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# Impact of COVID-19 on Engineering and Technology Course Outcomes

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# Impact of COVID-19 on Engineering and Technology Course Outcomes


## Abstract

Student learning experience can be disrupted significantly if the plan of study changes suddenly like it did due to the COVID-19 global pandemic in March 2020. The purpose of this paper is to compare the outcomes of two courses at Indiana State University such as student grades, number of students dropping the course, available resources, etc. before (pre-) and during (post-) the pandemic. The compared two courses are from two separate departments where one course is Engineering Economics and the other course is DC Circuits and Design. The course DC Circuits and Design has both theory and laboratory components. The null hypothesis is that there exists no difference between the course grade outcomes of pre- and post- pandemic. The hypothesis has been tested using Chi-square goodness of fit test at p=0.1. Engineering Economics on-campus post-unplanned pandemic section in Spring 2020 is found to be significantly different from the pre-pandemic in Spring 2019. However, in the online section, there is no difference between the post- and pre- because the online section is planned for virtual mode. Similar finding is reached for DC Circuits and Design that the post-unplanned pandemic section in Spring 2020 is found to be significantly different from the pre-pandemic in Fall 2019; but the post-planned in Fall 2020 is found to be statistically same as the pre-pandemic. Practical implication of this study will be helpful in planning to teach courses for pandemics or other situations outside of our control.


## Introduction

A planned, organized, and resourceful environment is important for expected student learning outcomes. These learning outcomes or experiences can be impacted if the plan of study changes abruptly like it did due to the COVID-19 global pandemic in March 2020. This paper aims to compare the outcomes such as student grades, number of students dropping the course, available resources, grading criteria, etc. of two courses before (pre-) and during (post-) the pandemic. The compared two courses are from two separate departments where one course is Engineering Economics and the other course is DC Circuits and Design. The course DC Circuits and Design has both theory and laboratory components.

First course: Engineering Economics was offered on-campus in two sections in Spring 2019 with combined enrollment as 53 students. One section was offered online with 37 students. All the three sections were taught by the same instructor (Author-3). These sections were not hampered by any unplanned situations during the semester. In Spring 2020, four sections were offered: two on-campus sections with 16 and 40 students, and two online with 40 and 45 students. Two instructors: Author-1 and Author-3 taught the course. The worldwide pandemic due to COVID-19 hit in the middle of the spring semester and all sections were changed to virtual mode. A comparison has been made between these two Spring semesters: 2019 and 2020 for this engineering economics course.

In addition, DC Circuits and Design course that has laboratory component along with the theory component has been studied to explore the effect of COVID-19 on a course with laboratory component. This course was taught by Author-2 in Fall 2019 to a class of 23 students. This section was not impacted by any unusual circumstances. During Spring 2020, one on-campus

section of this course was taught by Author-2 to a class of 15 students. Due to the pandemic this section was converted to remote learning mode like all other courses from the tenth week of semester on a short notice. During Fall 2020, two sections of this course: one with 11 students and another with 18 students were taught by Author-2 while maintaining the precautions for COVID-19. The details of instructions format are provided under Section Data and Results. The purpose of this paper is to investigate if the sudden change of instruction mode due to the COVID-19 pandemic has any effect on the course outcomes in the form of student grades, number of students dropping the course, available resources, etc. If there are any impacts, what can we do in the future in case of such sudden change to address these? This article also discusses how a planned semester is conducted during Fall-2020 while maintaining the precautions of pandemic and how the results of such a planned semester amid a challenge of pandemic compares to the semester which did not have this challenge.

The article has been organized as follows. Next section discusses relevant literature review. This is followed by methodology used in this study. Then results have been presented. Lastly, conclusion has been summarized.

## Literature Review

This section summarizes a review of literature related to pandemic, two courses: Engineering Economics and DC Circuit & Design, and comparing two independent groups using Chi-square.

### Pandemic

A pandemic is described as an epidemic which spreads across many countries and affects numerous people on a large scale. An epidemic occurs when an agent and susceptible hosts are present in sufficient numbers and the agent can be effectively borne from a source to the susceptible hosts [1]. The recent COVID-19 pandemic is a serious global health issue [2]. As of January 13, 2021, worldwide there were 92.264M confirmed cases of COVID-19 and 1.976M deaths due to this pandemic, whereas in the US alone there were 23.047M confirmed cases and 0.384M deaths [3]. The coronavirus disease 2019 (COVID-19) is caused due to infection from a novel coronavirus which was first found in Wuhan, China, in December 2019 [4]. CDC is working closely with the World Health Organization (WHO) and other partners to assist countries to prepare for and respond to COVID-19 [2]. Bhandari, Badar & Childress [5] have reported how a community healthcare setting used Lean Six Sigma methodology to plan for utilizing the resources effectively because of the surge in number of patients as a result of the COVID-19 pandemic. However, since pandemics are unplanned events, many organizations and countries find extremely difficult to have necessary resources, expertise and funds to fight the impact of a global pandemic [6].

### Engineering Economics

Engineering Economics course was studied earlier by Alberts, Badar & El-Mansour [7] for engineering technology curriculum at Indiana State University. Now this course is taken by both engineering and engineering technology students at this university. Since the course is offered on-campus as well as online for traditional, non-traditional, and transfer students, Alberts et al.

[7] advised to include hands-on and experiential activities in the course. Galati & Hartman [8] used a business game in teaching engineering economy. The game activities included choices among product designs, product manufacturing, equipment replacement decisions, raw material procurement, scheduling of production, trading of 'shares' in a stock market, etc. Nock [9] introduced a game "Let's Bid!" to encourage interest and understanding of engineering economic concepts. Badar & Bozai [10] recommended industry experience and partnership with the curriculum. Tas & Yeloglu [11] stressed a similar need for the partnership between universities and industries to enhance student learning and knowledge transfer. Al-Odeh, McLeod & Badar [12] re-designed a Simulated Industrial Manufacturing Company (SIMCO) course at a University using a lean tool: Value Stream Mapping. This course provides experiential learning of how industry works to students in a classroom setting.

DC Circuits and Design

This course introduces students to elementary circuits analysis and design involving DC (direct current). Schultz [13] 12$^{th}$ edition was used as a textbook. The course has a laboratory component as well. The laboratory experiments involve building electrical circuits on solderless breadboard and measuring various electrical quantities using digital multimeter. This is a required course for Electronics Engineering Technology, Automation and Control Engineering Technology, Information Technology, and Computer Engineering Technology programs. Students from some other majors of College of Technology also take this course.

Comparing Two Independent Groups Using Chi-Square

The Chi-square statistic can be used to compare two or more independent groups without knowing their population distribution or parameters [14-15, 17-18]. Observed and expected frequencies have to be obtained. Schober & Vetter [19] have used Chi-square test in medical research to compare observed and expected frequencies.

Pandemic affects health, economy, life style, and other aspects. Because COVID-19 pandemic started in Dec 2019 [4], there hasn't been enough studies to investigate its effects on student learning. This paper is an attempt to fill this gap.

## Methodology

The two courses are compared in terms of student grades, number of students dropping the course, available resources, and grading criteria in the semester before the pandemic (pre-) with those of the semester during the pandemic (post-). The data is obtained from the Faculty Activity Database for each instructor at Indiana State University. The null hypothesis is that there exists no difference between the course grade outcomes of pre- and post- pandemic. The hypothesis has been tested using Chi-square goodness of fit test [14]. Numbers of students earning specific grades of the pre- have been considered as expected frequencies. These have been converted to the respective probabilities. For the post-pandemic enrollment number (n), observed frequencies for different grades have been recorded from the University database. With the expected probabilities already determined, expected frequencies have been computed for n corresponding to the post-enrollment.

## Data and Results

This section describes the data analysis and results for the two courses considered in this work.

Engineering Economics

The course data has been compared for the Spring 2019 semester (pre-pandemic) with the Spring 2020 semester (post-unplanned pandemic).

*Pre-Pandemic Spring 2019*

Engineering Economics was offered on-campus in two sections in Spring 2019 with the combined enrollment of 53 students, and one section was offered online with 37 students. All the three sections were taught by Author-3. Newnan et al. [16] 12$^{th}$ edition was used as the textbook.

*Post-Unplanned Pandemic Spring 2020*

In Spring 2020, four sections were offered: two on-campus sections with 16 and 40 students, and two online with 40 and 45 students. Two instructors: Author-1 and Author-3 taught the course. Newnan et al. [16] 14$^{th}$ edition was used as the textbook. After nine weeks into the semester, in the middle of March 2020 due to the COVID-19 pandemic, the university decided to change the mode of all course delivery to virtual only in order to avoid any physical meetings. The online section students were already in the virtual mode, i.e., receiving the learning modules, recorded lecture videos, discussion forums, assignments, exams, group project, etc. via Blackboard course learning management and interacting with the instructor via email or Blackboard. But the on-campus section students were used to going to the class and interacting with the instructor and peer students in addition to accessing the course Blackboard website for extra information. For them, going to fully virtual was a sudden change, which they were not prepared for. Now they were also forced to access the recorded lectures via Blackboard.

A comparison has been made between these two Spring semesters: 2019 and 2020 for this engineering economics course. Author-3 taught this course in pre-pandemic in Spring 2019 as well as post- (during the pandemic) in Spring 2020. Author-1 taught in Spring 2020 only, so his classes were not included in the hypothesis testing. Author-3 on-campus section of pre- has been compared with the on-campus of post-, and online section of pre- has been compared with the online of post-. Author-3 on-campus and online grades for pre-pandemic (Spring 2019) have been shown in Table 1. Pre-pandemic has been considered as expected to compare the post-data for Chi-square goodness of fit test. During (post-) pandemic (Spring 2020) data is shown in Table 2. It can be noted that the difference in enrollment in Spring 2020 is due to the fact that Author-3 taught only one section of the on-campus class.

Table 1. Pre-pandemic (Spring 2019) student grades in Engineering Economics of Author-3

| | On-campus (53) | | Online (36) | |
|---|---|---|---|---|
| Grades | Number of students | Expected Probability | Frequency | Expected Probability |
| A | 11 | 0.208 | 7 | 0.194 |
| B | 23 | 0.434 | 17 | 0.472 |
| C, D, F, IN, W | 19 | 0.358 | 12 | 0.333 |

Table 2. During or Post-pandemic and unplanned (Spring 2020) student grades in Engineering Economics of Author-3

| | On-campus (16) | Online (40) |
|---|---|---|
| Grades | Number of students | Number of students |
| A | 0 | 5 |
| B | 3 | 18 |
| C, D, F, IN, W | 13 | 17 |

This work aims to compare the post- with pre-, the post- data corresponds to the observed frequencies in Table 3. The expected frequencies in Table 3 have been computed by multiplying the probabilities in Table 1 for pre- with the total enrollment in Table 2 for on-campus and online sections. The data in Table 3 has been analyzed for the null hypothesis using Chi-square test for a significance level (p-value) of 0.1. One expected frequency is lower than 3 in Table 3. Lowest expected frequency is a debatable issue among the researchers, some suggest 3, but others consider 1 or 2 if most of the other expected frequencies are 5 and above[14]. There are three grade categories or outcomes (k=3), so degree of freedom (df) = k-1-m = 2 as no parameters (m=0) are being estimated from the sample statistics. The Chi-square statistic is $\chi^2 = \sum_{i=1}^{i=3} \frac{(O_i - E_i)^2}{E_i}$ and critical value at p=0.1 is $\chi^2_{0.9,2}$ = 4.6 [15]. For the on-campus data in Table 3, Chi-square statistic = 14.76 > critical value of 4.6, null hypothesis is rejected. This means the grade outcomes of the on-campus section of during the pandemic (post- and unplanned) are significantly different from the pre-pandemic. However, for the online data in Table 3, Chi-square statistic = 2.0427 < critical value. This means for the online section, there is no significant difference between the post-(unplanned) pandemic and pre-pandemic.

Table 3. Engineering Economics course data for Chi-square goodness of fit test for Author-3

| | Post-: On-campus (16) | | Post-: Online (40) | |
|---|---|---|---|---|
| Grades | Observed frequency, $O_i$ | Expected frequency, $E_i$ | Observed Frequency, $O_i$ | Expected frequency, $E_i$ |
| A | 0 | 3.32 | 5 | 7.78 |
| B | 3 | 6.94 | 18 | 18.89 |
| C, D, F, IN, W | 13 | 5.74 | 10 | 13.33 |

Author-1 joined the university in August 2019 and taught Engineering Economics in Spring 2020. His class grade outcomes are presented in Table 4. Since he hadn't taught this course before, his student grades weren't compared. It's presented here just for information.

Table 4. During or Post-pandemic and unplanned (Spring 2020) student grades in Engineering Economics of Author-1

| | On-campus (31) | Online (39) |
|---|---|---|
| Grades | Number of students | Number of students |
| A | 8 | 27 |
| B | 15 | 6 |
| C, D, F, IN, W | 8 | 6 |

DC Circuits and Design

*Pre-Pandemic Fall 2019*

Author-2 taught this class in Fall 2019. Student grade outcomes are presented in Table 5. This data is considered as pre-pandemic. Author-2 taught the course in Spring 2020 when the pandemic occurred. This is the case of post-unplanned. Author-2 again taught in Fall 2020, which is considered as post-planned. The grade outcomes for Spring 2020 and Fall 2020 are displayed in Table 6. These outcomes have been compared with the pre-pandemic outcomes in Table 5 using Chi-square goodness of fit test at significance p=0.1.

Table 5. Pre-pandemic (Fall 2019) student grades in DC Circuits and Design of Author-2

| | (23) | |
|---|---|---|
| Grades | Number of students | Expected Probability |
| A | 10 | 0.435 |
| B | 7 | 0.304 |
| C, D, F, IN, W | 6 | 0.261 |

Table 6. DC Circuits and Design course data for Chi-square goodness of fit test for Author-2

| | Post-unplanned (15) | | Post-planned (32) | |
|---|---|---|---|---|
| Grades | Observed frequency, $O_i$ | Expected frequency, $E_i$ | Observed Frequency, $O_i$ | Expected frequency, $E_i$ |
| A | 2 | 6.52 | 16 | 13.91 |
| B | 7 | 4.57 | 6 | 9.74 |
| C, D, F, IN, W | 6 | 3.91 | 10 | 8.35 |

*Post-Unplanned Pandemic Spring 2020*

Initially there were 15 students enrolled in the class as shown in Table 6: column 2. One student withdrew with a 'W' grade. The students had regularly taken classes on-campus for nine weeks by the time instructions moved to remote learning mode due to pandemic. During remote learning time, lectures were delivered as asynchronous video lectures on the scheduled lecture days. The main challenge was conducting laboratory experiments. Students had completed seven labs on-campus and learned the required hands-on skills of developing DC electrical circuits on breadboard and measuring electrical quantities using digital multimeter. During remote learning time students were introduced to simulation software NI Multisim using which they can simulate the remaining laboratory experiments. However, since the software is not free, instructor considered it inappropriate to incur an added expense on students during a time of challenge. Therefore, simulation of lab experiments were given as optional assignments which have bonus credit. Instructor provided students with the instructions on how laboratory experiments can be performed using simulation software. One of the experiments during this time involved designing a circuit and since that experiment did not involve simulation or laboratory hardware, it was made mandatory for students to perform. This way students performed 80% of laboratory experiments during this semester.

*Post-Planned Pandemic Fall 2020*
In Fall 2020, on-campus classes were offered with reduced capacity in light of the COVID-19 pandemic. Two sections: Section 001 and 002 were offered with a combined enrollment of 32 students (see Table 6: column 4).

Section-001: Total enrolled students were 13 initially, but two (2) students withdrew with 'W' grade. This section had about half of class total capacity. So, both theory and lab classes were conducted in person. Pre Covid-19 students used to perform laboratory experiments in groups of two. However, during Covid-19 students performed experiments individually. The class performed all the experiments as the pre covid-19 class.

Section-002: Total number of initial enrolled students was 19. One student withdrew with a 'W' grade. This section had more than half of class total capacity. So, class was taught in a hybrid mode with theory lectures taught as synchronous online sessions and lab classes were conducted in-person with half of the class present at a time. Online lectures were conducted on Zoom platform. Pre Covid-19 students used to perform laboratory experiments in groups of two. However, during Covid-19 students performed experiments individually. The class performed all the experiments as in-person experiments except the last experiment. It was converted to online simulation demonstration due to classes converted to online mode in the last two weeks of fall semester.

Readers can refer to the description before Table 3 for the Chi-square calculations. For the post-unplanned Spring 2020 data in Table 6, Chi-square statistic = 5.547 > critical value of 4.6, null hypothesis is rejected. This means the grade outcomes of the post-unplanned are significantly different from the pre-pandemic of Fall 2019. However, for the post-planned Fall 2020 data in Table 6, Chi-square statistic = 2.076 < critical value. This means there is no significant difference between the post-planned and pre-pandemic.

**Concluding Remarks**

The purpose of this paper is to investigate if the sudden change of instruction mode due to the COVID-19 pandemic has any effect on the course outcomes in terms of student grades, number of students dropping the course, available resources, etc. The compared two courses are from two separate departments where one course is Engineering Economics and the other course is DC Circuits and Design. The course DC Circuits and Design has both theory and laboratory components. Engineering economics course was offered in Spring 2019 before the COVID-19 pandemic in three sections: two sections were taught in class (53 students) and another section via online (37 students). All the three sections were taught by the same instructor (Author-3). In Spring 2020, four sections were offered: two on-campus sections with 16 and 40 students, and two online with 40 and 45 students. Two instructors: Author-1 and Author-3 taught the course. The COVID-19 pandemic hit in the middle of the spring semester and all sections were changed to virtual mode. A comparison has been made between these two Spring semesters: 2019 and 2020 for this engineering economics course.

In addition, DC Circuits and Design course that has laboratory component along with the theory component has been studied to explore the effect of COVID-19 on a course with laboratory component. This course was taught by Author-2 in Fall 2019 to a class of 23 students. This section was not impacted by any unusual circumstances. In Spring 2020, one section of this was taught by Author-2 to a class of 15 students. This Spring 2020 section was impacted by COVID-19 and is referred as post-unplanned. This course is also taught during Fall 2020 with a plan to maintain the precautions for COVID-19. Two sections of this course: one with 11 students and another with 18 students were taught during Fall 2020. These sections from Fall 2020 are referred as post-planned.

The null hypothesis is that there exists no difference between the course grade outcomes of pre- and post- pandemic. The hypothesis has been tested using Chi-square goodness of fit test at $p=0.1$. Engineering Economics on-campus post-unplanned pandemic section is found to be significantly different from the pre-pandemic. However, in the online section, there is no difference between the post- and pre- because the online section is planned for remote mode. Similar finding is reached for DC Circuits and Design that the post-unplanned pandemic section (Spring 2020) is found to be significantly different from the pre-pandemic; but the post-planned (Fall 2020) is found to be statistically same as the pre-pandemic.

The significant difference between the grades of pre-pandemic and post-unplanned pandemic sessions for two different courses in different departments indicate that sudden disruption to the plan of study by global pandemic did impact the student learning. It is also worth mentioning here that the university administration has realized the impact of sudden pandemic on students learning. The University administration had provided students with the choice of choosing Satisfactory/Unsatisfactory (S/U) grade instead of regular letter grade for post-unplanned pandemic semester (Spring 2020). The choice of students was not shared with instructors. Instructors had performed remote instructions and assigned letter grades to students. Therefore, the grades reported in this paper are also letter grades.

This study will be useful in planning for pandemics in the future as it finds that the post-planned pandemic student outcome is same as the pre-pandemic. Therefore, in case of the possibility of any pandemics or other situations outside of our control, it’s better to plan for the pandemics as if these were happening rather than ignoring until the pandemics occur.

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