A Comparison between Mixed-Mode and Face-to-Face Instructional Delivery Approaches for Engineering Analysis: Statics.

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ABSTRACT

In recent years, the majority of engineering colleges and universities have been experiencing a vertiginous growth in the number of student applications and enrollment. Even though this tendency is very encouraging from the point of view of producing more engineers to satisfy the nation's demand, it also comes with serious drawbacks. Such growth in the student population requires increasing the number and size of the courses, adding parking spaces, and other facilities. Building new physical facilities is costly and takes considerable time. Some of these issues may be alleviated by offering Massive Open Online Courses (MOOC), however this approach is not feasible for some engineering courses. Another alternative that has been explored is the mixed-mode courses. This approach reduces the face-to-face time and use of physical plant by at least 50%. Traditionally mixed-mode courses use a "flipped" modality, placing the majority of the teaching/learning responsibilities on the students and meeting with the instructor only for practicing problems.

This paper presents the analysis of a mixed-mode approach, developed by the authors, for a Statics course. The online portion (~50%), conveyed via Canvas Learning Management System (LMS), contains video lectures, study-sets, self-assessment, hands-on homework, e-homework, proctored quizzes, and exams. The face-to-face component (~50%) includes concepts clarification, pre-class assessments, learning activities, real-life applications, problem solving, group quizzes, and discussions. Quantitative analysis of the results regarding students learning and class success are presented and compared with other purely face-to-face Static courses taught by the same instructor. Students' perception of instruction and opinions are analyzed and presented as well.

INTRODUCTION

According to the National Center for Education Statistics (NCES), students' enrollment in postsecondary education increased from 13.2 million to 16.8 million (27%) between 2000 and 2018 and is expected that by 2028 the total enrollment would be around 17.2 million [1]. At the University of Central Florida, the number of students have increased from 31,000 by the end of 1999 to more than 69,000 in 2019 (more than 122%) and it is projected to keep growing at approximately 2-3% per year. As expected, the size of the classes also increased; by 2019, the typical number of students in a sophomore engineering course is anywhere between 150 and 300. As a consequence, classrooms that large are becoming scarce since physical plant is not growing at the same rate as the students' population. To mitigate this problem, MOOCs have been used as a solution. Advantages and weaknesses of MOOCs are well documented [2-3]. Some of the disadvantages include reduced student retention, lower engagement, lack of practical lab-type implementation, and diminished students' satisfaction if compared the face-to-face interaction. In addition, engineering education research shows that incorporating high impact active learning strategies such as project based homework and experiential learning increase students' preparation, class success, retention, and graduation rates [4-7].

More recent tendencies opt for a hybrid method by using the massive reach capacity of online delivery with the benefits of face-to-face learning [8]. Several names are used for this type of approach being among the most common "Blended" and/or "Mixed-mode". Most of them apply a "flipped" classroom concept where conveying of the theory is achieved through on-line videos, which students are required to pre-learn on their own outside class time, while classroom time is invested on practicing problems with the students, conducting discussions, and answering questions [9-13]. This type of approach requires a more efficient time management and delegates a bigger responsibility to the students, who are in charge of learning the material on their own by using some provided tools.

We decided to conduct this study in a large course that lays the foundational concepts almost every engineering major: Statics. Additionally, it is pre-requisite for other courses such as dynamics, mechanics of materials and solid mechanics and it is in the critical path to graduation. Moreover, the failing (WDF)/ pass (ABC) ratio for statics is very high (40%- 50%) causing many students to abandon engineering to pursue other majors. At the University of Central Florida, students are not officially declared as part of their engineering majors until they approve and master this important class.

One of the authors presented his first attempt to create and implement a blended approach for a Statics course in [13] with very promising preliminary results. The following sections describe the results of that implementation for two large Statics sections compared with other two large statics sections taught by the same instructor with the same grading scheme in a face-to-face modality.

The purpose of this research was to investigate the impact of incorporating a mixed-mode instructional delivery approach in Statics.

METHODOLOGY

Research Questions

This study focused on answering two research questions:

1) Do students perform better in Statics after the inclusion of mixed-mode instructional delivery approach?
2) How the inclusion of a mixed-mode approach affects the different students' sub-groups such as gender and ethnicity?

Research Design and Control

To answer these questions, four Statics sections were taught in the same manner by the same instructor, the only difference was the inclusion of mixed mode in two of them. The Difference in the mixed-mode is that the lectures were only provided by online videos and in the face-to-face, same lectures were presented in-class by the instructor.

Course Organization

Table 1 show all the components for both BSC and face-to-face (F2F) approaches.

Classroom time: two 75-minutes sessions for F2F and one 75-min session for BSC

Delivery of information: both groups used Canvas LMS (adopted university-wide) to host the tools needed for the students to acquire the required level of knowledge per learning objective.

Learning Modules

Every module starts with a brief introduction to the topic, the objectives, required reading, video-lectures, study-sets, activities, and assignments.

Video-Lectures: Videos created by the instructor are provided to both groups. BSC students were required to watch them on their own before coming to their 75 min in-class session. F2F students were encouraged to watch them, however the instructor covered the same material in-class. Both, video lectures and in-person lectures, include animations and practical demonstration as well as embedded poll questions.

Online Study Sets: Several representative application problems selected by the instructor are provided via Canvas LMS with video and written solutions. Practice problems are adapted to represent real-life scenarios and they are analyzed, solved and discussed by using several possible approaches.

Online Homework (e-HW): BSC and F2F include hand-picked problems have been selected by the instructor to achieve the lesson goals reinforcing the video-lectures and study sets. All the e-HW have been created in Canvas LMS by using algorithmic questions.

Hands-on Project Based Homework (PBH): Both BSC and F2F includeactive learning project based homework. A complete description of PBH can be found in [6]. Alongside with regular e-HW students must create a physical model of one of the regular homework problems (selected by the instructor). Once the model is created, the students design and perform experiments and take measurements to compare with their original analytical calculations. The submission of this activity includes a report and a 5-min video clip of them explaining their model, experiment, and discussing how their experimental results compare with the purely theoretical calculations.

Online-Proctored Quizzes and Exams: Both BSC and F2F cover this base by using a proctoring center which is part of the University Central Florida.

Group Quizzes (in pairs): once a week during classroom time, the students are required to complete an assessment consisting of one question corresponding to the material they are required to learn before coming to class (usually 5-10 min). This question covers the basic principles to be deepened during the face to face time. The main objectives of this activity are 1) give the instructor a baseline for directing the class discussion and 2) keep the students reviewing the material and attending to class.

Discussions Clarifications: After the students complete the quiz, a discussion follows. More questions are asked and replied using the Socratic Method. This session may last for about 15-20 min and it is followed by the selected in-class problem solving.

Problem Solving: The instructor proceeds to discuss the representative selected examples, giving step-by-step problem-solving methodologies, tips, and strategies. In some cases, students ask for specific examples and the instructor addresses them too.

Table 1. BSC and F2F components

	Face to Face (F2F)	Blended Mode (BSC)
Classroom time	*Two 75-minute sessions per week*	*One 75-minute session per week*
Learning-Modules	Provided	Provided
Video-Lectures	*Provided but not requir*	*Required*
Online Study Sets	Provided	Provided
Online Homework	Required	Required
Hands-on Project Based Homework	Required	Required
Online-Proctored Quizzes and Exams	Required	Required
Group Quizzes	Required	Required
Discussions	Provided	Provided
Problem Solving	Provided	Provided

PARTICIPANTS

Rigorous analysis was performed on the participant data to ensure the validity of the study.

Instructor
The same instructor was in charge of delivering of the material and assessment for both studied sections. Two courses were taught face to face and two were mixed mode.

Students
Students enrolled in the course in accordance with their schedules and time preference. Data from both sections were analyzed to determine if both groups were similar of differed in any way. These analyses used data housed by Institutional Knowledge Management (IKM) of the University, which includes student's demographics such as gender, classification (sophomore, junior, senior), ethnicity, enrollment, cumulative GPA.

Analysis Methods
The research compares the performance of the students (grades) in either sections using descriptive analyses employing one variable and two variable relationships. The relationships considered include: (a) for one variable: comparing the grade distribution across the sections with and without mixed-mode, gender, ethnicity, student level, and prior GPA (b) for two variables: grade performance by gender and mixed-mode, and ethnicity. Further, we build on the descriptive analyses by developing individual level models of student grade performance while controlling for several covariates simultaneously. The modeling approach controls for several student characteristics and is more likely to offer stable model attribute impacts on grade compared to descriptive analysis where the analyst has no control over variables not included in the analysis.

DATASET DESCRIPTION

Final dataset consists of all records of the statics students in Spring and Fall semester in 2019. Estimation set consists of 447 observations. Dependent variable is five level grade of the students consisting of A, B, C, D, F/W/WM. Independent variables consists of different demographic characteristics of the students such as gender, race, students' classification by level of study, overall GPA prior to the course, number of prior attempts, etc. Descriptive statistics of the final dataset is provided in Table 2.

Table 2. Descriptive Statistics of the Variables in Final Dataset

Variables	**Description**	**Frequency**	**Percent**
Gender			
0	Female	101	22.6
1	Male	346	77.4
Race			
1	White	190	42.5
2	Asian	33	7.4
3	AA	36	8.1
4	Hispanic	143	32
5	Others	45	10.1
Level			
1	Junior	255	57
2	Senior	89	19.9
3	Sophomore	92	20.6
4	Others	11	2.5
UCF GPA			
1	4.00-3.50	79	17.7
2	3.50-3.00	108	24.2
3	3.00-2.50	87	19.5
4	2.50-0.00	65	14.5
5	Unavailable	108	24.2
Overall GPA			
1	4.00-3.50	105	23.5
2	3.50-3.00	154	34.5
3	3.00-2.50	112	25.1
4	2.50-0.00	43	9.6
5	Unavailable	33	7.4
Prior Attempts			
0		219	49
1		161	36
2+		67	15
Mixed-mode approach			
0	No	193	43.2
1	Yes	254	56.8

Variables	Description	Frequency	Percent
Official Grade			
5	A	59	13.2
4	B	124	27.7
3	C	115	25.7
2	D	32	7.2
1	F/W	117	26.2

Univariate Analysis

In univariate analysis of the variables, one to one comparisons between selected exogenous variables and the target variable, grade are performed to investigate potential associations between them. The comparisons are performed by identifying the possible significant distributional difference of grade across subgroups using chi-square statistics. Cross-tabulations between exogenous variables versus grade are presented in tables below:

Table 3. Gender Vs Grade

		Gender		Total
		Female	Male	
Grade	A	11	48	59
	B	23	101	124
	C	28	87	115
	D	13	19	32
	F/W	26	91	117
Total		101	346	447

Chi-square statistics: 7.847 (df = 4, p-value = 0.097)

Table 4. Race Vs Grade

		Race					Total
		White	Asian	AA	Hispanic	Others	
Grade	A	31	5	0	15	8	59
	B	55	11	5	46	7	124
	C	47	7	10	43	8	115
	D	12	1	5	11	3	32
	F/W	45	9	16	28	19	117
Total		190	33	36	143	45	447

Chi-square statistics: 31.866 (df = 16, p-value = 0.01)

Table 5. Level Vs Grade

		Level				Total
		Junior	Senior	Sophomore	Others	
Grade	A	28	8	21	2	59
	B	67	23	30	4	124
	C	66	22	25	2	115
	D	22	8	2	0	32
	F/W	72	28	14	3	117
Total		255	89	92	11	447

Chi-square statistics: 21.317 (df = 12, p-value = 0.046)

Table 6. Overall GPA Vs Grade

		Overall GPA					Total
		4.00-3.50	3.50-3.00	3.00-2.50	2.50-0.00	Unavailable	
Grade	A	40	13	3	0	3	59
	B	39	54	18	6	7	124
	C	17	36	38	12	12	115
	D	3	12	8	5	4	32
	F/W	6	39	45	20	7	117
Total		105	154	112	43	33	447

Chi-square statistics: 128.682 (df = 16, p-value = 0.000)

Table 7. Prior Attempts Vs Grade

		Prior attempts			Total
		0	1	2+	
Grade	A	41	18	0	59
	B	60	55	9	124
	C	48	45	22	115
	D	13	11	8	32
	F/W	57	32	28	117
Total		219	161	67	447

Chi-square statistics: 35.913 (df = 8, p-value = 0.000)

Table 8. Mixed-mode Approach Vs Grade

		Mixed-mode approach		Total
		0	1	
Grade	A	39	20	59
	B	97	27	124
	C	96	19	115
	D	27	5	32
	F/W	81	36	117
Total		340	107	447

Chi-square statistics: 11.221 (df = 4, p-value = 0.024)

From the above univariate analysis, it is found that race, level, overall GPA prior to the course, gender, number of prior attempts and inclusion of mixed-mode instructional delivery approach are potentially important variables for predicting future grade of the students in statics course.

To compare the distribution of gender, race, level and prior attempts of the students across the two instructional methods, chi-square test is also performed. From the analysis, it can be found that distributions of gender and level across the subgroups (Face to face and mixed method) are not significantly different. Distributions of race, prior attempts and overall GPA across two subgroups are significantly different. However, in our study, we are developing a student level grade prediction model i.e. the record of observation is no longer the class but the individual student. The proposed study framework explicitly controls for student attributes while predicting grade.

Table 9. Gender Vs. Method of instruction

		Gender		Total
		Female	Male	
Mixed Mode	No	49	144	193
	Yes	52	202	254
Total		101	346	447

Chi-square statistics: 1.515 (df = 1, p-value = 0.218)

Table 10. Race Vs. Method of instruction

		Race					Total
		White	Asian	AA	Hispanic	Others	
Mixed Mode	No	68	19	19	69	18	193
	Yes	122	14	17	74	27	254
Total		190	33	36	143	45	447

Chi-square statistics: 10.054 (df = 4, p-value = 0.04)

Table 11. Level Vs. Method of instruction

		Level				Total
		Junior	Senior	Sophomore	Others	
Mixed Mode	No	117	32	40	4	193
	Yes	138	57	52	7	254
Total		255	89	92	11	447

Chi-square statistics: 2.864 (df = 3, p-value = 0.413)

Table 12. Prior Attempts Vs. Method of instruction

		Prior Attempts			Total
		0	1	2	
Mixed Mode	No	0	133	60	193
	Yes	219	28	7	254
Total		219	161	67	447

Chi-square statistics: 327.172 (df = 2, p-value = 0.0)

Table 13. Overall GPA Vs. Method of instruction

		Overall GPA					Total
		4.00-3.50	3.50-3.00	3.00-2.50	2.50-0.00	Unavailable	
Mixed Mode	No	37	55	52	17	32	193
	Yes	68	99	60	26	1	254
Total		105	154	112	43	33	447

Chi-square statistics: 45.829 (df =4, p-value = 0.0)

The grade distribution for all students is presented in Figure 1. It can be observed that the percentages of "A's" improved from 7.77% for F2F to 17.72% for BSC. The "B's" also increased from 25.91% to 29.13%. Grades of "C" , "D", and "F" were reduced in the BSC and "W's" remained very similar. The overall passing rate increased more that 5 percent points in average for the BSC courses when compared with the F2F.

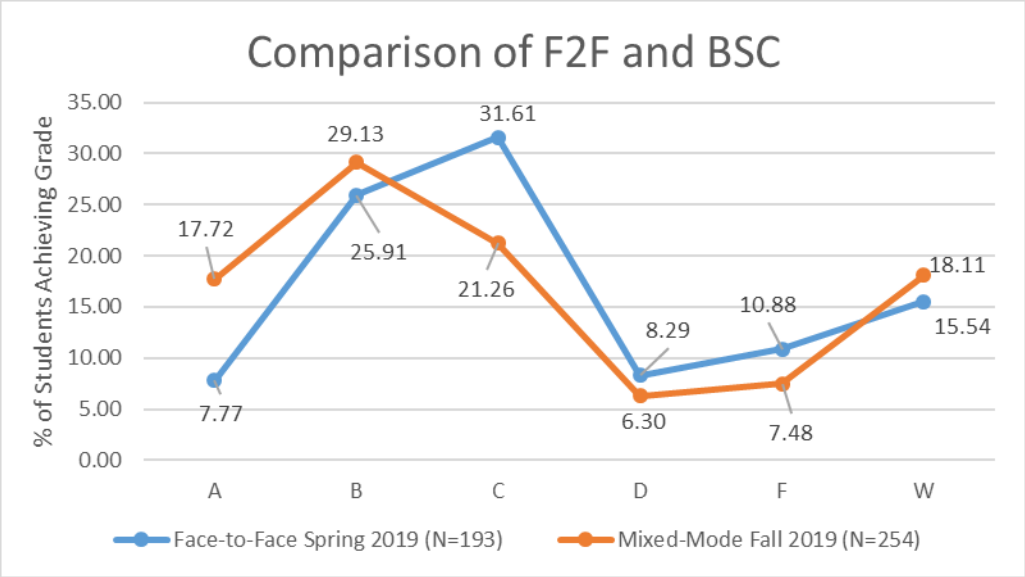

Figure 1. Comparison of F2F and BSC

MODEL AND ESTIMATION RESULTS

Econometric Model

In this research, we employ the ordered logit model for studying the ordinal categorical variable grade with the categories defined as Fail/Withdraw, D, C, B, and A.

Let *j* be the index for the discrete outcome that corresponds to grade for student q. In ordered response model, the discrete grade levels (y_q) are assumed to be associated with an underlying continuous latent variable (y_q^*). This latent variable is typically specified as the following linear equation:

$$y_q^* = \alpha' z_q + \varepsilon_q,\ y_q = j \text{ if } \psi_j < y_q^* < \psi_{j+1} \quad (1)$$

where, z_q is a column vector of exogenous variables for student q, α is column vector of unknown parameters, ψ_j is the observed lower bound threshold and ψ_{j+1} is the observed upper bound threshold for grade j. ε_q, with logistic distribution, captures the idiosyncratic effect of all omitted variables for student q.

$$Pr(y_q = j) = \Lambda(\psi_{j+1} - \alpha' z_q) - \Lambda(\psi_j - \alpha' z_q) \quad (2)$$

where, $\Lambda(.)$ is the cumulative standard logistic distribution.

The likelihood function with the probability expression in equation (2) for grade outcome can be expressed as:

$$L = \prod_{q=1}^{Q}\left[\prod_{j=1}^{J}\{Pr(y_q = j)\}^{\omega_{qj}}\right] \quad (3)$$

where, ω_{qj} is dummy with $\omega_{qj} = 1$ if the student q sustains a grade of j and 0 otherwise. All the parameters in the model are then consistently estimated by maximizing the logarithmic function of L.

RESULTS SUMMARY

Table 14 shows parameter estimates of the ordered logit model where effects of mixed-mode approach and other factors on final grade of the students can be captured. Positive (negative) coefficient corresponding to a parameter indicates that value of the parameter being one actually increases (decreases) the probability of higher grade while controlling for all other variables.

Table 14. Parameter Estimates of OL Model

Variables	**Estimates**	**t-statistics**
Thresholds		
Threshold F-D	0.3892	1.318
Threshold D-C	0.7913	2.680
Threshold C-B	2.1292	6.793
Threshold B-A	4.0488	11.419
Propensity Components		
Gender (Base: Female)		
Male	0.3398	1.627
Race (Base: White American, Asian and Hispanic)		
African American	-0.8740	-2.648
Race Others	-0.6341	-2.038
Level (Base: Junior, Senior and Others)		
Sophomore	0.4739	2.125
Overall GPA (Base: 0.00-3.00)		
4.00-3.50	2.5113	9.445
3.00-3.50	0.8016	3.745
Unavailable	0.8050	2.230
Prior Attempts (Base: 0 and 2+)		
1	0.6184	2.652
Mixed-mode approach (Base: No)		
Yes	0.6325	2.762
Model Fitness		
Number of observations	447	
Initial Log-likelihood	-719.42	
Log-likelihood at Convergence	-602.86	
ρ^2	0.162	
Adjusted ρ^2	0.150	

Gender of the students

The parameter estimates show that gender of a student is a statistically significant factor of his/her grade. Positive co-efficient related to male indicates that male students have greater chance to obtain a higher grade compared to female students if other factors remain constant. Therefore, if a male and a female students belong to same class (face to face/ mixed), race, level with equal overall GPA and prior attempts, the male student is more likely to get higher grade compared to the female student.

Race of the students

Race of a student is found to be impacting the grade of statics course. According to the model, African American students and students from other race groups have a lower grade compared to White American, Asian and Hispanic students controlling for other factors.

Students' Level

Level of the student is also an important determinant of grade. In general, sophomore students perform better than students from other levels. It may indicate the fact that junior, senior, other level students performed poor in their first (or second) enrollment and, this time they are retaking the course. Eventually, they performed poor this time as well.

Overall GPA

Intuitively, overall GPA of a student prior to the course is an important factor of his/her future grade. Parameter estimates show that students having GPA 3.00-4.00 actually perform better compared the students having GPA below 3.00 and unknown GPA. This indicates the fact that a student with higher GPA performs better than a student with lower GPA if other factors remain same.

Prior Attempts

Students, taking statistics course as their second enrollment, perform better compared to the fresher students and the students, who were enrolled in the course twice (or more) before.

Effect of Blended Method

Mixed-mode approach (combination of face-face and online lecture) of instruction has a positive effect on students' grade. Students from a class, where mixed-mode approach is used, perform better compared to students from a class, where only face-face method is used.

STUDENTS OPINIONS

An anonymous 5 point Likert scale survey was distributed to the students asking their feedback concerning video lectures, study sets, e-homework, in-class group quizzes, and hands-on PBH (Figure 2). 74.1% of the students strongly agree or agree with the effectiveness of the video lectures as a learning tool. 70.7% found the study sets very helpful and 67.3% recognize that the provided e-Hw makes them practice and better understand the class topics. In-class group quizzes were referenced by 75.5% of the students as a good tool that made them study and be prepared before class and 85% of the poll expressed that PBH helped them to better understand the class topics and make connections with real life engineering scenarios.

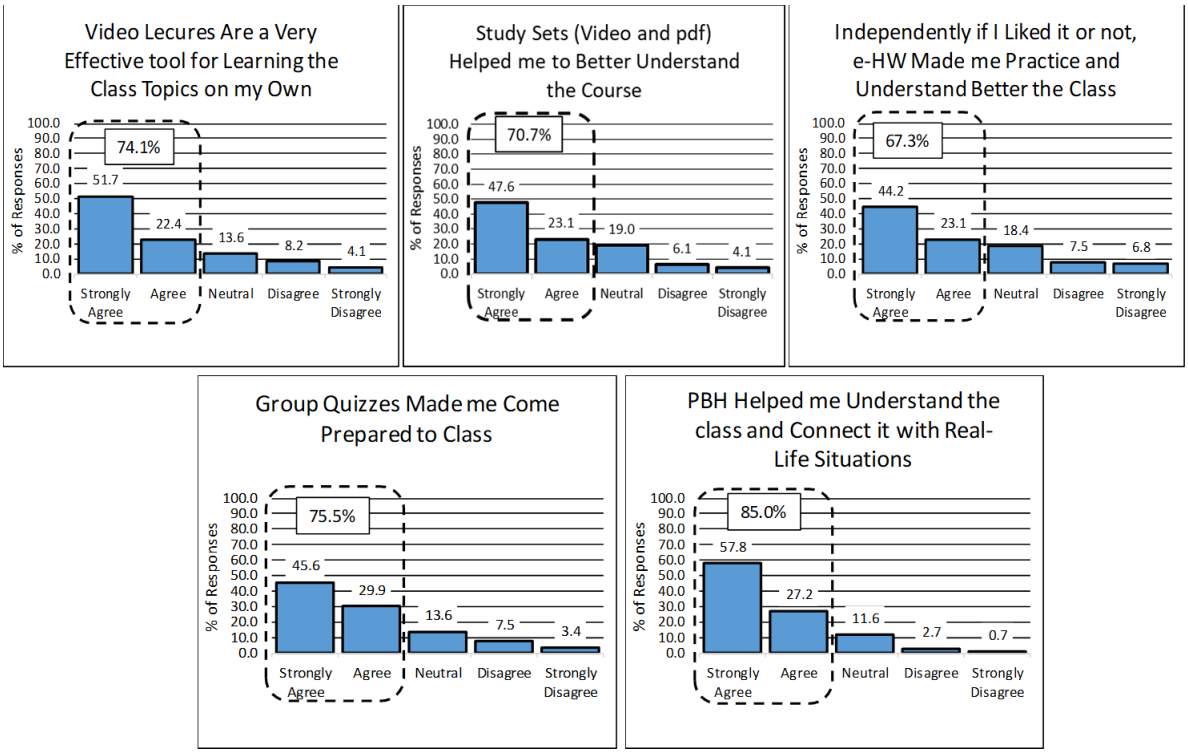

Figure 2. Students' opinions regarding BSC components

Two additional questions were asked to obtain the general opinions of the students with respect to the use of their time in the BSC (mixed-mode) and how likely they would recommend BSC instead of F2F. Regarding the better use of time, 69.35% agreed or strongly agreed on BSC providing them with a better use of the time and 11.29% disagree or strongly disagree (Figure 3a). In addition, 54.84% expressed that they would recommend a BSC mode instead the F2F and 16.13% disagree with it (Figure 3b).

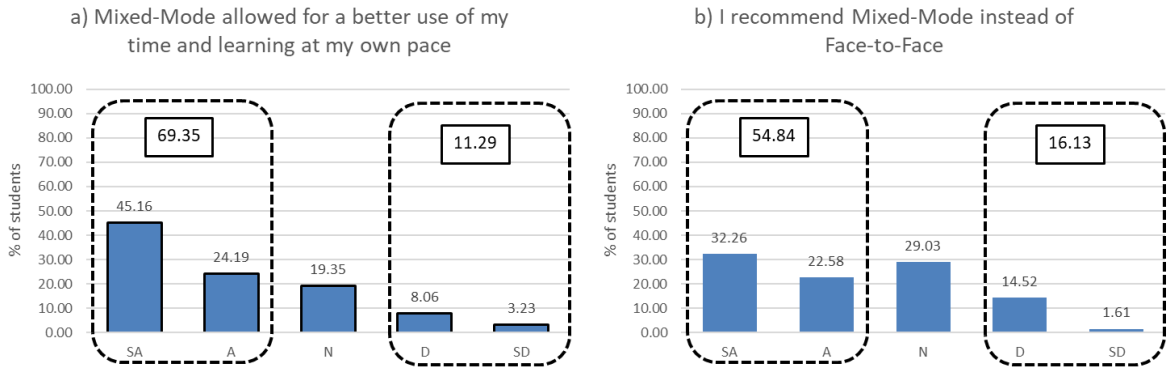

Figure 3. Student's opinions regarding mixed-mode time management (a) and likeliness to recommend it (b)

FINDINGS, CONCLUSIONS, LIMITATIONS, AND FUTURE WORK

This research investigated the effect of introducing mixed-mode instructional delivery approach into a large-size engineering class called Engineering Analysis-Statics. Statics was selected for

several reasons such as being in the graduation critical path as a required common prerequisite and co-requisite for more advanced engineering courses, having a large enrollment (around 1,700 per year), and presenting a high fail pass ratio of about 40-50%. Two main aspects were studied: students' success in the class and students' results per gender and ethnicity.

The first finding refers to students' success in the class: The percentages of mixed-mode students successfully completing Statics and advancing to other courses was in average more than 5 percent points higher than the F2F sections. The grade distribution also reflected an important increase in A's and B's with a decrease in C's, D's and F's.

Univariate and multivariate statistical analyses were conducted. From univariate analysis, it was found that race, level, overall GPA prior to the course, gender, number of prior attempts and inclusion of mixed-mode instructional delivery approach are potentially important variables for predicting future grade of the students in statics course.

Parameter estimates of the ordered logit model where effects of mixed-mode approach and other factors on final grade of the students were captured and showed that gender of a student is a statistically significant factor of his/her grade. If other factors remain constant, male students have greater chance to obtain a higher grade compared to female students. Race of a student is found to be impacting the grade of statics course. According to the model, African American students and students from other race groups have a lower grade compared to White American, Asian and Hispanic students. Level of the student is also an important factor. In general, sophomore students perform better than students from other levels. It may indicate the fact that junior, senior, other level students performed poor in their first (or second) enrollment and, this time they are retaking the course. Eventually, they performed poor this time as well. Parameter estimates also showed that students having GPA 3.00-4.00 actually perform better compared the students having GPA below 3.00 and unknown GPA. Additionally, students, taking statistics course as their second enrollment, perform better compared to the fresher students and the students, who were enrolled in the course twice (or more) before.

Mixed-mode approach of instruction (BSC) has a positive effect on students' grade. Students from a class, where mixed-mode approach is used, perform better compared to students from a class, where only face-face method is used. In addition, the students' opinion is that mixed mode helped them to better manage their time and succeed in the class.

These analyses were limited for the small size of some group samples such as African American women or African American men; however, this is an ongoing study. It would be useful to confirm our findings by extending this exercise with a larger data sample to account for potential differences across the current samples. More data is being collected and soon will be ready for analysis.

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