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Board 66: A Comparison Study: Challenges and Advantages of Offering Online Graduate Level Statistical Course

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A Comparison Study: Challenges and Advantages of Offering Online Graduate Level Statistical Course

Abstract

Conveying mathematical graduate-level courses online can be challenging. A graduate-level course in applied statistical process control and experimental design has been offered since 2015. This course includes three main themes: (1) probability theory with discrete and continuous probability distributions, (2) statistical tools for estimation, hypothesis testing, and control charts, and (3) 2^k full and fractional experimental designs and analysis. After three years of offering the in-person class, the program moved to an online modality to reach more professional students. All materials, modules, assignments, exams, and instructors remained the same between in-person and online modalities. The study compares the performance of students in the in-person and online cohorts of the graduate-level statistical class. The results evaluate the students' abilities in four topics: probability, hypothesis testing, experimental design, and manipulating the Minitab statistical software package. The study results demonstrate the strengths and weaknesses of conveying graduate-level statistical courses online. Student performance is not associated with gender or the time since completing a bachelor's degree but is related to the characteristics of the learning modules and advantages of online learning.

Introduction

The implementation of fully online courses, whether synchronous or asynchronous, is happening more frequently in order to reach a wider audience, including students who live far away from a university [1]–[3]. Asynchronous online courses offer the advantage of reaching a larger number of students and providing more flexible schedules for students who have full-time jobs while taking continuing education courses during their free time [4]. Another benefit of asynchronous online learning is that students can review learning modules multiple times until they fully understand the material, without having to worry about missing a class or falling behind [5]. This makes it easier for students to balance their academic pursuits with work and other personal obligations [5]. On the other hand, there are also some potential disadvantages that students should consider. One key drawback is the lack of in-person interaction with instructors and peers, which can be important for building relationships and networking, such as students in online courses reported feeling less connected to their instructors and peers than students in traditional in-person courses [6]. In addition, students may have limited access to reliable internet or may struggle with using online learning platforms. This can be particularly challenging for students in areas with limited internet infrastructure or who may be less familiar with technology [7].

The authors' institute offers a two-year Master of Manufacturing Management (MMM) program, which has been designed to meet the specific needs of manufacturers since 2015. The program focuses on building professional skills in engineering and management, thereby preparing students to lead in the manufacturing sector. Students learn from engaged faculty who bring expertise in areas such as engineering statistics, lean techniques, product delivery, six sigma quality, and modern supply chain management practices.

All students in the MMM program have full-time jobs, and most work in the manufacturing sector in the local community, such as transportation, aerospace, or plastic injection, etc. Students attend in-person classes two evenings a week in pursuit of their master's degree. In 2018, the school decided to expand the program to reach more potential professional students by transitioning from an in-person program to an asynchronous online graduate program. All in-person classes were changed to asynchronous online learning modalities. Students have access to course learning modules and resources through the university's online course management system.

The graduate-level engineering statistics class in the MMM program covers the concepts and techniques of statistical process control and the design of experiments. The course includes three main themes: (1) probability theory with discrete and continuous probability distributions; (2) statistical tools for estimation and testing of hypotheses; and (3) 2^k full and fractional experimental designs and analysis. The detailed learning topics within each of these themes are shown in Table 1.

Table 1. Three Main Learning Modules for the Course

Probability Distributions	**Testing of Hypotheses**	**Experimental Designs**
● Random variables, PDFs, and CDFs Discrete Distributions: ● Discrete uniform ● Binomial ● Geometric ● Negative binomial ● Hypergeometric ● Poisson Continuous Distributions: ● Continuous uniform ● Normal ● Exponential ● Weibull	● One sample z-test ● One sample t-test ● One sample χ^2 test ● Tests on a proportion ● Two samples z-test ● Two samples t-test ● Paired t-test ● Two samples F-test ● Tests on two proportions	● Analysis of Variance (ANOVA) ● Randomized Complete Block Design ● Multiple Comparisons Following the ANOVA ● 2^k Full and Fractional designs

Student and Course Performance Evaluations

Each module of the course had four weekly quizzes to evaluate students' performance, consisting of three written quizzes and one computer-based quiz to assess their ability in using the statistical software package, Minitab. After the completion of four quizzes, one exam was given to evaluate students' performance on the specific module. For the entire class, a total of twelve quizzes and three exams were used to assess the students. The quizzes and exams contributed 40% and 60%, respectively, to the semester grade.

In-person class

The in-person class followed a typical lecture style for the in-person classroom instruction. The instructor primarily taught using a chalkboard and also used PowerPoint slides to project key concepts and examples onto the screen. Figure 1 shows the setup for the in-person instruction. The slides were provided on the university's course management system and students could access them in advance. Students attended class two evenings a week, with each class session lasting 75 minutes. Weekly quizzes were held during the second class of the week and typically lasted 25 minutes. The Minitab quiz was a take-home quiz for students to complete over the weekend. The exams were 75-minute written exams taken during class time. Both the quizzes and the exams were closed-book and closed-notes evaluations.

Figure 1. In-person class for confidence interval on the ratio of two variables. Chalkboard used in combination with projected PowerPoint slides on screen.

Asynchronous Online Course

For the online class, the instructor worked closely with a course designer to move the teaching materials onto the university-wide web-based course management system. The modality used in the online class was to present key concepts with a brief description on a webpage, with embedded videos on the page to explain the concepts or examples. The instructor used PowerPoint slides and explained the concepts orally while adding handwritten notes to the slides. All videos were made and recorded using a tablet, allowing students only to hear the instructor's voice, and read the synchronized handwriting on the slides. Figure 2 shows the layout and configuration of the online class webpage. Since each video only explained one concept or example, the videos were typically five to seven minutes long. Students could change the video size to full screen mode and adjust the playback speed based on their preferences and learning pace. They could review the videos anytime and anywhere once they logged into the course management system and could revisit the material as many times as desired.

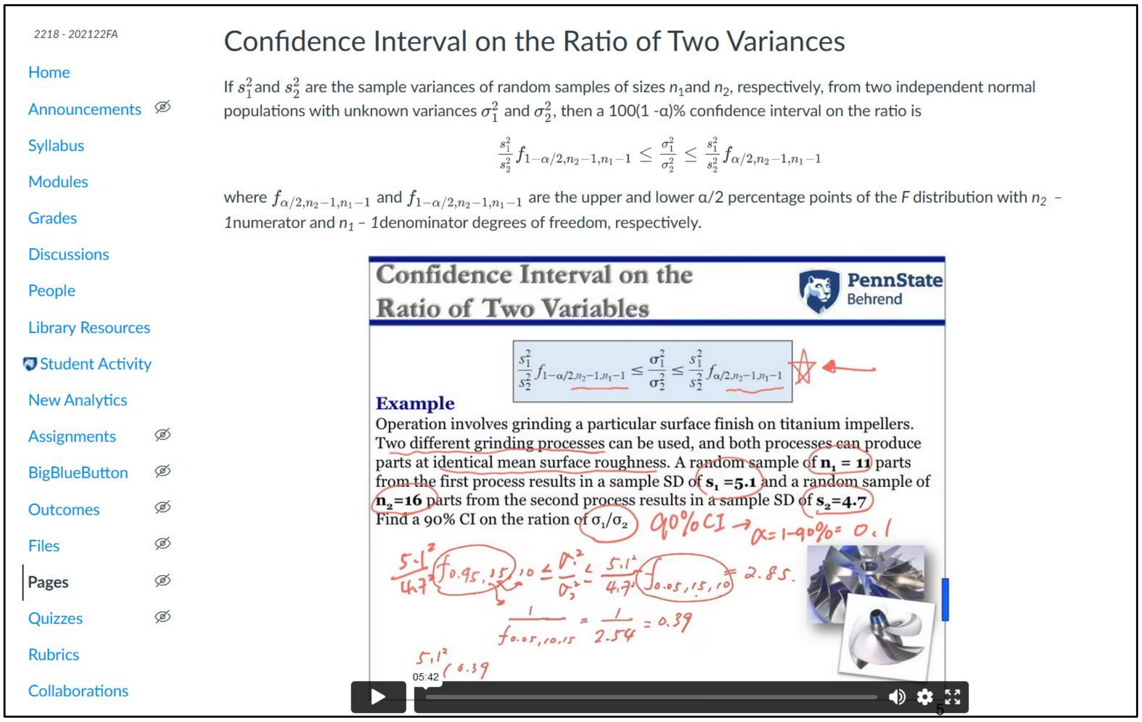

Figure 2. On-line class confidence interval on the ratio of two variables. The instructor recorded the lecture with handwriting on the slides while simultaneously explaining the concept.

For the course evaluation, the same number of quizzes and exams were administered in the online version of the class as in the in-person class, and both used the same weightings for the semester grade. Students in the online class were asked to complete a specific module within a week and complete a quiz before the weekend deadline, which was always before midnight on Sunday. Examinations took place after students completed the fourth quiz for each module. Once students accessed the exam, they had to finish and submit it within 24 hours of starting it. All quizzes and exams were administered through the course management system, and students were required to download, print, and submit their work by scanning it back to the course management system. Figure 3 shows a sample grade from an online course student. The scores on the twelve quizzes and three exams are the dependent variables used to evaluate student performance. Therefore, a student's performance in each module was calculated as the average of the grades on the three quizzes and one exam. For example, a student's performance in the "Testing of Hypotheses" module is the average of their scores on quizzes 5-7 and the second exam. However, in this study, the evaluations of the use of the Minitab statistical software for the three modules (quizzes 4, 8, and 12) have been excluded because both in-person and online cohorts used a similar take-home quiz format for Minitab.

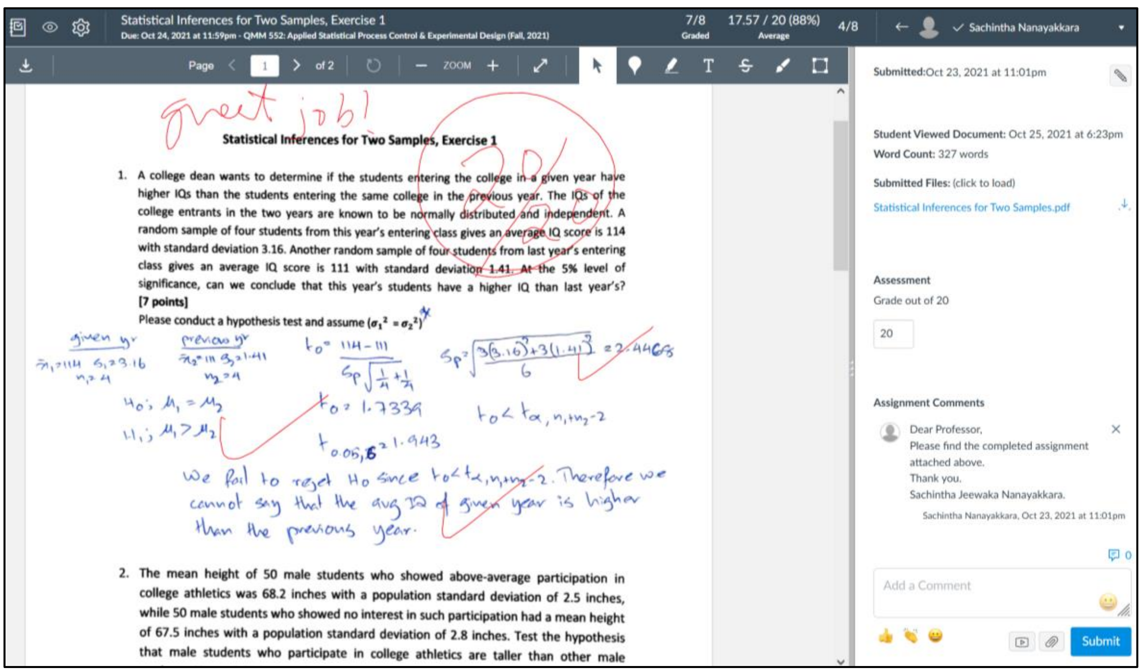

Figure 3. Sample graded assignment from a student in the online course.

Results

A total of sixty students enrolled in the MMM program from 2015 to 2020. Table 2 summarizes the student enrollment status in the study. 48.3% of the students 3enrolled in the in-person program and 51.7% took the online class. The in-person course was offered twice in 2017, in the Spring and Fall semesters, respectively. In the program, there were 26.6% female students, and 30% of the students returned for a graduate degree at least five years after obtaining their bachelor's degrees. Since the course modality was switched to online, the program saw an average increase of 42.5% in student enrollment per semester. In this study, no significant differences were found in student performance based on gender or the length of time since obtaining a bachelor's degree. The results also showed no significant differences in performance in the probability distributions and hypothesis testing modules between in-person course sections, but a statistically significant difference was found in the experimental design learning module (Table 2).

The Spring 2017 in-person class cohort had a relatively low average in the experimental design module compared to other years. On the other hand, no significant performance differences were found in the three learning modules between the online students. When comparing the cohorts between in-person and online students, significant performance differences were found between the two modalities in the probability distributions and experimental design modules.

Table 2. Student Demographic and performance evaluations

Demographic variables		*n*	**Probability Distributions**	**Testing of Hypotheses**	**Experimental Designs**
			p-value / *Mean (SD)*		
Gender			***0.124***	***0.257***	***0.777***
	Male	*46*	92.880 (6.820)	92.984 (6.472)	93.370 (8.670)
	Female	*14*	95.900 (4.210)	95.170 (4.460)	92.590 (9.800)
Time Since BS Degree			***0.372***	***0.645***	***0.581***
	<= 5 years	*42*	94.073 (5.374)	93.247 (6.125)	93.600 (8.150)
	> 5 years	*18*	92.450 (8.410)	94.070 (6.760)	92.210 (10.540)
In-Person Semester			***0.789***	***0.236***	***0.000****
	2015	*8*	90.040 (9.440)	91.250 (7.750)	89.870 (8.450)
	2016	*5*	93.830 (6.640)	97.230 (4.040)	95.630 (4.720)
	2017 (SP)	*11*	90.080 (7.600)	90.090 (7.020)	79.140 (7.630)
	2017 (FA)	*5*	90.050 (2.510)	92.300 (2.77)	97.030 (2.820)
Online Semester			***0.068***	***0.350***	***0.720***
	2018	*11*	94.090 (4.070)	94.510 (5.740)	97.320 (4.780)
	2019	*13*	97.100 (4.040)	96.380 (4.670)	98.385 (2.605)
	2020	*7*	98.170 (2.810)	98.170 (7.680)	98.939 (2.327)
Class Type			***0.000****	***0.090***	***0.000****
	In-person	*29*	90.710 (7.220)	92.070 (6.530)	88.030 (9.990)
	Online	*31*	96.274 (6.062)	94.820 (5.830)	98.008 (3.416)

**P<0.050*

Figure 4 shows the performance disparities between in-person and online students. The online students had better performance in all three learning modules, but no statistically significant difference was found in the testing of hypotheses module.

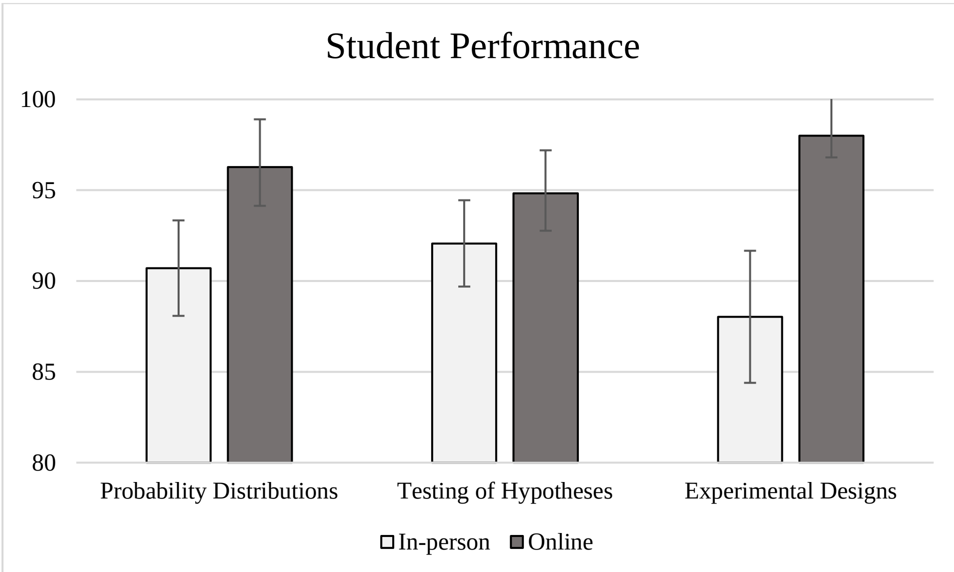

Figure 4. Student Performance Evaluation: In-person vs. Online (*95% C.I.*)

To further investigate the difference in student performance on the probability distribution and experimental design modules between the two modalities, the probability distribution module consisted of three submodules: (1) random variables, probability density functions, and cumulative distribution functions, (2) discrete probability distributions, and (3) continuous probability distributions. Table 3 shows that there was a on discrete probability distributions. In this submodule, students were expected to understand the assumptions for some common discrete probability distributions, such as the binomial, geometric, negative binomial, hypergeometric, and Poisson distributions, among others.

Table 3. Associations of Probability Distribution Submodule with Learning Modality

			Random Variables, PDFs, and CDFs	**Discrete Probability Distributions**	**Continuous Probability Distributions**
				p-value	
		n		*Mean (SD)*	
			0.353	***0.040****	***0.964***
Class Type	In-person	*29*	90.690 (19.073)	83.793 (21.030)	96.034 (8.170)
	Online	*31*	94.516 (11.997)	92.903(11.385)	96.129 (7.822)

**P<0.050*

The other module with a statistically significant difference between in-person and online cohorts was the experimental design module. This module also consists of three submodules: (1) Analysis of Variance (ANOVA), (2) Randomized Complete Block Design (RCBD) and ANOVA Multiple Comparisons, and (3) 2^k Full and Fractional Designs. Table 4 shows significant differences in the submodules on RCBD and 2k Full and Fractional Designs. The learning objectives for the RCBD submodule include understanding the blocking principle and its use in isolating the effect of nuisance factors, as well as the ability to use multiple comparison procedures to identify specific differences in data. The objectives for the 2^k Full and Fractional Design submodule include understanding the use of two-level series factorial designs and the interpretation of their main effects and interactions.

Table 4. Associations of Submodule on Experimental Design with Learning Modality

			Analysis of Variance (ANOVA)	**Randomized Complete Block Design and ANOVA Multiple Comparisons**	**2^k Full and Fractional Designs**
				p-value	
		n		*Mean (SD)*	
			0.948	***0.020****	***0.001****
Class Type	In-person	*29*	90.690 (20.166)	86.379 (20.869)	83.966 (22.811)
	Online	*31*	94.968 (12.139)	98.710 (4.466)	98.548 (3.463)

**P<0.050*

Student feedback for the courses was obtained through a teaching evaluation administered to students before the final exam week. Teaching evaluations in the authors' institute use two 7-point Likert scale evaluation questions: (1) rate the overall quality of this course, and (2) rate the overall quality of the instructor. Figure 5 shows the comparison of the student evaluation of teaching effectiveness for the in-person and the online students. The in-person cohort had a higher teaching evaluation response rate compared to the online cohort (90.6% vs. 43.6%).

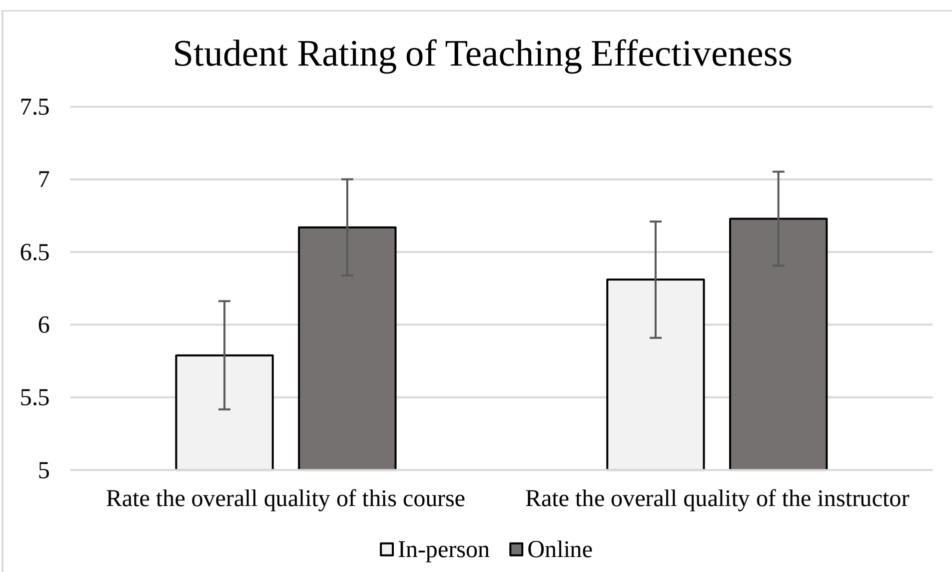

Figure 5. *Student Rating of Teaching Effectiveness* In-person vs. Online (*95% C.I.*)

The results suggest that there were large improvements in the ratings both of the quality of the course and of the instructor when the class was moved from in-person to online . A statistically significant difference was found between the two modalities in the rating of course quality . The online course was rated 15.2% higher than the in-person class.

Conclusion

In this study, a graduate-level statistical course was offered in both in-person and asynchronous online modalities and was taught by the same instructor using the same instruments (quizzes and exams) for evaluation. Student performance was found to be consistent in both modalities. However, significant differences were found between the two cohorts in two out of the three teaching modules. Online students had a better performance in modules on probability distributions and experimental design, with a significant difference in the submodules on discrete probability distributions. In this submodule, six different discrete distributions were introduced, along with their applications and assumptions. Online instruction may have been more beneficial in allowing students to review the material multiple times, leading to a more comprehensive understanding. In addition, significant differences were also found in the RCBD and 2^k fractional design submodules of the experimental design module, which may have been due to the presence of more formulas and calculations in these submodules. Online students had more time to complete these calculations and could review their work multiple times. Since online instruction provides students with the advantage of being able to review and compare concepts multiple times while having readily available reference materials, it can lead to better performance and less focus on memorization. Additionally, online students had more positive feedback about the quality of the course and instructor compared to the in-person students. From an institutional perspective, online courses can increase enrollment and allow students to access education at their own pace and fit it into their flexible schedules.

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