

A Comparative Analysis of Student Performance and Face-to-Face Engineering Courses

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A COMPARATIVE ANALYSIS OF STUDENT PERFORMANCE IN ONLINE AND FACE TO FACE ENGINEERING COURSES

In March 2020, all courses in the College of Engineering (CoE) at a large Southwestern university were forced to rapidly migrate to an online or remote teaching/learning environment in order to mitigate the effects of the COVID-19 pandemic. This rapid change in teaching and learning modalities caused disruptions in the learning cycles which led to the development and adoption of mitigation strategies. In almost all cases, the faculty made the choice of transitioning to fully online or remote teaching while the courses varied in quality. Initial data from the Spring 2020 semester were mixed, with students indicating a range of satisfaction in their experiences with online learning. With the understanding that the Fall semester and potentially the future year may require the use of alternative modalities of teaching, the CoE identified high enrollment courses and supported the development of fully online courses.

This study will examine the differences in performance between students in online, remote and face-to-face courses. In addition, this study will examine the differences in performance between students in courses influenced by deliberate instructional design processes vs. students in courses not influenced by deliberate instructional design process. Thirdly, this study will examine how students perceive their efficacy in online, remote, and face-to-face courses. Lastly this study will examine to what degree student self-regulation of academic practices and behaviors influenced performance.

The institution has adopted three modes of course delivery. Their definitions are given below.

Face-to-Face (F2F): A course where the interactive lectures and student interactions happen dominantly in a physical classroom space. Assessments may include in-class exams or equivalents thereof. A traditional course delivered in a classroom is an example of this course.

Online Course (OLC): A course that is carefully planned and pre-built in a learning management system or equally appropriate platform. Course content (lectures, readings, supporting materials) has been developed before the start of the semester. The course contains student-student, student-content, and student-instructor interactions. Assessments are delivered fully online.

Remote Teaching Course (RTC): A course that uses technology tools to achieve the same delivery systems as a face-to-face course. The course may be delivered in a classroom or from home using live synchronous lecture capture or asynchronous lectures delivered just-in-time. The course contains student-student, student-content, and student-instructor interactions. Assessments may be delivered fully online or using remote methodologies.

I. BACKGROUND

Despite all current knowledge around student satisfaction in higher education, researchers point out much remains unknown. The effects of the specific course elements, individually and collectively, when designing a course are not fully understood [1]. The multiple factors

surrounding the achievement of the learning outcomes can be related to several areas such as environment, learner aptitude, and course design elements [2]. The distinct effect specific to student engagement and learning strategies could potentially contribute to student satisfaction [3].

Studies have shown faculty reluctance to accept online learning as a valid modality of teaching and learning. Additionally, as recently as the spring of 2020, surveys identify a strong belief among faculty that online courses will lead to lowered student performance [7]. This disdain of the online experience is exacerbated by students' lack of confidence, insufficient support, poor course design, inadequate feedback, and lack of instructor presence in the online learning environment [8]. Shen [9] noted self-efficacy as the critical component for success in an online course. In a recent study of online computing courses, Kreth [10] found students with prior online learning experience actually possessed lower self-efficacy. The result may indicate the trait does not have a progressive effect.

Previous studies have shown that faculty who have a high degree of help in instructional design and development of their online courses demonstrate better course outcomes [4]. So, the college made the decision to provide faculty with substantial support in course design and development [5]. Academic departments identified the courses for development and selected faculty to collaborate with the CoE's internal instructional design group (IDG) to build online courses. The face-to-face courses experienced a deliberate design process of learning outcome examination and current content identification in preparation for the online transition. These interactions resulted in the creation of a course map. The course map laid the groundwork to achieve the desired learning outcomes in a stepwise manner aligned to the course timeline. In addition, this process of course mapping identified opportunities for learning interactions, content type, and materials needed for course building, and formed an essential cornerstone of a deliberate design model [6].

II. PURPOSE

The purpose of this mixed-method, exploratory case study was to examine the differences in performance between students in courses offered in different modalities (online, remote and face-to-face) and deliberately designed online undergraduate Engineering courses and their counterpart sections in face-to-face and other delivery modes, at a Tier I research university in the Southwestern United States. Chaney [11] and Lee [12] recognize that most engineering courses' highly technical subject matter can be challenging and amplify the need for intentional course design. The curriculum structure is imperative to satisfaction and academic achievement [13], [14], [15]. With the widespread applicability of this mixed-method, exploratory case study to other courses within the engineering domain, new insight into a framework of course design can be identified and explored. The study can be shared with instructional designers and professors for suggestions on course design. Therefore, a study examining the effect on student performance related to course design is well supported by the literature [12], [14], [16].

A. Specific Aims / Research Questions:

This analysis is centered in the following four research questions:

1. Is there a difference in student performance, between students in online courses vs. students in remote and face-to-face delivery modes?
2. Is there a difference in student performance, between students in courses influenced by deliberate instructional design processes vs. students in courses not influenced by deliberate instructional design process?
3. How do the students perceive their efficacy in online, remote, and face-to-face courses?
4. What are the self-regulatory characteristics of students in online, remote, and face-to-face courses?

Some courses that were expected to be offered as online courses were instead offered as remote courses. This resulted in a sample size disparity for statistical comparison of modalities.

III. METHODOLOGY

This study takes a quasi-experimental, nonequivalent group design to evaluate student performance in different modes of course delivery, the effectiveness of deliberately designed online courses versus courses offered in other delivery modes, and the relationship of metacognitive and self-regulatory factors on student performance.

Question 1 seeks to examine student performance equivalency among different modes of course modality. To answer this question, we will compare grade distributions across the three groups (F2f, OLC, RTC). A one-tailed t-test will be used to compare the grade distributions across the study pairs.

$$t = (x_1 - x_2) / (\sigma / \sqrt{n_1} + \sigma / \sqrt{n_2}), \text{ where}$$

x_1 = mean of sample 1

x_2 = mean of sample 2

n_1 = size of sample 1

n_2 = size of sample 2

x_3 = mean of sample 3

n_3 = size of sample 3

Similarly, Question 2 seeks to examine student performance equivalency among courses that differed in their design processes. To answer this question, we will compare grade distributions across two groups (IDG vs non-IDG). A one-tailed t-test will be used to compare the grade distributions across the study pairs.

Grades which have been traditionally used as a proxy for learning outcomes have been shown to be an imperfect measure [28]. Research questions 3 and 4 seek to examine perception and roles of metacognitive and self-regulation factors in online, remote, and face-to-face courses.

Understanding that grades may not be the best indicator of learning outcomes, we administered a metacognitive test using questions gleaned from the Self-Assessment of Learning Gains (SALG) inventory. The SALG has been developed specifically to measure the degree to which the course has affected student learning as self-reported by the student. This instrument was administered once towards the end of the semester. The data were analyzed to provide qualitative insight into student self-assessment of learning, and identify key elements of course design that helped with learning. Research studies have pointed out the critical role student self-regulation plays in academic success [1], [17]. Self-regulation surfaces as a crucial factor in online courses since time management and planning, which is a feature of face-to-face courses, are removed in the asynchronous online courses. A survey instrument was derived from the work by Chen [1] regarding satisfaction and asked students questions about their study environment, their planning strategies, and learning fluency. Positing those students scoring high on the self-regulatory scale will have better grades, we have chosen Pearson's R as an indicator of the relationships between the scales.

IV. PROCEDURES

A. Course Design Process

Once the CoE made the decision to invest in the design and development of high quality fully online courses, a call was issued to the department heads to identify courses with relatively high enrollments for inclusion in the deliberate design process with our instructional design group, thus maximizing the potential impact of this investment of monetary and human capital. Faculty who were determined by their academic department to be subject matter experts in the subject of the course were identified for each set of courses (typically same course, multiple sections) and connected with learning designers in the IDG to form a development team. The design followed a generalized schematic outlined below.

1. Align course learning outcomes across sections and develop agreement across the team on content.
2. Create a course map aligning outcomes to learning and assessment strategies.
3. Develop content with faculty serving as subject matter experts with an overlay of learning design.
4. Assemble courses based on the course map.
5. Test courses for technical functionality.
6. Release course for enrollment.

This process aimed to ensure content alignment and uniformity of the learning experience while leaving room for each faculty member to align the course to their teaching style.

B. Subjects

The population was derived from courses across five different departments in CoE and represent an approximate enrollment of 3000 students in the Fall 2020 semester. Course sections were selected from departments that participated in an online course development program. The homogeneous, purposive sampling typically relies on a sample size related to saturation [18]. The population was engineering students between 18 and 65 years of age. The choice of participants in this study was purposive [19].

Students in each course section received an electronically submitted questionnaire of multiple-choice, Likert-type responses and one open-ended question designed to gather responses on a variety of topics, including course satisfaction, metacognition, and self-regulatory factors.

TABLE I
DEMOGRAPHICS OF RESPONDING POPULATION (N=180)

CLASSIFICATION		
	Freshman	0.56%
	Sophomore	37.22%
	Junior	42.22%
	Senior	20.0%
GENDER		
	Male	62.2%
	Female	35.46%
	Other/No response	0.5%
ETHNICITY		
	Asian, non-Hispanic/Latino	14.44%
	Black or African American, non-Hispanic/Latino	0.56%
	Hispanic/Latino	22.22%
	Race and/or ethnicity unknown	0.00%
	Two or more races, non-Hispanic/Latino	5.00%
	White, non-Hispanic/Latino	57.78%

V. ANALYSIS

A. Comparison of performance in Online vs. Remote vs. Face-to-face Courses

Some courses that were expected to be offered as online courses were instead offered as remote courses. This resulted in a sample size disparity for statistical comparison of modalities.

Courses in this study were grouped and labeled by the mode in which they were offered. As defined above, the three modes offered were Face-to-Face, Remote, and Online. Analysis of the data identified a statistically significant relationship between Delivery Mode and Grade.

There was a notable disparity between the number of student respondents in each group. The sample sizes included 141 respondents registered in courses offered to students as Remote (n=141), 31 in courses offered as Face-to-Face (n=31), and only 13 respondents in courses offered as Online (n=13). The average Grade Point Average (GPA) was highest in courses offered as Face-to-Face with a GPA of 3.38 on a scale of 0 to 4.0. The average GPA in courses offered as Online was 3.10. Courses offered as Remote showed the lowest average GPA of 2.96. The p value indicates that modality of instruction played a non-trivial role in student performance. Because of the large disparities between the respondent sizes in online learning courses vs other modalities, we were unable to run statistically significant tests.

TABLE II
COMPARISON OF REMOTE VS. FACE-TO-FACE OFFERINGS

ANOVA	
P-Value	0.0000113
Effect Size (Cohen's f)	0.352

Summary					
Group	Average	Median	Sample Size	Confidence Interval of Average	Standard Deviation
Face-to-Face	3.38	3.5	31	3.23 to 3.54	0.42
Online	3.10	3.1	13	3.10 to 3.10	0.00
Remote	2.96	3.0	141	2.88 to 3.04	0.47

Pairwise Tests					
Group 1	Group 2	Difference in Averages (1-2)	Confidence Interval of Difference	P-Value	Effect Size (Cohen's d)
Face-to-Face courses	Remote courses	0.42	0.25 to 0.59	< 0.001	0.91

B. Influence of Instructional Design on Student Performance

Research shows that instructional design can at times have an impact on course performance. Even understanding that design is just one of the factors that play in student

performance, it was useful to examine the effects of design on course experiences. Even though all the courses that went through formal design to be converted to fully online courses were not offered as online, the different elements that were produced were used by most faculty to support their courses. For this study we grouped courses that were designed in collaboration with the IDG together irrespective of the modality of their offering and the second group comprised of courses that had not been worked on by the IDG. It was observed that the design influenced courses showed a overall higher GPA than the untreated courses.

TABLE III
COMPARISON OF INFLUENCED AND NOT INFLUENCED DESIGNS

Summary					
Instructional Designer Influence Groups	Sample Size	Median GPA	Average GPA	Confidence Interval	Standard Deviation
Influenced	131	3.1	3.14	3.07 to 3.21	0.41
Not Influenced	54	2.7	2.79	2.64 to 2.93	0.53

Analysis of broad course (N=18) design elements used in designed vs. Non designed (N=11 for designed and 7 for non-designed from a total of 23 courses) courses show that the designed courses tend to use active learning techniques and teamwork vs. the non-designed courses that show a lower use of teamwork.

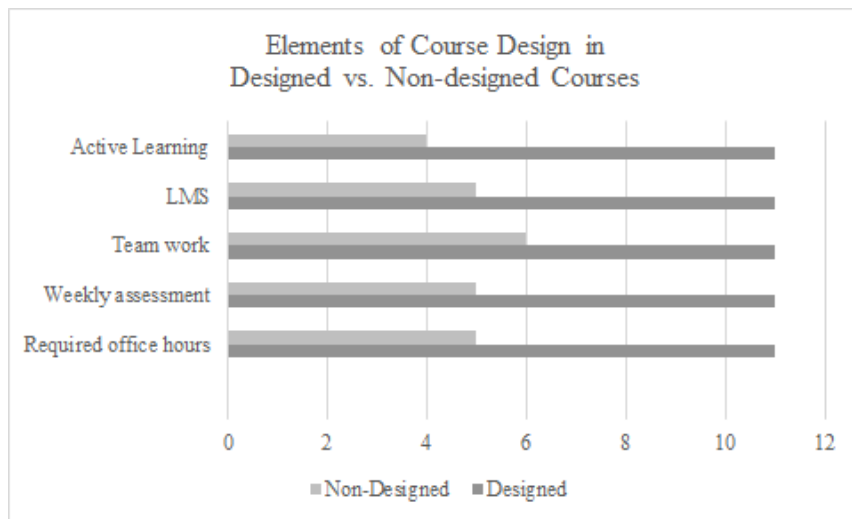


Fig. 1. Comparison of elements in designed vs. non-designed courses.

C. *Student Self-Perceptions of Efficacy in Online, Remote, and Face-to-Face Courses*

Students of this study engaged in courses presented in face-to-face, online, or remote modalities. Question 24 of the SALG asked all participants, regardless of course modality, “How has this class changed the way you learn/study?” Participants were not required to answer this particular question. However, 59 of the total 180 participants (7 - face-to-face, 4- online, and 48- remote) chose to respond.

Through a comparative approach (as seen in Table IV), analysis was conducted by designating codes from the individual responses in each course modality group. Emergent ideas were allowed to develop and grow in meaning and proceed to a collective response. Ideas and concepts that were shared by multiple participants were coded into themes and pursued to the point of saturation.

Face-to-Face (F2F): No single response was duplicated by any of the respondents. These learners responded mostly negatively with responses regarding the additional study time, lack of motivation, loss of grades, a decrease in writing quality, and increased rigor. Also mentioned was a feeling of being overwhelmed with “no chance of getting a good grade.” On the positive side, these students remarked about an improved way to learn and the utilization of many outside resources as necessities in this modality.

Online Course (OLC): The comments replicated most often reflected a feeling of detachment and isolation, as well as a feeling of being on their own and learning by themselves. Similar to responses in the face-to face modality, these learners also provided a majority of negative comments stating that the courses were more rigorous and required additional time for studying. Additionally, respondents believed they “learned a lot less” and faculty were viewed as restrictive with limited access and delayed feedback. The social aspects of teamwork appeared to be stressful due to the lack of face-to-face engagement in a live environment.

Remote Teaching Course (RTC): Dominant themes of these students, while primarily negative, mirrored most closely the online course modality. Students felt they learned a lot less and were detached while learning on their own with no support. Many felt that their study habits were negatively altered with less motivation and a reduced sense of enthusiasm. Respondents felt ill prepared with no study groups, lowered grades, and decreased time to complete class work. These students remarked that they believed the “class experience was less about learning.” Though the students did not identify what they believed was the focus of their courses. Similar to face-to-face students, they agreed the course necessitated the use of many outside resources. Adapting to this modality, students began assignments early if possible and some stated that the review of material was easier and readily accessible in this modality.

TABLE IV

COMPARISON OF THEMES AND MODALITIES

Theme	Face-to-Face	Online Course	Remote
Additional study time	X	X	
Increased rigor	X	X	
Learned a lot less		X	X
Faculty was restrictive		X	
Delayed feedback		X	
Teamwork was stressful		X	
Felt detached /isolated		X	X
No support			X
Study habits negatively altered			X
Less motivation/enthusiasm	X		X
Plummeting grades	X		X
Decreased writing quality	X		
Feeling overwhelmed	X		
Used many outside resources	X		X
Improved way to learn	X		
No study groups			X
Decreased time to complete classwork			X
Class experience was less about learning			X
Began assignments earlier			X
Material was easy to review			X

D. Influence Self-regulatory Factors in Online, Remote, and Face-to-Face Courses

The authors sought to learn more about the self-regulatory characteristics of students in online, remote, and face-to-face courses.

Students were asked “Before this semester, have you ever taken any fully online, Web-based course.” Of students in the online group, (n=12), 100% stated that they had, while only 67.9% of respondents in the remote group stated that they had, and 63.3% of the face-to-face group had taken a fully online course before this semester. While the numbers varied slightly, there was no statistically significant difference between delivery mode for this question.

Students were also asked to select among choices describing their personal study environment where they most often read, did their homework, listened to recorded lectures, etc. Analysis indicated that for students this study, there was no significant difference in the study environments of the three delivery modes. Furthermore, students predominantly reported that their study environments were usually or always quiet, comfortable, in a consistent location, and free from distractions. In face-to-face courses, 86.4% of students reported that their study environments were usually or always quiet, comfortable, in a consistent location, and free from distractions. For students in online courses, 88.9% reported the same, while in remote course, the percentage was 79.5%.

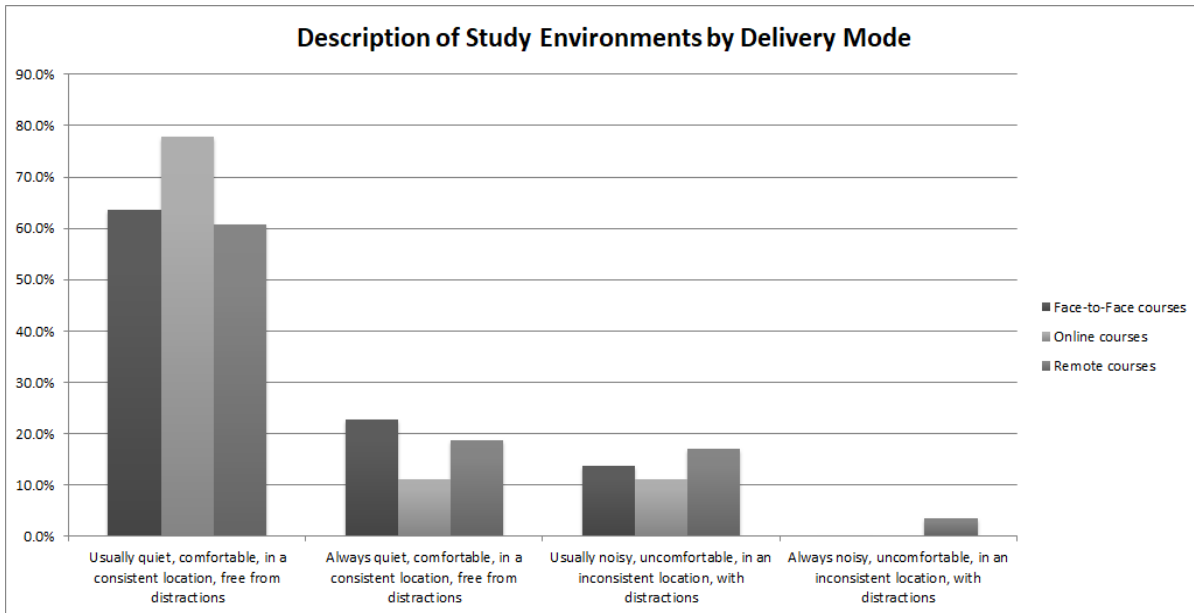


Fig. 2. Comparison of study environments and course modality.

Students were asked about the amount of time they spent working to complete homework and assignments each week. In face-to-face courses, 82.6% of students reported spending at least 4-6 hours per week working on homework and assignments. In online courses, 88.9% of students reported the same while in remote courses, the percentage of students reporting spending at least 4-6 hours per week working on homework and assignments was 77.7%. Analysis indicated that for students in this study, there was no significant difference in the amount of time the students spent working on homework and assignments between the three delivery modes.

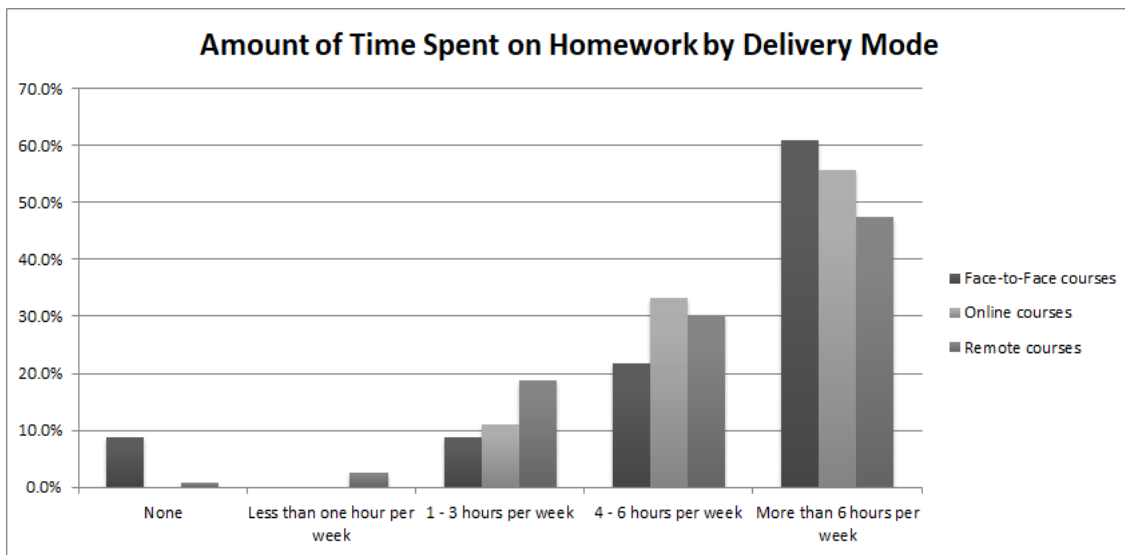


Fig. 3. Comparison of time allotment for homework and course modality.

Students were also asked about the amount of time they spent watching recorded lectures each week. In face-to-face courses, 60.9% of students reported spending at least 1-3 hours per week watching recorded lectures. In online courses, 66.7% of students reported the same while in remote courses, the percentage of students reporting spending at least 1-3 hours per week watching recorded lectures was 64.3%. Analysis indicated that for students this study, there was no significant difference in the amount of time the students spent watching recorded lectures between the three delivery modes.

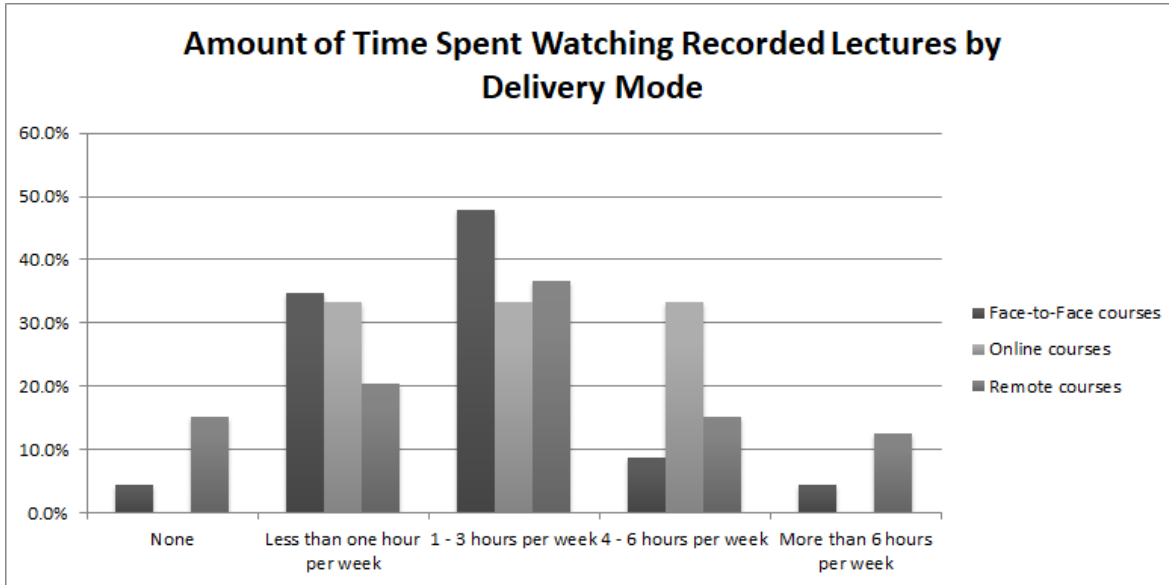


Fig. 4. Comparison of modality and recorded video viewership.

VI. DISCUSSION

Comparison of student performance in different modalities: While the broad disparity was unexpected given that students were not required to attend F2f classes, and most courses had varying degrees of attendance ranging from 10-60% with students mainly attending the class remotely, this result points to the importance of student agency in being able to choose a modality and environment they can learn in. It is interesting to note that the F2f courses were really more like remote courses, but even then, the students showed a higher proclivity to scoring these courses higher on a satisfaction scale. Another possibility is the role of faculty comfort and influence in student learning. Faculty in the F2f courses were in classroom spaces they were comfortable in vs. in remote courses where they were either providing lectures from their offices or homes, which may not have been set up as the best environments for teaching. Further study of this phenomenon will be carried out in the follow-up study.

Comparison of course performance in designed vs. non-designed courses: Aggregate grade data comparisons between courses that had undergone a formal design process as compared to courses that had not undergone a formal design showed that the designed courses

irrespective of the modality of delivery where faculty used the developed elements of courses for support showed a higher overall GPA than courses that had not gone through a design process. Comparison of design elements seems to indicate that the use of active learning strategies and frequency of assessments may play a role in enhancing student performance. All faculty who partook in the formal course design were introduced to ideas of formal instructional design to include course mapping, refining course outcomes, outcomes alignment and good evidence based practices in design and student engagement by IDG staff. This engagement in formal design and introduction to evidence may have affected the adoption of active learning strategies and tools. Further study is needed to conclusively make connections between the faculty adoption of design strategies as they related to designed courses.

Student perceptions of self-efficacy in different modalities: While study participants in the three modalities shared two or three commonalities of the 20 themes, the data sets were greatly offset in number. Recognizing that not all students provided at least one response to the open-ended qualitative Question 24 of the SALG, some inferences can still be constructed for consideration. While the similarities of the online and web modalities appear to be most homogeneous, this similarity did not necessarily produce uniformity of the same themes. Overall, all modalities yielded predominantly negative comments about the learning experience. Considering that most participants had previously learned in the face-to-face modality, detachment and isolation was expressed solely by those in online and web-based courses. The lack of social interaction common in the face-to-face courses was void in the other modalities and likely added to the feeling of learning less and needing to access outside resources.

Loss in final grades were concerns of students in the remote and face to face modalities, providing indication that at least some of the prior online experiences or perceptions of online courses were less than optimal. Some courses may have provided insufficient information, resources, and assurances. Study habits were affected for all students, however students in the remote courses remarked most positively about beginning assignments earlier which can reduce procrastination and stress. Additionally, the remote students found the course content easy to review. This may be due to the increased use of video and other multimedia elements in these courses.

Student self-regulatory factors: For this current study, there appeared to be no significant differences in the self-regulatory factors between the online, remote, or face-to-face groups. Regardless of the mode of delivery in this study, each group had significantly the same percentages of students who had previously taken an online course. In addition, students in this study appear to have practiced the same degree the self-regulatory behaviors such as amount of time spent watching recorded lectures and time spent completing homework and assignments. Further, there appears to be no significant difference in the students' personal study environments between the three delivery modes. Given these findings, it is reasonable to conclude that any differences in student performance among students in this study were likely not due to self-regulatory factors.

VII. LIMITATIONS AND FURTHER STUDY

This study was limited by the fact that dynamic scheduling scenarios means that courses that were planned for online, remote and face-to-face offering at the start of the study were necessarily offered in the format that they were designed for. This resulted in disparities in sample sizes across the different modalities. In addition while portions of the instrument were derived from other validated sources, the entire instrument was not validated for reliability criteria before the start of the study. Thus, the results of the study are limited in terms of their generalizability beyond the study's sample characteristics. Future research conducted would look to create a validated instrument which will be administered in a future study. In addition, a faculty survey and observational analysis of methods used in courses is needed to identify specific course design elements that may have a broader effect on student performance. Future work will expand upon the findings of this study and replicate with identifying population demographics which could produce findings to be generalized to a larger population. In addition, studies will perform discriminant analysis to identify key discriminating factors that lead to improved student outcomes.

VIII CONCLUSIONS

The findings of this study have identified areas of consideration worthy of further research. The research reinforces the value of collaboration between faculty and instructional designers by the fact that students performed well in courses irrespective of modality with engagement in instructional design possibly being a differentiating factor. The use of active learning strategies and deliberately planned student-student interactions can also mitigate the isolation that can be felt in technology enhanced and online courses. In addition, assessments can play a significant role in providing students continuous feedback which can serve as an engagement mechanism rather than just a measure of learning.

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