A Comparison of Student Performance in an Online, Hybrid, and Traditionally Delivered Numerical Methods Course

Michael Reynolds, PhD
Associate Professor and Head, Engineering
University of Arkansas - Fort Smith

Abstract

Numerical Methods is a course dealing with solving engineering problems using approximate mathematical techniques. It has been taught by this author 13 times in the past nine years at the University of Arkansas - Fort Smith campus. Six of those times the course was taught in a traditional lecture based format. Four times it was taught in a hybrid format where the class would meet once per week while having most of the content taught online via video instruction. Three times the course has been offered purely online during the summer. This paper analyzes 10 exam problems that have been given to students in at least two of the three formats, with 6 problems given to all three formats. Individual problems as well as the performance of the three student groups are compared to demonstrate the effect of the lecture format on learning.

Introduction

Online learning in higher education has experienced rapid growth over the last ten years [1]. The growth and acceptance of online education within engineering has been slower than other fields [2]. While barriers remain, one critical component is to study online engineering education itself. We must study how we can best use the Internet as a tool for engineering education. There is tremendous potential to broaden access and produce more engineers. One critical piece to studying online engineering education is to measure how students perform online versus traditional lectures. The purpose of this paper is to offer an additional data point in comparing online, hybrid (also known as blended format, a mix of online and traditional lecture), and purely online learning.

Approach

The Numerical Methods course at the University of Arkansas – Fort Smith has been taught 13 times in the past 9 years by the author of this paper. The course is at the sophomore level and is taken by mechanical (required) and electrical (elective) engineers. From fall 2004 to spring 2008, the course was taught six times in a traditional format that met two or three days per week for 150 minutes of class time. In the spring of 2009, the Numerical Methods course was taught as a hybrid course for the first time. In the hybrid course the students would meet with the instructor once per week for 50 minutes. The time was not used for formal teaching but instead was similar to a tutorial session where students could ask questions. Typically the instructor would prepare something each week covering one of the trickier subjects the students might encounter but leave sufficient time for other questions. All of the formal teaching would occur online, with a set of approximately 40 pre-recorded videos divided by topic. Some videos were shorter (perhaps as short as 20 minutes) while others were 40-50 minutes in duration. The course has been taught each spring since 2009 in the hybrid format, a total of four times. In the summer of 2009 the course was first offered purely online. The online format is popular with students in the summer due to various work and vacation conflicts. The course has been offered each summer in this format, with the past three years data included in this study.

An analysis of final exams has revealed six problems that have been given to at least ten students in each of the three types of teaching formats. There are also another six problems that have at least two of the three groups with at least 10 samples. The problems are identical and therefore represent a good subset to analyze for differences between the two groups. The goal of this paper is to study the performance of the students in each of the three class formats. One of the concerns many educators have with online learning is that it might not be as effective as the traditional classroom approach. This study might alleviate these concerns, demonstrate those concerns as valid, or perhaps be inconclusive. Regardless, it is important to study learning in the online format since there is a lot less data available then the traditional classroom approach.

The final exams are not handed back to students, lessening the potential that solutions might be shared with future classes. Another concern might be that these groups of students might not be comparable. Any instructor will tell you that summer students are not the same cohort as students in the spring or fall. With this in mind, the cumulative GPAs of each of the three student groups used in this study was determined. The results are displayed in Table 1 with N representing the number of students in each group. The GPAs are what the student had after completion of the semester before they took the Numerical Methods course. The online and hybrid students are very comparable, suggesting that there is little difference between recent spring students (hybrid offerings) and summer students (online offerings). The traditional students took the course either in the fall or the spring, with a GPA that is only slightly greater. The means in the following tables are the scores the students achieved out of 20 for each of the problems. The statistical analysis was done with a One-Way ANOVA in Minitab.

Table 1: Cumulative GPAs of students entering Numerical Methods course.

	N	GPA
Traditional	82	3.23
Hybrid	84	3.14
Online	55	3.15

Results for Problems with data from all three class types

This section will detail the results of each of the problems that had at least 10 samples in each of the three class types. One problem asked the students solve an integration problem that is difficult to solve using elementary calculus techniques. Table 2 contains the results of the problem analysis (the maximum score is 20) for traditional, hybrid, and full online courses. The full online students scored the lowest with an average of about 13.7 while the traditional students scored the highest with an average of 15.0. While there is a noticeable difference in scores, the large P value of 0.65 suggests that we are unable to reject the null hypothesis that the population means are equal. While it does not prove that the populations means are equal (and thus all students perform equally well regardless of format), there is a large overlap in the 95% confidence intervals of the three population means.

Table 2: Results from Numerical Integration Problem

Problem #1 – Numerical Integration of sin(x)/ln(x)			
	N	Mean	StDev
Traditional	18	15.000	1.188
Hybrid	20	14.750	5.025
Full Online	13	13.692	4.768
F = 0.43	P = 0.65		

Table 3 shows the results from a problem that asks the students to perform Gaussian elimination on a large, sparse matrix. The results again show that the traditional lecture students performed the best, but this time both the hybrid and full online students lagged behind equally. A P value of 0.237 again fails to reject the null hypothesis but does suggest there is a greater likelihood that the populations means are not equal. The 95% confidence intervals of all three means overlap in a range between about 17 and 19.

Table 3: Results from Gaussian Elimination of a Large Matrix

Problem #2 – Gauss Elimination			
	N	Mean	StDev
Traditional	18	18.722	2.244
Hybrid	16	16.938	4.008
Full Online	12	16.667	4.793
F = 1.49	P = 0.237		

Results from a first order differential equation solution are given in Table 4. In this problem students were asked to solve a first order differential equation using both Euler's method and the Fourth Order Runge-Kutta Method. The comparative results are different in this case, with the online students scoring the highest average and the traditional students scoring the lowest average. The means for the traditional lecture students and hybrid lecture students were very close in this case. The sample sizes were quite different as well, opening the possibility that the smaller sample of online students might be biased. The value of P=0.442 again fails to reject the hypothesis that the means are the same between all three groups. The 95% confidence intervals overlap in a range from around 13.5 to 15.5.

Table 4: Results from Solving a First Order Differential Equation

Problem #3 – Solve dy/dt = t*√y			
	N	Mean	StDev
Traditional	34	14.118	5.038
Hybrid	35	14.474	5.351
Full Online	13	16.154	2.853
F = 0.82	P = 0.442		

Table 5 shows the results of a linear regression problem that students solve using a pseudo inverse. The results from this analysis strongly suggest (P=0.003) rejecting the null hypothesis that the population means are equal between the three populations. The full online students did notably worse on this problem. The 95% population confidence intervals do not overlap in this case, with the hybrid and full online intervals being separate. The hybrid students performed the best on this problem, with about a 10% greater average score. There may be some explanation for the poorer performance of the full online students. The traditional and hybrid students take the course in a room that has MATLAB available to them while the full online students take the course in a room that does not have MATLAB. While the students were encouraged to learn how to do the problem on their calculators, some may have only used MATLAB when working their homework. Students were told they would not have MATLAB in the full online course and warned to make sure they know how to use their calculators. All students had access to Excel, which could be used to verify their results.

Table 5: Results from Solving a Linear Regression Problem

Problem #4 – Linear Regression using matrix methods			
	N	Mean	StDev
Traditional	13	16.308	3.924
Hybrid	20	18.200	3.222
Full Online	13	11.769	7.650
F = 6.54	P = 0.003		

The results from the Gaussian elimination of a 3x3 matrix are shown in Table 6. In this case all three means are relatively close, with the full online students performing slightly better than the traditional lecture students. The large P value suggests no evidence to reject the null hypothesis that the means are the same. The 95% confidence intervals show a large amount of overlap.

Table 6: Results from Solving a 3x3 Gaussian Elimination Problem

Problem #5 – 3x3 Gaussian Elimination			
	N	Mean	StDev
Traditional	10	18.720	1.695
Hybrid	20	17.800	3.968
Full Online	15	18.933	2.604
F = 0.62	P = 0.541		

Table 7 shows the results of another numerical integration problem that was given to all three groups of students. The results show that the full online students actually performed the best, but there was little difference between them and the traditional students. The hybrid student scored lower but there was not enough evidence to reject the null hypothesis that all three groups have the same population means. The 95% confidence intervals overlapped between 17.5 and 19.2.

Table 7: Results from a Numerical Integration Problem

Problem #6 – Integration of $e^{\wedge}(-x^2)$			
	N	Mean	StDev
Traditional	10	18.500	4.743
Hybrid	14	16.857	4.121
Full Online	12	18.833	2.125
F = 1.01	P = 0.373		

Combined Results

All six problems previously discuss were combined for each of the three student groups. The combined results are in Table 8. The means of the traditional lecture students and hybrid students are nearly identical with the full online students only being slightly less. The 1% reduction in the performance of the students in the full online sections might be explained by the difficulties previously discussed with the linear regression problem. The 95% confidence intervals of all three groups nearly coincide. The combined data demonstrate that students in hybrid and full online engineering courses can achieve similar outcomes to students in traditional classes that meet two or three days a week.

Table 8: Combined Results from all six problems given to three student groups.

Combined Results			
	N	Mean	StDev
Traditional	103	16.225	4.159
Hybrid	125	16.229	4.669
Full Online	78	16.038	5.100
F = 0.05	P = 0.953		

Comparing Student Performance in a Traditional Lecture to Pure Online Lectures

An additional four problems were chosen to directly compare student performance in a traditional lecture format to students in an online format. These four additional problems included a numerical integration problem (different from the previous examples), a first order differential equation solved with the Euler method, a function root solving problem with the secant method, and an optimization problem with Newton's method. Table 9 has the combined results of the traditional lecture students and the online students for these four problems.

Table 9: Combined Results from four additional exam problems.

Combined Results			
	N	Mean	StDev
Traditional	46	16.717	5.145
Full Online	55	17.182	4.493
F = 0.23	P = 0.629		

The combined results of Table 9 again show that full online students can perform just as well as the traditional students. In fact, the average score of the full online students was about 3% greater than the traditional cohort. This is not statistically significant though, as there is not enough evidence to reject the null hypothesis that the population means of the two groups are the same. The 95% confidence interval of their distributions overlap for most of their spread. Two additional problems had sufficient sample size to compare the hybrid and full online student groups. These two problems also showed little difference between the two groups.

Conclusion

A study of student performance in a sophomore level Numerical Methods course shows little difference between student outcomes in a traditional lecture format that meets 150 minutes a week, a hybrid format that meets 50 minutes per week with online lectures, and a purely online format with all instruction available via download. The results demonstrate the efficacy of the online format to produce desired learning outcomes. Further study is needed in engineering to determine when and how are the best ways to teach students in an online format.

References

[1] Allen, I.E., Seaman, J., *Going the Distance – Online Education in the United States, 2011,* Babson Survey Research Group and Quahog Research Group, LLC, 2011.

[2] Bourne, J., Harris, D., and Mayadas, F., "Online Engineering Education: Learning Anywhere, Anytime." *Journal of Engineering Education*, Vol. 94, No. 1, pp. 131-146.