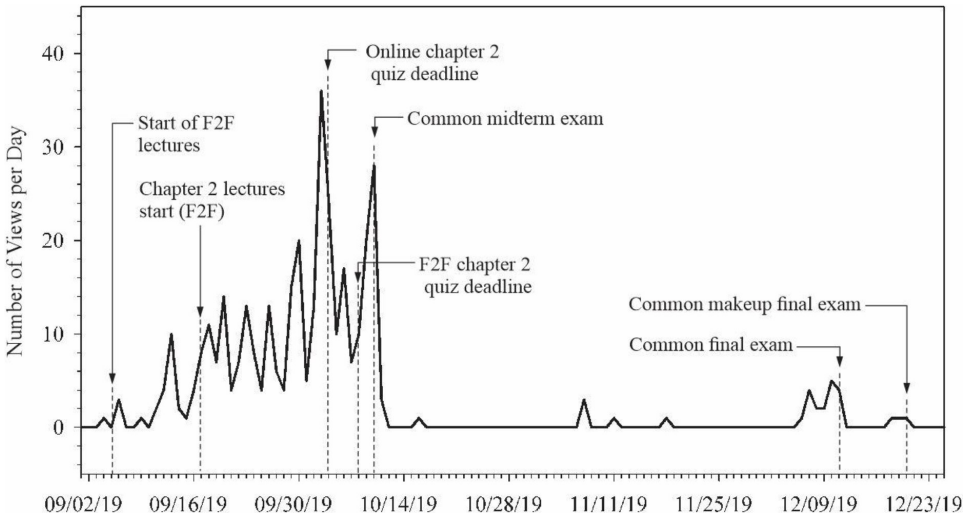

Fig. 1. Number of video views (or partial views) per day over the entire term for a single video lecture (Chapter 2, Part 1: Introduction to Fluid Statics).

number of F2F students were watching the videos. The dominant peak in number of views (~36 per day) occurred just before the quiz deadline for the online students. There is a smaller peak (~18 views per day) in the video views just prior to the quiz deadline for the F2F students (which was 4 days later than the quiz deadline for the online students).

5. Academic Performance Results

Since BME students were not allowed to take the online course, their academic performance was not included in the comparison analyses of academic performance. For each academic performance category, a two-way ANOVA was conducted, with course format (i.e., online vs. F2F) and student program (i.e., ME vs. IE) as the two between-subject independent factors. Table 3 presents a summary of the academic performance of students enrolled in the online and the F2F sections, as well as the univariate statistical comparisons between the two groups. The academic measures include overall grades, grades from quizzes, lab reports, midterms, final exams, as well as the course pass rate and success rate. The success rate indicates the percentage of the class that achieved a final grade of at least a C- (60%). This analysis excluded data from 4 students who took alternative makeup-tests, rendering the scores incomparable.

When the online group was compared to the F2F group, there was no statistical difference in most of the academic categories, except for the success rate ($F_{1,130} = 5.64$, $p = 0.019$). Specifically, a higher percentage of the online group achieved academic success (91%) than the F2F group (87%). However, it is important to note that this difference may be due to the exceptionally low (63%, or 5 out of 8) success rate of IE students in the F2F group. It is likely that this observed difference was driven by outliers and therefore may not represent the general population.

The comparison between students from different programs as well as the interaction between student program and the course format revealed some interesting findings. It showed that the ME students outperformed the IE students in overall grade ($F_{1,130} = 11.83$, $p < 0.001$), lab reports ($F_{1,130} = 6.12$, $p = 0.015$), midterm ($F_{1,130} = 6.04$, $p = 0.015$), and final exam ($F_{1,130} = 9.21$, $p = 0.003$) grades. No program difference was found for pass rates or success rates. In addition, significant format by program interaction was found for the overall grade ($F_{1,130} = 4.89$, $p = 0.029$). In particular, there was a F2F advantage over online for ME students, but an online advantage over F2F for IE students. Significant interaction was also found for pass rate ($F_{1,130} = 4.74$, $p = 0.031$) and the student success rate ($F_{1,130} = 7.17$, $p = 0.009$). An online advantage was observed in both pass rate and success rate for the IE students, yet no format differences were found for the ME students.

Table 3. Comparison of academic performance between Online and F2F (ME and IE students only)

	Online (n = 74)		**F2F (n = 60)**		**ANOVA results (p for each effect)**		
	Mean	**(SD)**	**Mean**	**(SD)**	**Format**	**Program**	**Interaction**
Overall Grade	**73.1**	**(12.0)**	**78.8**	**(13.2)**			
ME (n = 111)	73.9	(13.1)	80.9	(11.4)	0.812	**0.001**	**0.029**
IE (n = 23)	70.3	(6.2)	64.7	(16.3)			
Quiz scores	**66.8**	**(24.2)**	**71.2**	**(23.9)**			
ME (n = 111)	66.1	(26.7)	72.5	(23.4)	0.963	0.564	0.247
IE (n = 23)	69.5	(9.8)	62.5	(27.0)			
Lab reports	**77.5**	**(10.5)**	**82.7**	**(8.1)**			
ME (n = 111)	78.0	(9.9)	83.9	(4.9)	0.216	**0.015**	0.171
IE (n = 23)	75.5	(12.9)	75.2	(17.3)			
Midterm exam	**74.9**	**(13.0)**	**79.5**	**(13.0)**			
ME (n = 111)	75.3	(14.3)	81.2	(11.5)	0.869	**0.015**	0.074
IE (n = 23)	73.3	(5.9)	68.3	(16.9)			
Final Exam	**71.7**	**(16.7)**	**78.3**	**(18.4)**			
ME (n = 111)	72.7	(17.5)	80.7	(16.1)	0.864	**0.003**	0.095
IE (n = 23)	66.9	(12.0)	60.4	(25.6)			
Pass rate	**96%**		**98%**				
ME (n = 111)	95%		100%		0.360	0.360	**0.031**
IE (n = 23)	100%		88%				
Success rate	**91%**		**87%**				
ME (n = 111)	88%		90%		**0.019**	0.282	**0.008**
IE (n = 23)	100%		63%				

6. End-of-Course Survey

An end-of-course survey, adapted from Russell [17] was conducted in the last three weeks of lectures, which gathered student feedback on their experience. Table 4 gives the mean responses from the end-of-course survey. These results show that the student experience was generally positive, with only minor differences in general satisfaction levels between the two lecture modes. In terms of levels of satisfaction, it is noteworthy that the students in the online course would recommend this format to their friends more strongly than the F2F students.

As part of the end-of-course survey, students were asked to provide written comments on three aspects of the course that they liked most, as well as three improvements they would like to see. The most common responses have been grouped by general subject category for the online sections in Tables 5 and 6. The students in the online course liked the flexibility of the video lectures. The ability to pause and re-watch sections of videos, and the option to work at one's own pace, were common themes in the comments from the online students. Flexibility in time and location was also seen as an advantage of the online format. In a previous study of this online course [18], we found that the video lectures are watched over the entire day, with view-

Table 4. Mean responses from the end-of-course survey of student feedback (based on a Likert scale of 1 to 5, with 5 being strongly agree and 1 being strongly disagree)

Question	Online (n = 80)	F2F (n = 54)
1. This course taught me how to arrive at appropriate answers.	4.19	4.35
2. The course resources effectively conveyed information to be learned.	4.44	4.41
3. The course took considerations of my needs and concerns.	3.86	3.75
4. I spent more time or effort to study this class than average due to the class format (online or in class).	3.05	2.91
5. Overall, I am satisfied with my learning experience in this course format (online or in class).	4.30	4.26
6. I will likely take more courses in this format (online or in class) in the future.	4.29	4.50
7. I will recommend my friends to take this course in this format (online or in class).	4.40*	4.11*

* Significantly different at p = 0.05 level in t-test.

Table 5: Most common responses of the online students when asked what they ''liked'' about the course

Online Student "Likes"	Number of similar comments
Ease of access/Learning environment	
Video format allows for pause, rewind, slow/fast, and repeat	30
Can study at one's own pace	25
Flexible study schedule	24
Flexible study location	15
Course material is always accessible, allows studying ahead	13
Course Content	
Quizzes make sure one is up to date and understands material	12
Clear layout of course material/website	9
Videos explain concepts in detail	7
Videos were well recorded	7
Videos provided helpful demonstrations	6

Table 6. Most common responses of the online students when asked what improvements they would like to see in the course

Online Student "Dislikes"	Number of similar comments
Course Content	
Need more practice problems to prepare for midterm or final	17
No midterm review video	4
Remove labs or have virtual labs	4
Support	
No office hours to ask questions*	8
Should offer tutorials	4

* The instructor had two traditional office hours per week, available to the online students.

ing peaking at about 8pm. Several of the online students indicated that they would prefer virtual labs, rather than a hybrid course.

7. General Discussion

A series of statistical analyses were performed on the students' grades in common course assessments. The students' academic program (ME, IE) was found to have the most influence on academic performance. On average, IE students performed poorly relative to ME students. This result could be partly explained by differences in curriculum requirements for students from the two programs. The topic of fluid mechanics is more relevant to the professional practise of mechanical engineering than industrial engineering. Furthermore, fluid mechanics is not a prerequisite for any subsequent courses in the industrial engineering program. In contrast, ME students require fluid mechanics knowledge for several other core courses, including a second course in fluid mechanics. For these reasons, it is likely that the average IE student is less motivated than the average ME student, regardless of the instructional format. In addition, ME students also take a course in applied thermodynamics at the same time as *MEC516*, which is not part of the IE program. Thus, ME students have more familiarity with the thermo-fluid applications that arise in *MEC516*, which may also provide some academic advantage.

The effect of the mode of instruction on performance was mixed and depended upon what was being assessed: the mean grades of lab reports, exams and final scores were higher in the F2F group than in the online group; on the other hand, the overall success rate was higher in the online group than in the F2F group. However, it is important to consider the difference between IE and ME students and pay special attention to the format by program interaction revealed by the ANOVA results: the F2F advantage was exhibited in the ME students whereas the online advantage was exhibited in IE students. Directly opposite patterns were observed in the two different programs. These results raise some intriguing questions: Why do we see better performance for IE students with online lectures compared to F2F instruction, but the opposite is true for ME students? Based on the in-class experience of the instructor, it is likely that IE students have a poorer attendance record at F2F lectures than ME students, in part because of the lower professional relevance of the course. When the F2F students missed a lecture, they could only self-study or rely on the practice material (i.e., textbook or practice problem sets) to learn the missed course content; however the online students could review the course material at their own pace without the risk of missing out on course content. Self-awareness of the tendency to skip traditional lectures may also partly explain the high percentage of IE students who opted for the online mode (as shown in Table 1). Unfortunately, as no measure of attendance was implemented in the F2F sessions, this speculation could not be supported by empirical data in the current study. One caveat is the disproportionately small percentage of IE students who took the F2F version of the course. As displayed in Table 3, only 63% of IE students reached success (at least C- in final grade), which is exceptionally low when compared to the other groups. However, it is important to note that there were only 8 IE students in this category and a few outliers could have a dramatic impact on the mean scores in this group. Due to the low sample size, we could not afford to remove the outliers from the analysis. The speculation of low motivation and absence from F2F lectures may be only valid for students involved in this study and we could not yet make any conclusive generalization to all students enrolled in the IE program.

When the two programs were collapsed together, it appears that the result on overall grades did not replicate the Shachar and Neumann meta-analysis [10] as well as several other recently published meta-analyses [19, 20] comparing online instruction with traditional face-to-face instruction, all of which reported that students performed better in online format than in the traditional face-to-face format. We speculate that the contrasting results may be rooted in the fundamental differences in curriculum. The majority of the studies included in the meta-analyses were for courses from the social sciences or entry-level courses. In these kinds of courses, a heavy emphasis is placed on understanding and memorizing concepts and principles. In contrast, Fluid Mechanics I require students to be able to understand and utilize complex formula in order to compute and solve problems, in which hands-on experience with problem solving is crucial. When problem solving was demonstrated in the F2F lectures, students could ask questions and get direct feedback during (or immediately after) the lecture, whereas the online students could only passively receive the knowledge from video lectures. This speculation could be supported by student feedback as reported in Table 6: the online students felt that they needed more opportunities to solve practice problems and more office hours to ask questions. Although physical office hours were offered to the online students, the lag between the time they had a question from the video lectures and the time that they receive the answer would be

extended, putting them at a disadvantage in fully understanding the material. This explanation echoed the results from Todd et al. [20], which found that instructional contents were better delivered using online teaching, yet process-based or skill-based content was better delivered in face to face format.

8. Conclusion

An undergraduate course in introductory fluid mechanics was offered in online and traditional lecture modes by the same instructor to students in three engineering programs. The student assessments (quizzes, labs, midterm and final exams) were common for both groups of students. This study observed an overall F2F advantage over online instruction in the students' academic performance. An interesting course format by student program interaction was observed as well. It appears that for IE students, for whom the fluid mechanics course was not related to future studies, the online course was more beneficial to them achieving success than the F2F format. The pre-course survey showed that online and F2F students were not statistically different on several measures that could affect academic performance (course load, hours of employment, etc.). A post course student survey demonstrated a generally high level of student satisfaction in both instructional modes. The students in the online course particularly liked the flexibility and convenience of asynchronous video lectures. The ability to pause and re-watch sections of videos was identified as a positive feature. The students who chose the F2F lectures liked the classroom environment and identified the in-class demonstrations as a positive feature of the traditional lecture course. These findings provide novel insights into the understanding of online and F2F teaching and their impact on students' academic outcome.

These are several limitations of this study. First, due to the lack of a lecture attendance measure in the F2F group, the speculation about the poor performance of IE students could not be supported by empirical evidence. A future study may consider implementing a measure of attendance, such as asking in-class questions that requires students to respond with "clickers". In addition, the current study includes students from various backgrounds that may impacted their existing knowledge about the course content and their motivation to succeed in this course. Future study may aim to focus on these factors and examine how they would impact study outcome in online and F2F courses. For instance, would online and F2F courses result in different study outcomes in required courses versus optional courses? Would forced assignment of the course format generate a different outcome compared to when students freely choose either format?

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