Online Synchronous Delivery of Environmental Engineering During COVID-19 Pandemic: A Case Study on Assessment

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Abstract

Online synchronous/asynchronous/hyflex delivery of courses is a time-demanding approach to web-based teaching and learning systems that is designed to engage students in investigations of authentic concepts/problems without coming to the pre-set classrooms two or three times a week. This paper presents the assessments of students' performance in environmental engineering for hybrid delivery mode and then suddenly converted to an online synchronous delivery mode due to COVID-19 pandemic. The course, `Introduction to Environmental Engineering', was developed as an on-line course for Civil and Environmental Engineering program students but taught as a face-to-face course and as a hybrid for several semesters. In the hybrid course set up, all the quizzes and homeworks were online while the midterm and final exams were in-class. However, for Spring 2020, the final exam was online, for Summer and Fall 2020 both midterm and final exams were online due to COVID-19 adjustment. Although it could not be confirmed by statistical analysis of the final exam scores, weighted average GPA, and the overall course grades, the online synchronous delivery approach seemed to degrade the levels of students' performance to some extent. Additionally, it could be somewhat concluded that online synchronous delivery approach apparently did not maintain the same levels of students' performance.

Keywords
Environmental engineering, COVID-19 adjustment, online synchronous/asynchronous course offering, performance assessment.

Introduction
Online and internet-based teaching and learning is becoming necessary and popular that was a dire need during pandemic and other unavoidable circumstances. The relatively recent advent of Learning Management Systems (LMS), such as blackboard, eCollege, Moodle, and WebCT and offering the lectures via MS Teams, Zoom and other platforms in the undergraduate setting in educational institutions has made it easy to provide on-line user education, that is, web-based augmentation to traditional (face-to-face) classroom instruction[1]. This online, hybrid, HyFlex (hybrid-hyflex) or other mixed delivery approach lets instructors combine the advantages of online class learning with the benefits of face-to-face interaction with relatively limited technological sophistication on their part[2]. The addition of a hybrid/on-line approach to the existing in-class lecture-centric environmental engineering course would not reduce the quality of teaching and learning as well as would be welcomed and well received by students[3,4]. Preliminary reports suggest that the hybrid approach holds significant benefits for students and instructors, regardless of their level of technological expertise[4,5] and regardless of whether the classroom is hard-wired for live Internet access[6]. Despite frequent use of an LMS for course administration purposes (content and lecture delivery), the faculty do not appear to be harnessing the full pedagogical

potential of web-based augmentation via LMSs[6]. The possible potential of LMS tools along with other on-line and mobile technology flatforms to increase course administration/lecture delivery efficiency and enhance learning in traditional settings is an important educational issue that must be fully explored from both faculty and student perspectives[7,8,9]. However, combining multiple modalities (lecture videos, pdf files, etc.) of on-line content with a *pot pouri* of in-class learning exercises that appeal to several learning styles may precipitate higher overall learning outcomes[10].

This study was designed mainly to answer a question: Is there any effect of course delivery approach changes due to COVID-19 pandemic in students' performance levels? To answer the above question, an objective was formulated to see the effect of COVID-19 change in the students' performance levels. The objective was accomplished with statistical analyses of final exam scores, weighted average GPA, and the overall course grades. In author's opinion, although teaching hybrid or online courses may increase time demands and, in some cases, result in a loss of control, many faculties enjoy this approach because it allows for significant flexibility and benefits in instruction. Due to COVID-19 in March 2020 the face-to face course delivery options had to change to online synchronous and all the exams had to administer online. The overall goal of this study was to assess the effect of COVID-19 pandemic on students' performance level and to compare the performance levels between hybrid and online synchronous course delivery options.

The terms Face-to-face, Hybrid, HyFlex (hybrid-flexible), and Online synchronous/asynchronous have been used in this manuscript. The following definitions of the terms are provided for clarification.

Face-to-Face - A traditional higher education **course** that occurs with the learner and the instructor physically located in the same place at the same time[1]. A **course** in which zero to 29% of the content and instruction is delivered online[2]. A **course** which delivers at least 80% of its content in person[3].

Hybrid - A hybrid approach to course delivery combines face-to-face (less than 80%) classroom instruction with online (more than 20%) activities. This approach reduces the amount of seat time in a traditional face-to-face course and moves more of the course delivery online. During classroom instruction time, students can be engaged in authentic, collaborative learning experiences. The online components can include multimedia-enhanced content and channels for ongoing discussion. The best practices and resources on this site will primarily focus on hybrid courses that utilize classroom sessions with or without a video conferencing component[4].

HyFlex - Short for "hybrid flexible", HyFlex learning is a variation of the hybrid programs we have come to know. It includes in-person, synchronous online *and* asynchronous online options for every course. According to Dave Lungren, vice president of content solutions at College Education, universities have an opportunity to evolve into the University of Tomorrow through the flexibility offered by this modality[5].

Online synchronous/asynchronous - Both are **primarily delivered online, accessible via online course modules** from your own computer or laptop. Both could be completed from anywhere.

[1] Learn more in: Promoting Digital Teaching and Learning: Faculty Development Options for Distance Learning Instructors

[2] Learn more in: The Relationship between Individual Student Attributes and Online Course Completion

[3] Learn more in: Doctoral Student Experiences in an Online Degree Program: A Review of the Distance Education Literature and an Exploration of Their Perspectives

[4] https://sites.psu.edu/hybridlearning/what-is-hybrid/

[5] https://collegiseducation.com/news/online-learning/hyflex-course-model/

Both are flexible options, designed to help all kinds of different students earn their degrees on their own terms. Both synchronous and asynchronous learning options, in some cases, might even be offered by the same program. However, beyond that, they can be a little different. Synchronous learning is when classes **occur on set schedules and time frames**. Students and instructors are online at the same time in synchronous classes since lectures, discussions, and presentations take place at specific hours. All students must be online at that exact time in order to participate in the class. Asynchronous classes let students **complete their work on their own time**. Students are given a timeframe – it is usually a one-week window – during which they need to connect to their class at least once or twice. The good news is that in asynchronous courses, you could hit the books no matter what hour of day (or night)[6].

Intervention

Intervention simply means purposeful actions by a human agent to create and implement change[11]. As we all know that end of 2019 and early in 2020, a pandemic of coronavirus (COVID-19) broke out in China and then spread globally. In the USA, spring semester starts in January and ends in May. Due to public health advisory and presidential Corona virus taskforce guidance, the education institutions in the USA had to make several changes in the course delivery in order to limit the spread of COVID-19. Within two weeks of this advisory, the educational institutions had to come up with an approach that would meet the guidance (6-ft social distance, washing hands, and face covering) without interruption of education. Several options were thought out such as converting all the courses to 100% online, either asynchronous or synchronous. Asynchronous delivery calls for video recording of lecture sessions and posting them in LMS. Since all faculty were not trained to be online instructors, synchronous option was chosen, with some training sessions for the faculty how to use MS Teams, Zoom, or Blackboard Collaborate for online synchronous delivery platform. That is how our university ended up delivering all courses online synchronous since mid-March 2020.

It is the author's reflection and opinion that depending on the type of course, project-based or problem-based learning (PBL) option with alternative evaluations processes[12,13] can be introduced and implemented in a situation during COVID-19 or in the future semesters to maintain the levels of students' performance same as before COVID-19 era. Studies conducted by several researchers[14,15,16,17,18,19,20] elaborated the optimum group forming strategy, content design, effectiveness measurement, implementation framework, and other procedures for optimum learning that were acceptable to students and instructors. To maintain the quality of teaching and learning and level of students' performance same as before COVID-19 era appropriate courses have to be designed by closely following procedure and guidance available in the literature and offered them accordingly.

Study Methodology

The instrument used in this study was the final exam scores, weighted average GPA, and the overall course grades to assess the students' performance level and to compare the students' learning environment between hybrid and online synchronous delivery. The data collected and used to assess the performance levels was the final exam scores (maximum minimum, and average) and the overall course grades (Letter grades and weighted average GPA considering A = 4.0, B = 3.0, C = 2.0, and D = 1.0). F-grade was not included in the assessment as the students got F-grade

[6] https://www.elearners.com/education-resources/degrees-and-programs/synchronous-vs-asynchronous-classes/

when they stopped coming to the class or dropped after the deadline. The data was collected for Spring, Summer, and Fall 2020 as online/hyflex delivery and compared with Spring, Summer, and Fall 2019 as hybrid delivery. There was a total of 37 students enrolled in Spring 2019, 34 in Summer 2019, 35 in Fall 2019, 48 in Spring 2020 (2 sections), 33 in Summer 2020, and 27 in Fall 2020. Final exam scores, weighted average GPA, and the overall course grades were statistically analyzed and compared for hybrid and online delivery. The analysis of data was performed with simple statistics and with excel for Goodness-of-fit tests such as ANOVA, χ^2-tests, student *t*-Tests, and *F*-Tests, as necessary. The results of the data analysis are illustrated in the following section.

Results and Discussions

An assessment was performed based on the final grades for hybrid (Spring, Summer, and Fall 2019) and online/hyflex (Spring, Summer, and Fall 2020) delivery options and the data are presented in Table 1. As mentioned earlier that "F" grade is not included in the assessment. From the chi-square test, a *p*-value of ***0.1076*** was obtained which is greater than both 0.05 (α = 5%) and 0.01 (α = 1%). A χ^2-value of ***22.0060*** was also obtained. For a degree of freedom (DF) of 15, the critical values for χ^2 are 25.0 (for α = 5%) and 30.6 (for α = 1%). The *p*-value is greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and χ^2-value is less than critical values for both α = 5% and α = 1%. Therefore, null hypothesis cannot be rejected and concluded that "no significant differences in the semester to semester and between hybrid and online delivery options." This means, no significant differences could be observed in the semester to semester and between hybrid and online delivery options. The expected grades are estimated based on the total columns and total row values and the overall total. For example, expected grades for row 1 and column 1 = 35 x 46 /210 = 7.666 ≈ 7.67. The number of students enrolled and total in Table *1* may match as "F" grades are not reported in this study.

Table 1: Assessment based on final grades using Chi-square Goodness-of-fit test

Delivery Option	**Semester**	**Observed Grades**					**Expected Grades**				
		A	**B**	**C**	**D**	**Total**	**A**	**B**	**C**	**D**	**Total**
Hybrid	Spring 2019	7	17	8	3	**35**	7.67	15.83	8.83	2.67	**35**
	Summer 2019	10	14	7	3	**34**	8.04	14.01	9.65	2.30	**34**
	Fall 2019	9	18	5	1	**33**	7.80	13.60	9.36	2.23	**33**
Online (synchronous)	Spring 2020	9	13	22	4	**48**	11.35	19.78	13.62	3.24	**48**
	Summer 2020	7	16	8	2	**33**	7.80	13.60	9.36	2.23	**33**
	Fall 2020	4	17	3	3	**27**	5.91	12.21	6.81	2.06	**27**
	Total	**46**	**95**	**53**	**16**	**210**	**46**	**95**	**53**	**16**	**210**
p-value = 0.1076; χ^2-value = 22.0060; DF = 15, χ^2-critical = *25.0* (for α = 5%) and 30.6 (for α = 1%)											

Another assessment was performed based on the weighted average GPA for hybrid and online delivery options and the data is presented in Table 2. From the chi-square test, a *p*-value of ***1.0000*** was obtained which is greater than both 0.05 (α = 5%) and 0.01 (α = 1%). A χ^2-value of ***0.0469*** was also obtained. For a degree of freedom of 5, the critical values for χ^2 are 11.1 (for α = 5%) and 15.1 (for α = 1%). The chi-square (χ^2) value obtained from the test is less than the critical values of both for α = 5% and α = 1%. Therefore, from both the χ^2-value and *p*-value point of views, the null hypothesis cannot be rejected and conclude that "no significant differences in the

semester to semester and between hybrid and delivery options". This means, statistically similar trends were observed in the semester to semester for both hybrid and online delivery modes. The *t*-Test performed for this parameter also confirmed that the observed difference between the sample means is not convincing enough to say that the average weighted GPA between hybrid and online delivery options differ significantly. Although *F*-Test performed for this parameter differed from the χ^2- and *t*-Test results, it could be statistically confirmed that the average weighted GPA between hybrid and online delivery options did not differ significantly. The weighted average grades are estimated based on the number of A, B, C, D, and F with a score of A=4.0, B=3.0, C=2.0, D=1.0, and F=0. For example, weighted average GPA for spring 2019 = (7x4+17x3+8x2+3x1+0x0)/(7+17+8+3+0) = 2.800. The expected GPA is estimated as total GPA for all semesters divided by number of semester (16.9982/6 = 2.8330).

Table 2: Assessment based on weighted average GPA using Chi-square Goodness-of-fit test

Delivery Option	Semester	Observed GPAs	Expected GPAs	Statistics
Hybrid	Spring 2019	2.8000	2.8330	***p-value*** *= 0.9999≈1.00* ***DF*** *= 5* ***χ^2 value*** *= 0.0469*
	Summer 2019	2.9118	2.8330	
	Fall 2019	3.0606	2.8330	
Online (synchronous)	Spring 2020	2.5625	2.8330	
	Summer 2020	2.8485	2.8330	
	Fall 2020	2.8148	2.8330	
	Total	**16.9982**	**16.9982**	

An additional assessment was performed based on the final exam Minimum, Average, and Maximum scores obtained by students and the data is presented in Table 3. From the chi-square test, a *p*-value of ***0.3443*** was obtained which is greater than both 0.05 (α = 5%) and 0.01 (α = 1%). A χ^2-value of ***11.1715*** was also obtained. For a degree of freedom of 10, the critical values for χ^2 are 18.3 (for α = 5%) and 23.2 (for α = 1%). The chi-square (χ^2) value is less than the critical values of both the significance levels. Therefore, from both the χ^2-value and *p*-value point of view, the null hypothesis cannot be rejected and conclude that that "no significant differences in the semester-to-semester delivery options". This means similar trends are observed in the semester to semester for both hybrid and online delivery options.

Table 3: Assessment based on the final exam scores using Chi-square Goodness-of-fit test

Delivery Option	Semester	Observed Values				Expected Values			
		Min	**Avg**	**Max**	**Total**	**Min**	**Avg**	**Max**	**Total**
Hybrid	Spring 2019	18	37	98	**193**	30.84	65.83	96.33	**193**
	Summer 2019	30	58	88	**176**	28.12	60.04	87.84	**176**
	Fall 2019	30	67	100	**197**	31.48	67.20	98.32	**197**
Online (synchronous)	Spring 2020	35	55	95	**185**	29.56	63.11	92.33	**185**
	Summer 2020	30	57	87	**174**	27.80	59.35	86.84	**174**
	Fall 2020	35	66	88	**189**	30.20	64.47	94.33	**189**
	Total	**178**	**380**	**556**	**1114**	**125**	**237**	**370**	**1114**
p-value = 0.3443; χ^2-value = 11.1715; DF = 10, χ^2-critical = *18.3* (for α = 5%) and 23.2 (for α = 1%)									

Students' perceptions based on the another study by the author[12] was compared with the performance (weighted average GPA converted into percentage) as shown in Figure 1. The students' perceptions were collected via a survey with two questions: Q1 - Did tests reflect material covered in the class? and Q2 - Is there a good agreement between the course outline (syllabus) and the course content? There is no clear correlation among students' perceptions and the performances in terms of GPA.

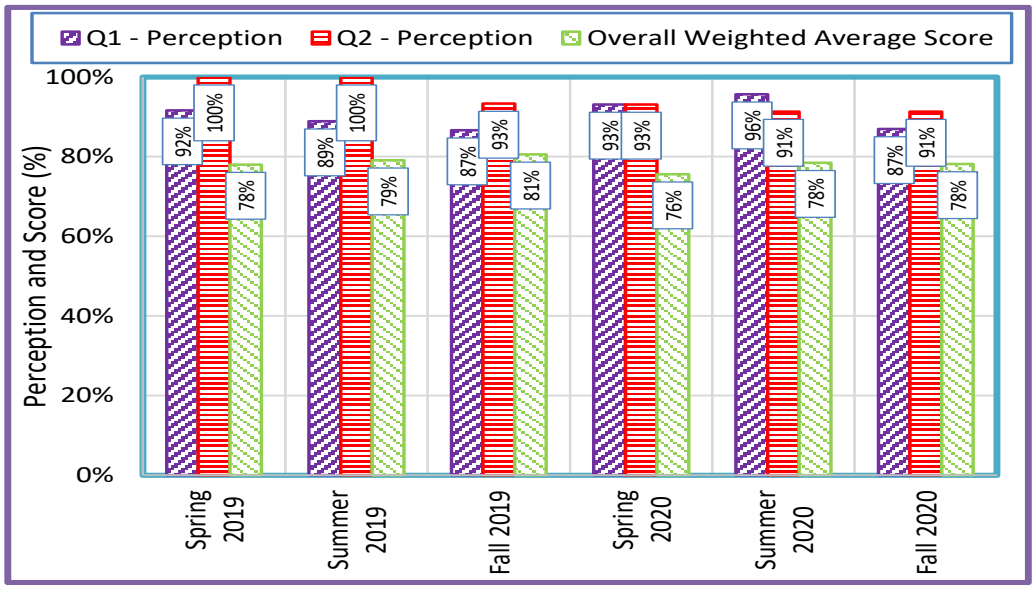

Figure 1: Students' perception and performance

The summary of the goodness-of-fit test analyses is listed in Table A-1 in Appendix A for different types of data. The assessment of weighted average GPA, final exam grades, and maximum, minimum, and average scores in the final exams statistically confirmed that the difference between the sample means and variances were not convincing enough to say that online synchronous delivery option did not maintain the same levels of students' performance although direct data showed that online synchronous delivery option did maintain the same levels of students' performance.

Study Limitations

The main source of bias for this study could be the fact that the author was the only person who designed this study, collected the semester end data, and analyzed the data. The other limitation could be the number of subjects used to test the concept and hypothesis. Several other subjects in engineering field along with other faculty collaboration could make the study more reliable and conclusive.

Summary and Conclusions

In this paper, an effort was made to assess effect of COVID-19, which influenced the learning environment and the performance in environmental engineering for the changes in the course delivery mode due to COVID-19 pandemic at the middle of Spring 2020. The course, `Intro to Environmental Engineering', was developed and approved as a fully on-line and taught as a hybrid

and face-to-face for several semesters. In the hybrid delivery mode, all of the quizzes and homeworks were on-line and only the midterm and final exams were in-class. At the middle of Spring 2020, the course delivery was changed to an online synchronous mode of delivery due to COVID-19 situation. For the same reason, the course was offered online synchronous in Summer 2020 and HyFlex in Fall 2020. In Spring 2020, the final exam and in Summer and Fall 2020 both the midterm and final exams were conducted online using Respondus lockdown browser and webcam. It could not be proved by statistical data analysis that online synchronous approach significantly degraded the level of students' performance, however, the assessments of the study indicated that online synchronous delivery approach apparently did not maintain the same level of students' performance which is an agreement of findings that was published by the author[11] in a journal. It is the author's opinion and reflection that PBL delivery with alternate evaluation such as take-home exam option, as preferred by the students in another study by the author[12], along with other alternative evaluation processes such as oral evaluation, can be adopted to maximize and augment the students learning that may improve the level of students' performance for the future semesters.

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M. A. Karim

Dr. Karim spent about six years as a full-time faculty at Bangladesh University of Engineering and Technology (BUET) after his graduation from the same university in 1989. He came to USA in 1995 and finished his Ph.D. in Civil/Environmental Engineering from Cleveland State University in 2000. He worked about three years for ALLTEL Information Services in Twinsburg, Ohio as an Applications Programmer. Then he worked about eight years (in two different times) for the Virginia Department of Environmental Quality (VDEQ) as a Senior Environmental Engineer and taught at Virginia Commonwealth University (VCU) as an Affiliate Professor before he went to Trine University in January 2008, as a full-time faculty of Civil & Environmental Engineering. He taught part-time at Indiana University-Purdue University Fort Wayne (IPFW) while employed at Trine University. During his time at Trine University, he taught an online course for VCU. He also taught at Stratford University, Richmond, Virginia campus as an adjunct faculty while working for VDEQ. Since fall of 2011, Dr. Karim has been working for Kennesaw State University (KSU), Marietta Campus, Georgia as a full-time faculty in Civil and Environmental Engineering. Currently he is a full professor of Civil Engineering. He served as an Assistant Department Chair and an Interim Department Chair of Civil and Environmental Engineering Department at KSU. He is a registered professional engineer for the State of the Commonwealth of Virginia and the state of Georgia. He has more than forty journal and proceeding publications and several professional reports in the area of soil and sediment remediation, environmental management, waste treatment and management, wastewater treatment, statistical hydrology, project-based learning (PBL), and engineering education. He is a fellow of American Society of Civil Engineers (F.ASCE), American Society for Engineering Education (M.ASEE), and a Board-Certified Environmental Engineer **(**BCEE) from American Academy of Environmental Engineers and Scientists **(**AAEES**).** He is also an ABET EAC Program Evaluation Volunteer (ABET EAC PEV) both for Civil Engineering (through ASCE) and Environmental Engineering (through AAEES) Programs.

Appendix A

Table A-1: Summary of Goodness-of-fit test analysis

Data Type: χ^2-*Test*	***p-value***	***χ^2-value***	***DF***	***Critical Value***		**χ^2-Test Comment**
				0.05	***0.01***	
Weighted average GPA (Table 2)	0.9999	0.0464	5	11.1	15.1	The *p*-values are greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and χ^2-values are less than the corresponding critical values. Therefore, null hypothesis cannot be rejected and concluded that "no significant differences in the semester to semester and between hybrid and online exam options."
Final exam scores (Min., Avg, Max. - Table 3)	0.3443	11.1715	10	18.3	23.2	
Final Grades (Table *1*)	0.1076	22.0060	15	25.0	30.6	The *p*-values are greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and χ^2-values are less than the corresponding critical values. Therefore, null hypothesis cannot be rejected and concluded that "no significant differences in the semester to semester and between hybrid and online exam options."
Data Type: *t-Test*	***p-value***	***t-value***	***DF***	***$t_{Critical}$ (two tail)***		***t*-Test Comment**
Weighted average GPA	0.2918	0.5954	4	2.7764		Since *t-value* is within $-t_{critical}$ and $+t_{critical}$, the null hypothesis cannot be rejected. The observed difference between the sample means is not convincing enough to say that the average GPA between hybrid and online exam options differ significantly.
Data Type: *F-Test*	***p-value***	***F-value***	***DF***	***$F_{Critical}$ (one tail)***		***F*-Test Comment**
Weighted average GPA	0.2720	2.6709	2	19.0		Since *F-value* < $F_{critical}$, the null hypothesis cannot be rejected. Therefore, variances of the two populations, hybrid and online exam options are statistically equal.