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Farnaz Ghazi Nezami

Kettering University, fghazinezami@kettering.edu

M. B. Yildirim

Wichita State University, bayram.yildirim@wichita.edu

G. Grossi Crema

Kettering University, giovannicrema@hotmail.com

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Comparing Three Instructional Modes for an Engineering Economy Course

F.Ghazi Nezami*¹, M.B. Yildirim² and G. Grossi Crema¹

¹ Kettering University, Flint, MI, USA

² Wichita State University, Wichita, KS, USA

Abstract— This study compares three instructional modes in an “Engineering Economy” course: online, face-to-face (FtF), and flipped. Engineering Economy is a core course in this study and incorporates students with diverse backgrounds from different engineering majors. To discern the relation between student characteristics and teaching modality, an online questionnaire was designed for each mode and distributed over a two-year period. Data was collected and several statistical analyses were conducted to study the relationship between pedagogical delivery modes and various student-based factors such as gender, age, course load, living distance from campus, computer skills, work status, and first language. Students’ performance, persistence, and knowledge self-evaluation were also compared in different modes. The statistical analyses of data at 95% confidence level show that among all the factors, only the ratio of native English speakers, course load and work category differ significantly in different instructional modes. No statistically significant difference was observed between different modes for other factors.

Index Terms— Engineering Economy, Face-to-face, Online, Flipped, engineering education, education mode.

Introduction

In this study, we compared three instructional modes—online, face-to-face (FtF), and flipped classroom—for the “Engineering Economy” course offered in the College of Engineering. We were interested in identifying student characteristics that can influence the choice of enrollment in different pedagogical modes. We also investigated the impact of instructional mode on student performance and persistence rate.

Students have diverse learning styles, and different teaching styles and instructional methods to address this diversity can facilitate the learning process. Affordability and easy accessibility of computers and the World Wide Web provide an immense opportunity to enhance the traditional teaching environment with innovative learning/instruction methods that incorporate technology.

The increasing popularity of technology-deploying classes as a replacement for traditional face-to-face lectures necessitates more investigation on their effectiveness. This challenge is more acute for undergraduate engineering majors where mathematical problem solving and critical thinking about the results are key aspects of the learning process.

Time and distance flexibility, unlimited access to knowledge, capability of archiving knowledge for students as well as the instructors, and promoting independent

learning are some of the main reasons that contribute to the increased demand for online classes that integrate technology into instruction and learning [1]. In addition, online classes mostly facilitate student enrollment problems that originate from capacity constraints in face-to-face classes. Some instructors believe that the online presentation mode promotes deeper learning and higher-order thinking among students by shifting the learning procedure from an instructor-based style to a learner-based style. On the other hand, some may argue that online classes are not efficient enough because there is no direct contact among students, or between the students and the instructor, which can negatively influence learning [2]. These opponents believe that teaching and learning are social activities that take place through interactions with the environment [3], and online learning lacks in this regard. The existing challenge addresses the fact that students not only learn by receiving information, but they need to have constructive reflection on material to assure deep understanding [4]. Opponent groups name lack of immediate feedback, confusion and frustration, inconvenience for some groups of students, and longer preparation time for instructors as other disadvantages associated with online classes [1].

Face-to-face classes, known as the most prevalent presentation mode, provide an opportunity for students to take advantage of classroom discourse [3], whereby classroom discussions are used to organize and direct the knowledge and foster the reflective thoughts. Immediate feedback, a familiar environment for students and instructors, and social interaction are the main advantages of FtF classes [1].

Flipped classrooms combining the advantages of FtF and online instruction methods, can provide an effective learning environment. These classrooms employ asynchronous video lectures along with FtF group-based problem-solving sessions [5]. In flipped classes, students learn the material outside the classroom and then enhance their learning in the classroom through problem solving and class discussions under the supervision of an instructor [6].

The success FtF, online, and flipped classes depends on a wide variety of factors such as course design, experience of the instructors, student characteristics, their background, and their general attitude about these types of classes.

Several studies compare the effectiveness of classroom and online instruction delivery. Ref. [7] provides a comparison between student persistence and performance in the Statistics classes offered in online and classroom settings, noting that there is a big difference in persistence between online and face-to-face students; however, among

students who persist, no significant difference was observed in performance. Ref. [8] compares student performance in both online and classroom environments for a course called “Information Society,” and they conclude that performance is not affected by the presentation mode. Ref. [9] makes a similar observation for an online and traditional “Accounting” course: student performance is not influenced by the instruction mode. Ref. [10] discusses the “no significant difference” paradigm, which can gloss over the “real” difference between online and FtF education modes and their impacts on learning. Ref. [4] studies how the World Wide Web could be used as a partial supplement to traditional classroom instruction, and their results show that online supplemental components improve grades significantly. When the efficacy of collaborative learning is compared in online and FtF classes for a psychology major course, Ref. [11] observes that student outcome levels are the same for both groups. Ref. [2] discusses students’ characteristics and explanatory factors influencing students’ enrollment and performance, and they show no significant impact on completion percentage and performance between online and lecture classes in an “Introduction to Programming” course. Similar comparisons and observations of online and FtF instruction modes are presented in [12, 13, 14].

Several studies discuss different approaches to improve delivery methods in engineering classes. Ref. [15] utilizes information technology to develop an online portal for an “Engineering Economy” course, enabling students to solve real engineering problems online and facilitating the evaluation procedure for instructors. Flipping out the “Engineering Economy” class was studied by [16], and they reported no significant difference in course evaluation and grade analyses. Ref. [17] compares student performance in online, flipped, and FtF classes in an “Engineering Graphics” course, and found that the cost efficiency of online classes, possibility of offering more course sections with fewer faculty, and enhanced learning flexibility are the main motivations for incorporating online and flipped classes into their curriculum. They show that there is no significant difference in students’ final exam grades regardless of the instruction delivery method. The impact of the teaching mode on student performance in a graduate-level “Computing Program” course is analyzed over a four-year period for online and FtF traditional classes by Ref. [18]. Their results indicate that although FtF students slightly outperformed online students, the difference in performance was not statistically significant. Ref. [19] compares student performance, content coverage, and student perception of inverted classes in a “Control Systems” course in flipped and traditional courses. They conclude that flipped classroom students performed at least as well or better than traditional classroom students. Ref. [20] observes that engineering students perceive instruction using a flipped classroom for an “Introduction to Work Design” course to be effective. However, course offerings using the flipped method should be very well planned in advance to increase the effectiveness of information delivery. Ref. [21] summarizes a survey of studies adopting flipped approach in engineering education, and evaluate its impact from different perspectives.

To summarize, an extensive number of studies in other engineering disciplines compare student outcome in

online, flipped, and face-to-face lectures, and results indicate that when carefully planned, all instruction modes have similar impacts on performance measures. In this study, we conduct a comparative analysis for three course delivery modes in an “Engineering Economy” course. The main contributions of this paper are as follows:

i) We compare online, flipped, and face-to-face classes from the student characteristics perspective. We analyze student demographics and profiles in different modes to determine if there is any significant difference between student characteristics in different instructional delivery mode; i.e., analyses can show if there is any dependency between student characteristics and selection of instruction mode.

ii) We analyze the impact of three modes on key metrics such as student performance, persistence rate, and self-evaluation of perceived knowledge.

iii) We provide some insights based on the lessons learned from teaching the “Engineering Economy” course in three different modes.

The rest of this paper is organized as follows: Section 2 provides an introduction about the course structure in each setting. Section 3 presents a detailed statistical analysis of student profiles, and section 4 compares education modes from the perspective of performance and persistence rate. Section 5 discusses the learned lessons and section 6 summarizes research findings.

II. COURSE INFORMATION

In the “Engineering Economy” course, which is a three-credit-hour course, and meets in two 75-minute blocks of instruction, students first learn how to evaluate a single project with different cash-flow patterns and interest rate expressions, and then extend this analysis to evaluate multiple projects using present worth, annual worth methods and rate of return and public sector analysis. Finally, students utilize these concepts in understanding replacement, inflation, breakeven, payback period, costing and after-tax cash flow analysis concepts [22]. Often this course is not challenging with respect to the math involved. However, engineering students find it to be non-traditional because they must convert a scenario into a mathematical model, which is a fairly complex and demanding task, since this involves not only comprehension and analysis but also synthesis.

The data for this research was collected in a total of nine sections of the “Engineering Economy” course over four semesters indicated by Fall 1, Spring 2, Fall 2, and Spring 2 to keep the data unanimous. During this time period, the course was taught by three instructors (I1, I2, and I3). Note that for simplicity, we have combined the data for two sections of the FtF class in Fall 1 since they were taught by the same instructor using the same syllabus.

The “Engineering Economy” course in this study has a large enrollment because it is a required core course for all electrical and computer, mechanical, biomedical, industrial, manufacturing, and aerospace engineering majors. The same text book and course materials were used for all three types of delivery methods during all semesters. Table I presents class information about the course offering mode schedules, grading schema, and student enrollment in each of the classes. Note that each activity contributes a certain percentage to the overall

course grade. The initial enrollment number represents the enrollment capacity of the courses as shown on the university portal during registration, and the classes were full at the time of enrollment. In this table, final enrollment is measured by the number of students who took the final exam.

A. Face-to-face Class Setting

To promote active learning in face-to-face classes, short lectures were given in each session, and then students were encouraged to solve problems in groups. Next, the problems were discussed by the instructor. In this setting, tutorial videos from the text book publisher and PowerPoint presentation files summarizing each chapter were available to students on the Blackboard Course Management System. Having access to multimedia such as PowerPoint presentations and videos in addition to in-class lectures provides better control on extraneous cognitive load during the learning process. Weekly quizzes and unannounced quizzes were administered at the beginning of some sessions to ensure students' timely attendance and to facilitate timely learning of course material, since new concepts highly depend on prior topics.

B. Online Class Setting

In the asynchronous online class setting, recorded videos were prepared in short segments of 3 to 15 minutes. Ref. [23] claims that the optimum size of an educational video should be less than 20 minutes because of the limits of working memory. The videos were posted on Blackboard system following a predetermined schedule, and students were able to access the course material, including videos, instructor's notes, and PowerPoint presentations, anytime, as long as they

completed the prerequisite work, which was usually online quizzes for the previous chapter. The course schedule included a course agenda and a timetable of the course expectations and milestones, which provided a reference for students to monitor their progress towards course learning objectives and expected milestones. Students took five-question, online, multiple-choice quizzes, which usually covered a few concepts from each chapter. Students could earn bonus points by providing weekly progress reports to assess their self-regulation through a designated form. To ensure the effectiveness of online lectures, several online quizzes were administered.

For each chapter of the textbook, 5 to 15 questions (one to three quizzes) were developed. For each question, a pool of questions was created while keeping the essence of the question the same and changing the parameters to create twenty versions of the same question. When students took the quizzes, randomization of the question further ensured that no one would receive the same quiz in order to prevent plagiarism and assure students' independent work. This quiz design was structured using interconnected topical modules such that each module covered the course material in accordance with posted tutorial videos.

C. Flipped Class Setting

In the flipped classroom setting, students had access to the same short 3- to 15-minute lectures and course notes to convey concepts that online class had. Students were required to study the online material prior to the on-campus 75-minutes-per-week sessions, which were devoted to class discussion, problem solving, and case study analysis.

TABLE I.
COURSE SECTION DATA SUMMARY

| | <i>Online Fall 1</i> | <i>Face-to-Face 1 Fall 1</i> | <i>Face-to-Face 2 Fall 1</i> | <i>Flipped Spring 1</i> | <i>Face-to-Face Spring 1</i> | <i>Online Fall 2</i> | <i>Face-to-Face Fall 2</i> | <i>Online Spring 2</i> | <i>Face-to-Face Spring 2</i> |
|--|--------------------------|----------------------------------|----------------------------------|-----------------------------|----------------------------------|--------------------------|--------------------------------|----------------------------|----------------------------------|
| <i>Initial Enrollment (number of students)</i> | 45 | 75 | 75 | 75 | 75 | 60 | 60 | 75 | 75 |
| <i>Final Enrollment (number of students)</i> | 25 | 57 | 62 | 62 | 74 | 41 | 53 | 72 | 60 |
| <i>Homework</i> | 20% | 10% | 10% | 15% | 15% | 20% | 15% | 17% | 15% |
| <i>Quiz</i> | | 20% | 20% | 15% | 15% | | 15% | | 10% |
| <i>Exam 1</i> | 25% | 20% | 20% | 20% | 20% | 25% | 20% | 25% | 20% |
| <i>Exam 2</i> | 25% | 20% | 20% | 20% | 20% | 25% | 20% | 25% | 20% |
| <i>Final Exam</i> | 30% | 30% | 30% | 30% | 30% | 25% | 30% | 25% | 30% |
| <i>Term Project</i> | - | - | - | - | - | 5% | - | 5% | 5% |
| <i>Participation</i> | bonus | bonus | bonus | bonus | bonus | bonus | bonus | 3% | bonus |
| <i>Instructors</i> | I1 | I2 | I2 | I1 | I2 | I1 | I3 | I1 | I3 |

D. Exams and Quizzes

Regardless of the delivery mode, mid-term exams were regular, free-response type problem-solving tests. The comprehensive final exam was administered as a multiple-choice test for Fall 1 and Spring 1, and as a free-response test for Fall 2 and Spring 2 semesters. Online and flipped-class students had to physically attend campus for the exams, similar to FtF class students. As a result, there was no probable bias while comparing exam results.

All tests were open book and closed notes, and the duration of the exam was the same for all sessions, i.e., 75 minutes for each of the midterm exams and 120 minutes for the final exam. The instructors came to a consensus while designing the exam questions in collaboration. The questions given for the midterm tests for different classes were not necessarily identical (because the exams were not simultaneous) but were consistent in terms of concept coverage and level of difficulty. The final exam was identical for all classes and administered simultaneously in each semester.

Several quizzes were given in all classes for assessment purposes such that each quiz covered a single concept. In the face-to-face lecture and flipped sessions, the time allotted to each quiz was 15 minutes, and all quizzes were open book and closed notes. In the online setting, students were given a set of five problems for their quizzes, and each problem was selected randomly from a pool of designed questions. Students were required to finish the quiz within an hour.

In the next section, we analyze the data collected from the surveys and the final exam scores. In this paper, we use the average of the final exam grades for statistical analyses, since the final exams for different modes were identical and administered at the same time and location, thereby ensuring that the grade comparison among modes was unbiased from the exam-setting perspective.

III. DATA ANALYSIS

For analysis purposes, student demographics and feedback about educational modes for the "Engineering Economy" course were collected via a questionnaire. For this purpose, separate questionnaires were designed for each mode and distributed online at the end of the semester once internal Institutional Review Board (IRB) approval was obtained. The instructors accessed student responses after the final grades were posted. We were interested in determining the relationship between presentation modes and any student demographics data, student knowledge evaluation, performance, and persistence rates. The statistical analyses provided in the following sections were conducted in Minitab 17 and Excel 2010, and held at the significance level (α) of 0.05. Note that the surveys resulted in a total of 482 complete clean responses: 297 were from face-to-face teaching, 135 from online delivery, and 50 from flipped classroom instruction.

A. Analyzing The Impact Of Instructors On Students' Performance

A critical discussion that may arise in this comparison is that since the instructors teaching online/flipped and face-to-face sessions are different (see Table I), the comparison results might be biased. In this section, we are interested in investigating the impact of instructors on student performance measured by grades and persistence rate, which is the ratio of students who complete the course and is measured by the number of students who participated in the final exam.

Instructors I1 and I2 had been teaching in the FtF mode for four semesters (two years) prior to this study, and both were utilizing the same instructional materials and textbook. To assess the impact of these instructors, the average final exam grades and enrollment numbers of the last four semesters prior to this study are compared at $\alpha = 0.05$, and results are summarized in Tables II.a and II.b and Fig. 1. Note that the initial enrollment number in Table II.a is based on the initially defined capacity by the department as shown to students, and the capacity of the sessions was full on the first day of classes. Table 2b presents the results of comparisons between average grades and persistence rate for different instructors. Results of the analysis, using the t-test of hypothesis, reveal that at the 95% confidence level, there is no significant difference in the average of final grades in classes taught by different instructors in a given semester (i.e., p-value greater than $\alpha = 0.05$). In other words, the two instructors impacted student grades equally. In general, the effect size ratios, using Cohen's d measure, are less than 0.29, which verifies the insignificance of the difference between the two groups. In addition, this shows that the non-overlap percentages of grades vary from 8% to 20% among classes taught by the different instructors.

Fig.1 box plots provide an illustrative comparison between final exam averages of classes taught by instructors I1 and I2. As depicted, the boxes are overlapping, which indicates there is no significant difference between averages.

In addition, no significant difference was observed in student persistence rate between I1 and I2 instructors during Fall I, Fall III, and Spring IV semesters (P-value $> \alpha = 0.05$). In Spring II, the persistence rate varied significantly from one class to another. With our available data, we are not able to explain this discrepancy.

Beginning Fall 1 (see Table 1), the FtF class instructor I2 was replaced with instructor I3, which implies that no prior historical data is available for evaluating the impact of the I1 and I3 instructors in a given instructional mode. However, the adopted course notes and materials were identical for both instructors. As a result, by controlling the evaluation process, exam setting, and homogeneity of the concepts, examples, and class supporting materials, we have tried to minimize any possible discrepancy between instructor impacts on the discussed metrics. The remaining analyses in this paper are based on information collected during Fall 1 and 2, and Spring 1 and 2 semesters (Table I).

Table II. a
DESCRIPTIVE ANALYSIS OF STUDENT GRADES BY INSTRUCTOR 1 (I1) AND INSTRUCTOR 2 (I2)

| | Initial Enrollment | | Number of Students Taking Final | | Final Exam Average | | Final Exam Standard Deviation | | Final Exam Median | | Final Exam Range | |
|-----------|--------------------|----|---------------------------------|----|--------------------|-------|-------------------------------|-------|-------------------|----|------------------|----|
| | I1 | I2 | I1 | I2 | I1 | I2 | I1 | I2 | I1 | I2 | I1 | I2 |
| Fall I | 75 | 75 | 50 | 49 | 72.8 | 68.61 | 13.13 | 19.43 | 73 | 70 | 53 | 76 |
| Spring II | 75 | 75 | 41 | 60 | 63.88 | 62.43 | 12.33 | 12.48 | 64 | 64 | 54 | 58 |
| Fall III | 75 | 75 | 53 | 58 | 58.29 | 62.78 | 18.90 | 12.27 | 63 | 63 | 81 | 46 |
| Spring IV | 75 | 90 | 58 | 79 | 59.2 | 62.8 | 13.50 | 11.80 | 60 | 64 | 60 | 56 |

Table II. b
COMPARING THE IMPACT OF INSTRUCTORS I1 AND I2 ON GRADES AND PERSISTENCE RATE AT 95% CONFIDENCE LEVEL

| | Final Exam Variance Comparison | Normality Test (P-Value) | | Final Exam Average Comparison (t-Test) | | Persistence Comparison (P-Value) |
|-----------|--------------------------------|--------------------------|------|--|-------------|----------------------------------|
| | P-Value | I1 | I2 | P-Value | Effect Size | (P-Value) |
| Fall I | 0.01 | 0.50 | 0.05 | 0.21 | 0.25 | 0.86 |
| Spring II | 0.95 | 0.88 | 0.43 | 0.57 | 0.12 | 0.001 |
| Fall III | 0.00 | 0.04 | 0.27 | 0.14 | 0.29 | 0.35 |
| Spring IV | 0.29 | 0.43 | 0.17 | 0.11 | 0.29 | 0.08 |

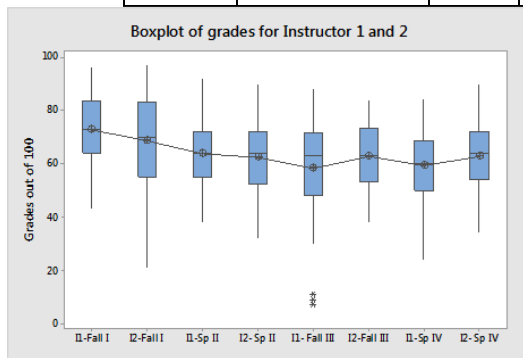


Figure 1. Average historical final exam grades for instructors I1 and I2

B. Analyzing Relationship between Instruction Mode and Student Characteristics

In this section, we have studied student profiles including academic characteristics and some demographics, and compare those in different modes. In other words, we are investigating the relationship between student characteristics and selection of education mode. Among the online students who completed the survey, 35.3% of them were experiencing their first online class. Among flipped class students, 90% did not have any prior flipped classroom experience. In the following subsections, we address several questions as a result of analyzing the collected survey data over two years.

1) Analyzing Relationship between Gender and Choice of Instruction Mode

We analyzed the relation between student gender and choice of instruction mode. Detailed information about gender per class type and semester is summarized in Fig. 2, which shows the percentage of female and male students per instructional delivery method. The contingency table analysis at 95% confidence level reveals that there is no significant difference between the proportion of male and female students in various class

modes since the test statistics $\chi^2_0 = 3.77 < \chi^2_{0.05,2} = 5.99$. In other words, student enrollment in different types of classes is not affected by gender.

2) Analyzing Relationship between Age and Choice of Instruction Mode

In this analysis, we question if there is any statistically significant difference between the average age of the online, FtF, and flipped mode students. Fig. 3 shows the distribution of age for all the class sections.

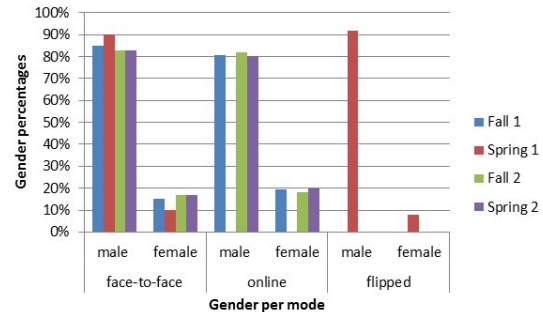


Figure 2. Gender comparison data

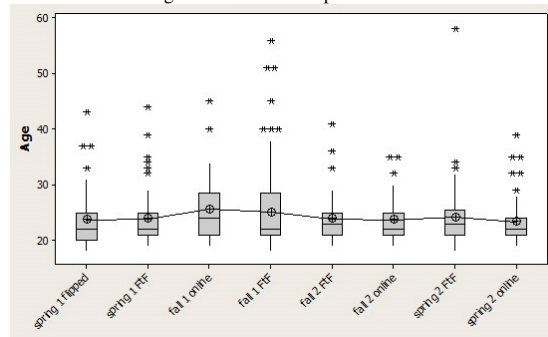


Figure 3. Age distribution for different class sections

The Analysis of Variance (ANOVA) concludes that there is not enough evidence to reject the equality assumption of age average among three different instructional modes at a 95% confidence level, i.e., test statistics $F_0 = 0.7$, and $P\text{-value} = 0.5 > \alpha = 0.05$. As a result, it can be claimed that there is no statistically significant difference between age averages of all three modes.

3) *Analyzing Relationship between Course Load and Choice of Instruction Mode*

Our goal was to determine if there is any significant difference between student course load in different instruction modes. In the first step, we categorized students based on the number of courses in which they were enrolled (Fig. 4). This analysis shows that the most common course load is between four and five courses (i.e., 12 to 15 credit hours). Our hypothesis was whether the average course load was the same for all instruction modes. Using ANOVA analysis, we have concluded that this hypothesis is not supported ($P\text{-value} = 0.024$ and $F_0 = 3.75$). In other words, the average number of courses taken by students differs in different modes, where online students indicate higher load.

4) *Analyzing Relationship between Work Status and Choice of Instruction Mode*

In order to compare the instruction mode enrollments from a student work status perspective, students were asked about their type of employment (full-time, part-time, non-working). Descriptive statistical analyses of the data show that face-to-face instruction has the largest group of non-working students (See Fig. 5). Investigating to determine if work status and instruction mode are independent, the chi-square test concludes that a dependency exists between working status and instruction mode ($\chi^2 = 12.5 > \chi^2_{0.05,4} = 9.488$).

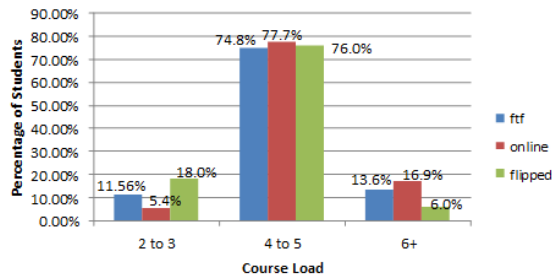


Figure 4. Course load frequency percentage for different instruction modes

As a result, a post hoc Marascuilo procedure was applied to perform a pairwise comparison between different work status categorizations in all three modes. Post hoc analysis results are summarized in Table III, which presents a significant difference between the ratio of part-time and full-time categories in different modes. Note that the pairwise difference is assumed to be significant when the absolute value of the difference exceeds the calculated Marascuilo threshold [24].

Further analyses were performed to investigate the difference between modes for a given work category. We tested if the percentage of part-time, full-time or non-working students in different course delivery modes were equal at the 95% confidence level. The chi-square test statistics (χ^2_0) were calculated for each work category and compared with the rejection threshold $\chi^2_{0.05,2} = 5.991$ (Table IV). For any $\chi^2_0 > \chi^2_{0.05,2} = 5.991$, we can conclude that there is a statistical significant difference between ratios of a given work category in different types of classes. The results show that the percentage of part-time working students is different among instruction modes, whereas the percentage of full-time or non-working students does not differ among instruction modes.

Post-hoc Marascuilo procedure, presented in Table V, reveals that there is a difference between FtF and online instruction modes for part-time working students at the 5% significance level.

TABLE III. COMPARING WORK CATEGORY RATIOS (* SHOWS SIGNIFICANT DIFFERENCE)

| | Difference | Marascuilo Threshold |
|--------------------------|------------|----------------------|
| Part-time vs full-time | 0.23* | 0.17 |
| Part-time vs non-working | 0.08 | 0.16 |
| Full-time vs non-working | 0.15 | 0.17 |

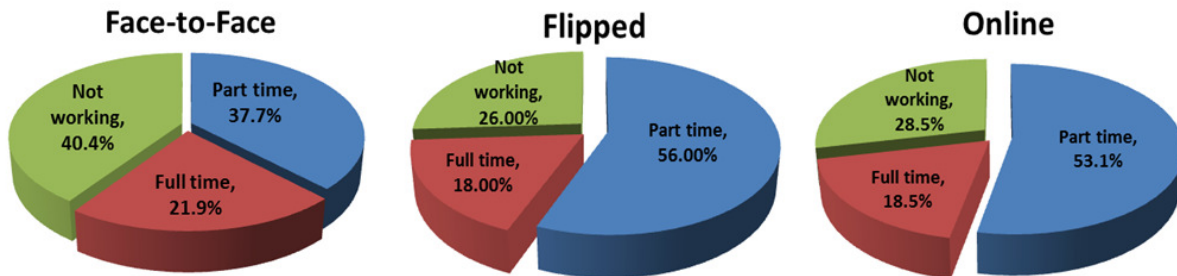


Figure 5. Employment type per education mode

TABLE IV. COMPARING DIFFERENT MODES FOR A GIVEN WORK CATEGORY

| Given Work Status | Test Statistics χ^2_0 | Conclusion |
|-------------------|----------------------------|---|
| Part-time | 6.75* | 6.75 > 5.991, percentage of part-time working students differs significantly between different modes |
| Full-time | 0.7 | 0.7 < 5.991, no significant difference between modes in terms of percentage of full time working students |
| Non-working | 5.05 | 5.05 < 5.991, no significant difference between modes in terms of percentage of non-working students |

TABLE V. PAIRWISE COMPARISON OF PART-TIME WORKING STUDENTS (* SHOWS SIGNIFICANT DIFFERENCE)

| Pairwise comparison | Difference | Marascuilo Threshold |
|---------------------|------------|----------------------|
| FtF-Online | 0.15* | 0.13 |
| FtF-Flipped | 0.18 | 0.19 |
| Online-Flipped | 0.03 | 0.20 |

5) A

analyzing Relationship between Living Distance and Choice of Instruction Mode

In the questionnaire, the distance that students live from campus is categorized into two groups: less than or equal to 20 miles and more than 20 miles (i.e., less than approximately 25 minutes commuting distance, or more, where 25 minutes is the average travel time to work in U.S. based on census data¹). The chi-square test of the hypothesis shows that the living distance from campus is not statistically different (P-value=0.75 > $\alpha=0.05$) among students of different instructional modes at the 95% confidence level ($\chi^2_0 = 0.58 < \chi^2_{0.05,2} = 5.991$), i.e., living distance is not influencing the student choice of enrollment.

6) Analyzing Relationship between Computer Skill and Choice of Instruction Mode

A student’s computer skill level might impact the type of enrollment chosen. In the survey, students report their computer skills as low (1), medium (2), high (3), or (4) very high, and their recommendations about any special instructional mode in two different questions. We were interested in determining if there was any significant difference between learners’ computer skill levels in different modes. The test of hypothesis gives $\chi^2_0 = 7.36 < \chi^2_{0.05,6} = 12.592$ (P-value=0.29 > $\alpha=0.05$), and concludes that there is no statistically significant difference among students’ computer skill levels in different modes. As a result computer skill level and choice of enrollment are independent.

We studied the student responses to determine if computer skill level is related to their “recommended” mode of instruction for this course. Contingency table tests are used to investigate if computer skills and recommended instruction mode are independent, with a

threshold of $\chi^2_{0.05,1} = 3.84$. According to the summarized results in Table VI, computer skill levels and recommendation about instruction mode are independent for all the four listed categories. In addition, a detailed analysis of data from FtF class students indicates that the chance of recommending the flipped mode is higher than recommending the online mode (ratio: 1:34).

7) Analyzing Relationship between students’ mother/first language and Choice of Instruction Mode

Our collected data shows that the percentage of native English speakers in online, FtF, and flipped classes are 66.9%, 53.5%, and 50.0%, respectively. We test the equality of the percentage of the native English speakers in different instruction modes, and observe that there is a significant difference in the percentage of students whose first language is English in the three instructional modes ($\chi^2_0 = 7.9 > \chi^2_{0.05,2} = 5.991$). In other words, the first language has impacted students’ choice of enrollment. The post-hoc Marascuilo procedure shows that the significant difference exists between online and FtF classes, indicating that online classes include more English native speakers.

One other research questions of interest relates to the students’ first language and its impact on their recommendations about a specific instruction mode. Table VII summarizes the results of this analysis.

The detailed analysis of responses from both groups of native English speakers (Group A) and “other” language native speakers (Group B) shows that FtF students whose native language is not English presented a 0.66 times less tendency of recommending the online instruction mode (scenario 1, Table VII). Similarly, based on the second scenario analysis, category B students are 0.55 times less likely to recommend the flipped classroom as a replacement of the FtF instructional mode.

In the third scenario, we observe that the likelihood of online students recommending the FtF mode in lieu of the online class is dependent on their first language (P_value=0.03 < $\alpha = 0.05$). In this case, non-native speakers are 2.92 times more likely to recommend the FtF mode for this course. In the fourth scenario, results indicate no significant difference (P-value = 0.64 > $\alpha = 0.05$) among student recommendations with different languages. This test also concludes that non-English speakers recommend the FtF mode 1.5 times more than the other group of students.

TABLE VI. EVALUATION OF COMPUTER SKILLS VS. STUDENT RECOMMENDATIONS

| Recommendations from | Test of dependency of recommendation to computer skills (P-Value) |
|---------------------------------|---|
| FtF students about online mode | 0.17 ($\chi^2_0 = 1.92$) |
| FtF students about flipped mode | 0.99 ($\chi^2_0 = 0$) |
| Online students about FtF mode | 0.46 ($\chi^2_0 = 0.54$) |
| Flipped students about FtF mode | 0.82 ($\chi^2_0 = 0.05$) |

¹ ACS Census 2009, <https://www.census.gov/prod/2011pubs/acs-15.pdf>

TABLE VII. EVALUATING THE IMPACT OF FIRST LANGUAGE ON STUDENT RECOMMENDATIONS

| Scenario | Recommendations from | Test of dependency of recommendation to first language (P-Value) | Conclusion |
|----------|---|--|--|
| 1 | FtF students about taking this course in online mode | 0.11 | Fail to reject H_0 , recommendation is not dependent on students' first language |
| 2 | FtF students about taking this course in flipped mode | 0.095 | Fail to reject H_0 , recommendation is not dependent on students' first language |
| 3 | Online students about taking this course in FtF mode | 0.03 | Reject H_0 , recommendation is dependent on students' first language |
| 4 | Flipped students about taking this course in FtF mode | 0.64 | Fail to reject H_0 , recommendation is not dependent on students' first language |

Analyzing student responses to their mode of recommendation, regardless of their native language, yields the following information:

- 50.60% of FtF students recommended online instruction, while 68.03% recommended flipped classes (students could recommend both online and flipped modes). Therefore, a significant number of students from the traditional mode are willing to try a new method of learning.
- 58.62% of students from the online mode recommended FtF delivery instead of online classes.
- 29.63% of students from the flipped mode recommended FtF instruction in lieu of flipped classes.

As a result, between the online and flipped class options, the flipped mode seems to be more attractive to students, since it is a compromise between online and FtF instruction modes, i.e., the students can see the benefits of both instruction modes with this instruction mode.

8) Analyzing Why A Student Selects A Particular Mode of Instruction

The survey asked students to rank why they chose to enroll in an instruction mode. Figures 6, 7 and 8 show the frequency of their responses and ranking of reasons for their choice of enrollment. Fig. 6 indicates that instructor and student interactions, and more motivation and organized planning for studying are ranked as the top reasons given by students for their choice in enrolling in the FtF of instruction.

Fig. 7 and Fig. 8 indicate that time and location flexibility are the most common motives for students enrolling in online and flipped classes. Insufficient capacity of FtF classes is the next reason for learners enrolling in online and flipped modes.

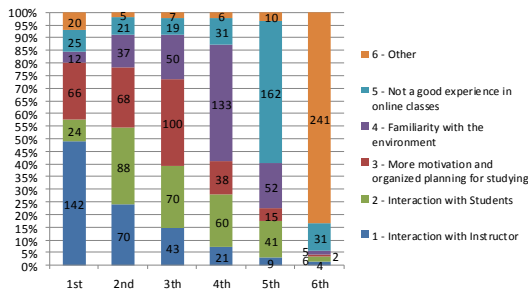


Figure 6. Reasons for enrolling in FtF mode

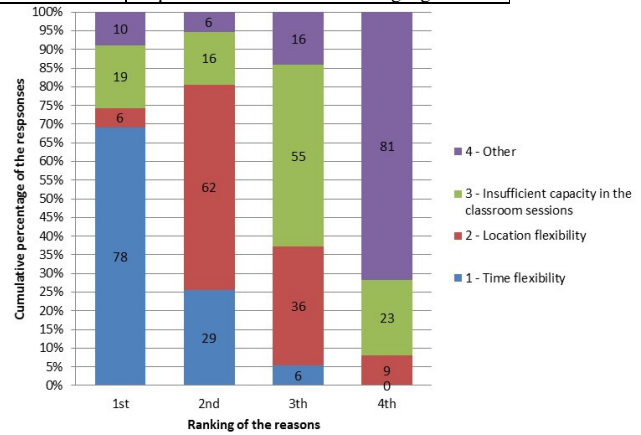


Figure 7. Reasons for enrolling in online mode

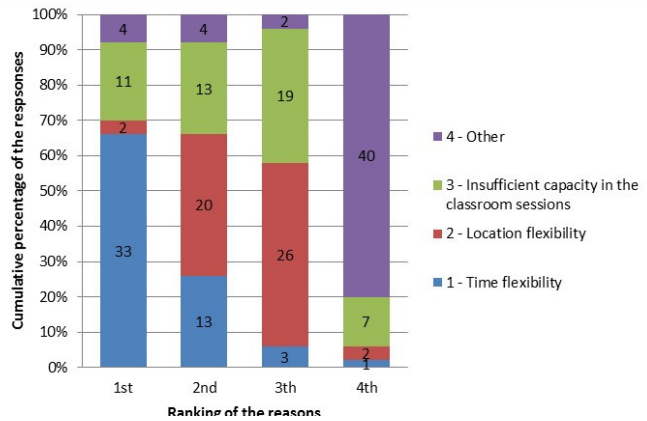


Figure 8. Reasons for enrolling in flipped mode

IV. ANALYZING THE IMPACT OF EDUCATION MODE AND STUDENT EVALUATION OF KNOWLEDGE, PERFORMANCE, AND PERSISTENCE RATE

The following sections compare different instruction modes based on the common quantitative criteria of performance, persistence (or drop) rate, and student evaluation of knowledge.

A. Knowledge Perception And Education Mode

Student self-evaluations of knowledge gained in the "Engineering Economy" course during the semester were analyzed to determine if the developed knowledge was affected by the instructional delivery mode. Students ranked their own level of understanding from 1 (very low) to 7 (very high). The relative rankings of perceptions from student perspectives in each mode are depicted in Fig 9.

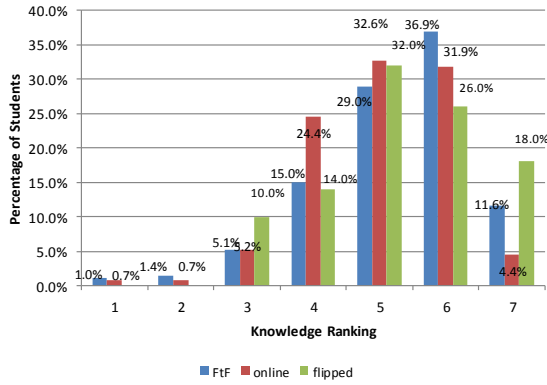


Figure 9. Ranking of the knowledge and delivery mode

Note that 77.5%, 76%, and 68.9% of FtF, flipped, and online students rank their perceived knowledge as medium-high (5) or more (6 or 7), respectively. Furthermore, statistical analyses reveal that percentages of students who rank their developed knowledge level as medium-high or more are the same for all three modes of instruction

$$\chi_0^2 = 3.66 < \chi_{0.05,2}^2 = 5.99, P - value = 0.16 > \alpha = 0.05.$$

Although, this difference between instructional delivery methods is not statistically significant, it can be observed that students in FtF (77.5%) and flipped (76%) classes have higher self-confidence than students in online classes (68.9%) when assessing their knowledge level. This is also a concern that arises in the literature, pointing out that “statistical” and “actual” significance may not necessarily be the same [11].

B. Performance And Education Mode

ANOVA was used to investigate whether there was any significant difference in performance among various modes of learning. Since the final test was comprehensive and the exam settings were identical for different modes, the final exam grades were used for an unbiased comparison. For this purpose, the grades are combined per mode and analyses are conducted for three categories of online, FtF, and flipped. Performing the Bartlett test of hypothesis to assess the equality of the variances of the grades for the three modes gives P-value= 0.001 < $\alpha = 0.05$, which implies that the difference between variances is statistically significant. The Bonferroni 95% confidence

intervals represent a larger variance for the online mode (18.03, 24.34), in comparison to the flipped (11.41, 17.41) and FtF (14.8, 17.97) classes.

The cumulative ANOVA analysis using unequal variances assumption shows that at 95% confidence level, there is no significant difference between final exam averages in various modes with P-value= 0.18 > $\alpha = 0.05$. Such a conclusion is consistent with most of the published research papers in this area as discussed in the literature review. It is worth mentioning that all the ANOVA assumptions on residuals, $\epsilon \sim N(0, \sigma^2)$, are satisfied in this analysis. Fig. 10 provides a comparative illustration of grades for all three modes, showing the highest average, but not statistically significant, for the FtF classes.

Table VIII presents a summary of information about grades out of 100 points for each section.

In another analysis on grades, the student performance are compared per semester, and the P-value of the comparisons are reported in Table IX. As shown in Table IX, all the P-values > $\alpha = 0.05$, indicating no significant difference in student grades in different modes in a given term.

A. Persistence Rate And Education Mode

We also tested if there is a difference in the drop rate among the three modes of instruction. Statistical analyses reveal that there is no statistically significant difference in drop rates among various modes at 95% confidence level ($\chi_0^2 = 1.13 < \chi_{0.05,2}^2 = 5.991$). As a result, persistence rate, which is defined as “1- drop rate” is not affected by education mode.

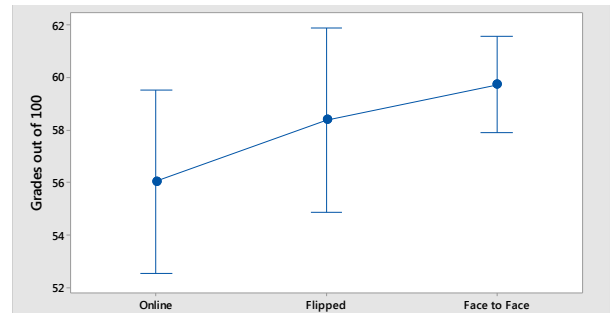


Figure 10. Interval plot of grades for three modes

TABLE VIII. FINAL EXAM GRADE DATA

| | Online Fall 1 | Face-to-Face 1 Fall 1 | Face-to-Face 2 Fall 1 | Flipped Spring 1 | Face-to-Face Spring 1 | Online Fall 2 | Face-to-Face Fall 2 | Online Spring 2 | Face-to-Face Spring 2 |
|---------------------------|------------------|--------------------------|--------------------------|---------------------|--------------------------|------------------|------------------------|--------------------|--------------------------|
| Final Exam Average | 57.4 | 58.9 | | 58.4 | 55.8 | 63.8 | 72.5 | 51.2 | 54.9 |
| Final Exam stdv | 10.72 | 12.08 | | 13.82 | 11.87 | 21.51 | 20.97 | 21.75 | 17.87 |
| Final Exam Median | 58 | 58 | | 57 | 54 | 67 | 79 | 54.5 | 54 |
| Final Exam Range | 44 | 70 | | 58 | 52 | 82 | 76 | 88.5 | 83 |

TABLE IX. COMPARING STUDENT PERFORMANCE PER SEMESTER

| | P-value |
|----------|---------|
| Fall 1 | 0.57 |
| Spring 1 | 0.252 |
| Fall 2 | 0.052 |
| Spring 2 | 0.292 |

II. LESSONS LEARNED

In addition to the micro level analysis of student profiles in different modes, this study provides some insights about the current state of the course structure and possible areas of improvement. These insights can be helpful in enhancing learning process and increasing student satisfaction. The obtained insights are summarized as follows:

- Instilling entrepreneurial mindset among engineering students: To enhance the learning process, improve material retention and broaden student knowledge, more real life case studies and open ended analytical problems can be presented to the students as part of the course load. This practice enables students to think about the application of the methods they have learned to create value.
- Providing more visualization in online instructional videos: Updating the videos to include short texts addressing the key words might be a great assistance to students specifically the ones whose native language is not English. This is in addition to the video captioning, and is aiming at attracting students' attention to key concepts.
- Exam type: It will be more beneficial to the student to administer free-response exams for this course. Due to the nature of the course which is mainly based on problem solving, students are more prone to make mistake in calculations. Using free response tests enable student to receive partial credits.
- The online homework/quiz database mechanism is an extremely helpful method because it enables the instructors to create their own question banks, customize the questions, and is free of charge to students. It also ensures the independent work of the students. This approach is applicable to any other course, especially engineering classes which are more problem-solving based.
- Since, flipped mode was better received by students, it can be suggested as the recommend mode for the Engineering Economy course in this school.

III. CONCLUSION

This research presents a comparative analysis among face-to-face, online, and flipped modes of instruction for the "Engineering Economy", a core undergraduate engineering course. To collect information on students' background and demographics, a questionnaire was designed for each mode and distributed online over four semesters. This study is based on data collected over two years, and collecting more information over more

semesters can strengthen the validity of the obtained conclusions.

Several statistical analyses were performed at the 95% confidence level to discern the relationship between these characteristics and the delivery mode. The impact of instruction modes on student self-evaluation of perceived knowledge, performance, and persistence rate was investigated in detail. A summary of these analyses is provided in Table X.

Analyses indicate no statistically significant difference between student self-evaluation of knowledge, performance and drop rates as the most common comparison criteria used in the relevant literature studies. Also, analyses show that gender, age, living distance from campus, course load, and computer skills do not influence student choice of enrollment in this study. First language and work status represent a significant difference among different education modes. Non-English native speakers show more desire for FtF type classes, and in general, flipped mode seems to be more attractive than online classes to the learners. Student self-evaluation of knowledge does not differ among the three modes as well.

In addition, students in FtF instruction mention that greater interaction with instructor and other students, and more organization, and motivation in studying are the main reasons why they decided to enroll in FtF classes. Time and location flexibility are ranked as the dominant reasons for students registering in online mode.

It is worth mentioning that in this study, we compared different instruction modes from different perspectives, and analyzing the impact of these factors on student performance is not within the scope of this research. Proposing a multiple regression model to predict performance as a function of all these factors can be an area for future study.

TABLE X. SUMMARY OF ANALYSES

| Comparison | Conclusion |
|--|---------------------------|
| Gender vs. instruction mode | No significant difference |
| Age vs. instruction mode | No significant difference |
| Course load vs. instruction mode | Significant difference |
| Work status vs. instruction mode | Significant difference |
| Living distance vs. instruction mode | No significant difference |
| Computer skills vs. students' recommendation | No significant difference |
| First language vs. students' recommendation | Significant difference |
| Knowledge perception vs. instruction mode | No significant difference |
| Performance vs. instruction mode | No significant difference |
| Drop rate vs. instruction mode | No significant difference |

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AUTHORS

F. Ghazi Nezami (corresponding author) is an Assistant Professor in the Industrial and Manufacturing Engineering Department at Kettering University, Flint, MI, 48504 USA (e-mail: fghazinezami@kettering.edu).

M.B. Yildirim is a Professor of Industrial and Manufacturing Engineering Department at Wichita State University, Wichita, KS, 67260 USA. (e-mail: bayram.yildirim@wichita.edu).

G. Grossi Crema was an undergraduate student at the Industrial and Manufacturing Engineering Department at Kettering University Flint, MI, 48504 USA (e-mail: giovannicrema@hotmail.com)