Should Graduate Mathematics Courses Be Taught Fully Online?

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Abstract

In this paper, an assessment is done on graduate distance courses in the mathematical sciences based on two formats of instruction: the traditional face-to-face lecturing with e-learning support and the online synchronous lecturing for distance students. It is shown that with a synchronous teaching tool, it is possible to create a learning environment in which distance students are provided with the necessary tools to lift up the level of learning to the same level as what can be achieved in traditional face-to-face instruction of mathematics.

1. Introduction

The demographics of the Florida Panhandle present a situation where potential graduate students live in locations that are spread over large areas. The economics and the required efforts of having to drive to the main campus make it a situation where some type of distance learning becomes not just an option but in many cases a necessity. There is also a population with jobs, such as high school mathematics teachers, prohibiting many to pursue additional training in mathematics unless a program is offered to them as a distance learning program. The problem is that it is not straightforward to offer fully online graduate courses in mathematical sciences. The nature of mathematical sciences dictates that students need to hear the instructor explain the concepts and ideas. It is equally important that students are able to get immediate feedback to all their questions during the lectures. While there are numerous publications on the usefulness and the success of distance learning of lower level mathematics [3, 6, 9, 11, 12], there are few publications on distance learning at the graduate level in mathematical sciences [1, 5].

The traditional approach to online teaching includes some asynchronous e-learning systems (such Desire2Learn and others) to deliver the course material to distant students. While such systems may be useful platforms with which instructors and students can exchange ideas and can hold discussions, they are insufficient by themselves for mathematical sciences courses to provide distance students the same learning possibilities that traditional face-to-face students are benefiting from [4]. There is a need to provide real time access for distance students to ongoing class discussions and lectures [8]. Another factor affecting distance students is the need to feel they belong to the class and that they are not "distant". It is a fact that limiting the exchange of feedback to e-learning postings and discussion forums may not provide distance students with

the interactive learning experience and feeling of belonging to a class they usually would get in a traditional face-to-face class. The bonding and the support between mathematical science students is an important factor in the success of some students to overcome what may appear as difficult hurdles. This is especially true for students with relatively weaker mathematical background than other students. It seems that the traditional asynchronous online teaching for mathematical sciences graduate courses does not work well or at least, has room for improvement. It is not surprising that the number of departments of mathematical sciences that offer fully online Master's programs is quite low in the USA when searching with Google.

In the assessment section, we will show the assessment result of traditional face-to-face vs. synchronous instruction of graduate courses. For comparisons purposes, we also show the assessment result of traditional face-to-face vs. traditional online instruction of college algebra. It shows that the synchronous instruction of math courses is as good as the traditional face-to-face instruction, but the asynchronous instruction of math courses are not as good as the face-to-face instruction.

2. Course Design

When a course is taught with a synchronous software package, the faculty member creates the links for the lecture sessions, and emails the students the links so that they can access the lectures real time from distance. The distance students must log on to the lectures at the same times at which the lectures are offered. The instructor writes all lectures on a smartboard or a sympodium. Anything shown on the sympodium, from lectures to usage of software packages and other material, will be seen by all students. The students see the lectures and hear the voice of the instructor. It is also possible to make use of a camera to have the students see the instructor. If a distance student has a question, the student can send a signal to the screen of the sympodium, showing a hand. The instructor can then give the microphone over to the student to allow her/him to ask questions. While such synchronous software packages have been used at many universities, it is unique that an entire Master's program in mathematical sciences be offered to distance students via a synchronous teaching platform.

The Department of Mathematics and Statistics at the University of West Florida started its first synchronous distance graduate course offering in the summer 2008. In the fall semester of 2008, three graduate courses in mathematical sciences used *Elluminate Live!*, one of the synchronous software packages to deliver lectures real time to distance students, while simultaneously teaching face-to-face students from a classroom. This was followed in spring 2009 with three graduate courses being offered the same way. This approach has several advantages over separate online offering of the courses. From an administrative perspective, the class scheduling stays the same as it would be for a traditional Master's program that is taught face-to-face, with an addition of distance students. Now, the entire Master's program is offered via *Elluminate Live!*. It is a unique experience that is as close as it gets to attending courses face-to-face. For additional information on *Elluminate Live!*: http://www.elluminate.com/index.jsp

The authors are part of the design team of the online graduate program, and both have taught synchronous graduate distance courses. Dr. Li is Chair of the department, and has played an important role in establishing the online graduate program, while Dr. Amin led the design and analysis of the student surveys for the assessment of the synchronous graduate distance courses.

3. Method of Synchronous Instruction

We will now describe how the distance courses were taught with a synchronous platform. Each course was taught from a classroom with a computer equipped with a sympodium on which the instructor writes the lecture material. The sympodium replaced the traditional chalk/marker board on which lecturers would traditionally write. The synchronous software package we used is *Elluminate Live!*. There were students enrolled in the traditional face-to-face section, while distance students were enrolled as distance students from various locations in the USA. Some of the distance students had already taken face-to-face classes in the past, but they opted this time to take the course as a distance course due to the availability of the synchronous software package. Very little training is needed for students to grasp how to connect to the lectures and how to ask questions in real time during lectures. The following practices were used in the course:

- Each distance student must receive permission before being enrolled in a course. Permission is contingent on completing a 30 minute training session with an instructor on the use of the synchronous software.
- All distance students must be committed to be logged on during all lectures.
- All lectures were recorded with *Elluminate Live!*, followed by posting the recorded lectures on e-learning.

The availability of recorded lectures to students allowed them to review lectures or parts of lectures repeatedly as needed. This was acknowledged by some students as being extremely valuable for their learning process. Students were able to review how the instructor taught specific concepts or maybe how a software package was used, and the availability of recorded lectures also provided a safety net for weaker students who felt that they need to listen and to see the lectures more than once to fully understand the course material. Although the posted materials on e-learning are only for the students who registered for the class, with the instructor's permission, anyone can review the lectures.

An important aspect for the success of distance teaching with a synchronous software package is to provide all necessary elements to remove anxiety from the instructors in using technology in teaching mathematics and statistics. All faculty members received training on the use of the software. One graduate student was also trained on how to set up the synchronous lecturing sessions, and the same student became the "in-house expert" to support instructors for all technical aspect of the software use. The student set up the computer before the start of the lecture, and then he would upload the recorded lectures on e-learning for students to benefit from. The technical support student had as responsibility to attend all lectures and to provide assistance to the lecturers if there was any need for it.

The Department of Mathematics and Statistics regularly uses assessment methods in several mathematical sciences courses. The assessment activities focus on undergraduate general studies courses and on graduate courses taught with *Elluminate Live!*. The assessment results for several types of sections (face-to-face, online, hybrid) were discussed, with the main finding that the withdrawal rate (W) for online courses was the highest [8]. In order to correct this problem, we have taken some steps to improve online courses. Distance students may feel less connected to the class as compared to face-to-face students [8]. One possible approach in helping distance students to stay enrolled is involving them in group work for the class.

To illustrate how synchronous lecturing was blended with an asynchronous platform, we will refer to one particular statistics graduate course (Multivariate Methods). While the levels of our graduate students in general were excellent, there existed differences in how much students had knowledge in mathematics/statistics, and in the use of different statistical and mathematical software packages. Here, it was important to level the playing field by placing students in groups such that students with different knowledge characteristics were placed in groups. For example, there would be two students from the main campus who were taking the course as a face-to-face course, and where one student was concentrating on mathematics courses while the other student was mainly interested in statistical training. The remaining two students in this group would be distance students. Having such a group not only allows students to benefit from each other's knowledge bases, but it also brings in the distance students to the class by forming closer ties between distance students and face-to-face students.

While student group work may be more utilized in some disciplines, it usually is frowned upon or it is viewed as irregular in mathematical sciences graduate programs. It is reported in the literature that interaction between a small number of students and a lecturer is perceived as the most effective teaching method of mathematical sciences [5]. It was concluded that students participating in group work learn by virtue of mediating socio-economic variables that create a favorable climate to learning [7]. It was showed that promoting and sustaining a sense of an online learning community is important [2]. In order to best make use of groups in the course, we set rules how students were allowed to benefit from group work. In regular homework assignments, it was encouraged to discuss the ideas behind the exercises online, but no copying of complete work was allowed. The discussions usually start out within each group for the different groups, and only when the group finds itself in need for more information will students "peek" into other groups. Each group of students was provided its own discussion forum for the semester. It allowed students to feel at home with their group members. The e-learning discussion boards were very useful for the groups to post and to read typed discussions, but we also provided each group with a semester-long link for the synchronous software package (*Elluminate Live!*) so that students can communicate with each other at any time they choose to make use of the software.

It was recommended focusing research on the interaction of multiple technologies rather than the impact of single technologies [10]. The only part of the course material in which students were allowed to fully make use of group work and where a group grade was awarded was the review of research articles. Distance students and local students were placed together in groups, and they were encouraged to use *Elluminate Live!* for synchronous discussions within each group in addition to asynchronous discussions via e-learning. Students who were unable to join any of the synchronous group discussions were able to review the recorded discussions, followed by participation in asynchronous e-learning discussions. A common practice in such a project would be in the shape of having all students in a group read an article, followed by a distribution of tasks which students choose to implement. One student may be in charge of reviewing the literature while another student would create a glossary of definitions for the important terms in the article … etc. The groups work resulted very clearly in increased cohesiveness between the students. Online discussions between group members assisted students in better work distribution and in the effective facilitation of group work. Occasional "loners" found students they could easily communicate with, while students with superior knowledge base would recognize opportunities for being mentors. No student was left behind.

The use of a synchronous software package allowed the instructor to switch roles between face-to-face students and distance students. For example, a distance student was singled out by the rest of the class as being more knowledgeable than any other student in the class on the use of the software EXCEL. They asked the instructor to pass the microphone to that student so that he taught the rest of the class how to make use of EXCEL in some exercises. Here, the formerly distance student became the instructor, while the all other students turned to being distance students. It showed students that everybody was connected and that everyone was part of the larger group, the class.

Here is a link to a lecture recorded with *Elluminate Live!:*
https://sas.elluminate.com/mr.jnlp?suid=M.0462B6B3C94FF67AE6746A116462ED
In this particular lecture, distant and face-to-face students participated in the lecture by teaching the rest of the class how they used certain statistical software packages for multivariate analysis. A distant student "Gene" became the instructor, and he used *Elluminate Live!* from his home to explain to the students how he used EXCEL.

4. Assessment Results

4.1 Traditional Face-to-Face vs. Synchronous Instruction of Graduate Courses

Table 1 gives the detailed grade distribution for all graduate courses taught in the Summer 2008, Fall 2008, and Spring 2009. There were seven graduate courses taught simultaneously face-to-face (T) and with the synchronous software package (*Elluminate Live!*) (E).

The graduate courses were as follows:

- Partial differential equations,
- Mathematical Modeling,
- Matrix Theory,
- Mathematical Statistics I,
- Operations Research I,
- Multivariate Methods, and
- Numerical Analysis.

Table 1 shows the grade distribution for three semesters.

Table 1. Students' performance with synchronous instruction

Type of Instruction	Enrolled	Withdrew	A	B	C	D	F
Synchronous Distance	54	7	23	14	9	0	1
Face-to-Face	112	5	67	33	4	1	1

We compared the grades of the sections that were taught as face-to-face courses with the distance sections during these three semesters. The grade distribution in table 1 is a useful descriptive method to illustrate differences between the two types of teaching methods. In order to take into account any existing differences by different teaching methods and different classes, we obtained the GPA *for each course* as paired data (face-to-face students and distance students), resulting in a meaningful statistical analysis of the GPA values.

We are summarizing the main results below:

- The mean GPA for the traditional sections was 3.39 compared to 3.30 for the distance sections. Using a Wilcoxon two-sample test, the difference in the GPA means is not significant statistically [p-value=0.2744 one-sided test]. Since it is more likely that we want to guard against a drop in GPA due to distance teaching, the one-sided test is more appropriate here.

- It is a reasonable practice to compare the grade distribution in the two categories (A,B,C) and (D, F,W) for the two types of sections (T vs. E). In the traditional sections there were 93% of students in the (A,B,C) category compared to 85% for the Elluminate sections. Fisher's Exact Test gives a p-value of 0.1313 for a left-sided test, indicating that the difference is statistically non-significant. This is a very promising result since it shows that using a synchronous learning platform for the distance sections has not significantly lowered the student learning levels as measured by the GPA.

- While the mean performance level according to GPA values is a good indicator on how well students have performed, the variability within each group of students is also important as it shows us how different the student learning is for each group of students (T and E). The standard deviations for the GPA values were 0.46 and 0.49 for groups T and E, respectively.

- A second look at the data suggests that using the interquartile range (IQR) is more revealing since extreme values have a smaller effect on the IQR than on the standard deviation. The IQR is the spread [or range] for the middle 50% of the ordered data values in a sample. The standard deviation is highly susceptible to extreme values, and it can be misleading if so-called "outliers" are present. The IQR=0.49 for the group T, compared to having IQR=0.90 for the group E. Group T has one outlier, resulting in an inflated standard deviation, suggesting a misleading conclusion that variability was roughly equal in both groups (T and E). In fact, variability is nearly twice higher for sections taught with Elluminate than what we found in the traditionally taught sections [based on the IQR]. It is expected that there is more variability in sections for distance students.

  While assessment of student learning based on GPA is useful and important, it is also important to have assessment on the benefits resulting from the use of the synchronous software package and related e-learning practices. For this purpose, two student surveys were given during the fall 2008 semester in addition to the regular mandated student evaluations at the end of each term.

4.2 Traditional Face-to-Face Vs. Traditional Online Instruction of College Algebra

We assessed undergraduate College Algebra courses taught in the spring 2008 term. Teaching Assistants and a faculty member taught eight sections of College Algebra in a blended learning format, with face-to-face lectures and a web-based homework system that was supported by an elaborate E-learning system. Students in this course could seek help from their instructors or the free Math Tutoring Lab that opened for 32 hours per week. The same faculty member also taught a traditional online section of College Algebra that did not use synchronous instruction. The materials were posted online weekly. The students in the online section could seek help from their instructor via *Elluminate Live* in a synchronous, two-way, dynamic live discussion with video capability during their office hours.

Table 2. Students' performance in College Algebra

Spring 2008								
Section	Enrolled	Withdrew	A	B	C	D	F	Pass
online	38	12	7	8	4	1	6	19
face-to-face	306	41	83	70	57	16	38	222

Similarly, we performed a statistical analysis to compare the success rates in College Algebra for the fully online section in the spring 2008 term to the face-to-face sections (see table 2). The Chi-square Test with p-value = 0.0001 shows that the success rates for the two groups differed significantly at a significance level of 0.05. Furthermore, the fully online class performed significantly worse in almost every category in comparison to the face-to-face sections. In particular, for the online class: (a) the drop rate was 32%, a significantly higher rate than the 13% and 14% for the face-to-face groups; (b) the success rate was 50% which is much less than the 69% for the face-to-face sections; (c) the percentage of students who achieved high success grades was 39%, a rather low rate in comparison to those for the face-to-face groups at 50% for 2008; and (d) 15.8% of students received a grade of F, a rate that is much higher than the 12.4% recorded by the face-to-face groups in the spring 2008 term. However, considering only those students who did not drop the online class, 58% received a grade of B or better on their final examination. This rate is identical to that for the face-to-face group with web-based homework.

For College Algebra we conclude, therefore, that the overall success rate for the traditional face-to-face instruction was comparable to that of the blended face-to-face format with a web-based homework system. The greater rate of high success for the blended format as compared to the traditional instruction was neutralized by an equally greater rate of very low achievement in the group with the blended platform. However, our results show that the two groups with the face-to-face instruction outperformed the fully online group with respect to success rate, drop rate, rate of high success, and rate of very low performance. While it is possible that the lower performance of the online students could be attributed to more than one factor, and that it was because of a different group of undergraduate students and not due to the nature of the teaching set-up (traditional versus online), it is a fact that about 80% of students enrolled in online UWF courses are in fact students taking both face-to-face courses and online courses based on the information from the Office of Admission at UWF.

4.3 Assessment of the Interactive Learning Practices

During fall 2008, and after six weeks of using Elluminate, a survey was created and distributed to each of the three graduate classes in which this software was used. The survey had multiple choice questions on how students perceived several aspects of the course. In particular, we wanted to make sure that the distance students were actually benefiting from the real time access to the lectures, and we wanted to check whether the face-to-face students were OK with this set-up, as compared to traditional face-to-face classes. We will summarize the main findings from one of the sections below:

- Students that were taught face-to-face did not view the merger of their section with a distant students section as negative. While a few isolated comments suggested that some students preferred the traditional use of a "blackboard and chalk", most students were perfectly fine with the inclusion of a distance section and with the instructor using a Sympodium. Distance students were unanimously positive about using the synchronous platform to deliver the lectures to them. It was a major "hit" for the distance students to be able to see and hear all lectures in real time with the ability to ask questions if needed. While some students commented that they still preferred a face-to-face section, they acknowledged that their distant locations made it far more efficient to take courses as distance courses. A chi-square test was used to test the hypothesis that distance students show the same satisfaction level than face-to-face students. The p-value equals 0.1328, resulting in not being able to reject the claim.

- It is important to make distance students "feel home" when taking a distance course. The hypothesis that distance students have the same level of feeling involved in the course as face-to-face students could not be rejected. The p-value of the chi-square test was 0.3350.

- The survey showed that an important factor in the success of the integration of traditional sections with distance sections is to have students from both groups (T and E) work together within groups. While face-to-face students may not view group work to be important to their learning, it was expected that distance students would feel otherwise about group work. A chi-square test was used to test the hypothesis that distance students view group work equally important for student learning as face-to-face students. The hypothesis was rejected as the p-value was 0.0155. Here is a situation where the instructor has to carefully balance what is viewed favorably by distance students with what is viewed favorably by face-to-face students. Most of the time the two groups (T and E) share the same preferences.

Close to the end of the fall 2008 semester, a follow-up survey was distributed to all three courses having distance sections. This survey was based on obtaining constructive feedback in the shape of comments on how to improve the hybrid teaching of traditional and Elluminate sections. Based on our survey, having active e-learning discussions is very helpful for effective student learning. Student mentoring seems to have become more widely spread through e-learning discussions about posted homework problems and solutions. Students learn from what other students have contributed in exams and in assignments. As expected, mathematics and statistics majors are unhappy about points being assigned for mandatory e-learning discussions. It was the students' single complaint in all assessment stages for the course. While students acknowledged

in the surveys that the online discussions were useful for a better understanding of the course material, they were uncomfortable about being "graded" for such discussions. Here is where the instructor has to motivate the importance of holding e-learning discussions for the success of the course.

5. Conclusion

Should graduate mathematics courses be taught fully online? Based on the assessments, there is no statistical evidence that distance learning students do differently than face-to-face students when synchronized instruction is used. We can safely say that upper level mathematics and sciences courses can successfully be taught fully online with synchronous instruction. The Department of Mathematics & Statistics will offer in the following semesters all of its graduate level courses with the synchronous instruction.

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