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Analysis of the Effectiveness of Online Learning in a Graduate Engineering Math Course

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Abstract

This paper describes a collaborative effort between faculty in the College of Engineering and the College of Education at the University of Alabama. A graduate course in engineering mathematics called Partial Differential Equations was developed, then taught in the Spring 2002 term to 26 onsite students and 14 off-campus students. The students in the class were divided into three tests groups: (1) traditional mode of delivery only, (2) online delivery only, and (3) a mixture of traditional and online delivery. In addition, the performance of the students taking the class was compared to that of a previous semester's students who took the class via the traditional mode of delivery. Results indicate that the mode of delivery had little effect on student performance.

There is little doubt that changes in higher education are occurring rapidly. Many of these changes are being driven by technological advances such as real-time video streaming and the Internet. Even today, it is possible for students to obtain a quality education without ever stepping foot on a college campus. Further, a generation of "new learners" responds to visual cues, is comfortable and actually expects to utilize technology, and even demands it from colleges and universities. Many of these new learners seek out the best possible learning opportunities, irrespective of location. If colleges and universities are going to continue to be the prime provider of advanced education, it is imperative that they remain at the forefront of distance education.

The University of Alabama initiated a totally video-based graduate/undergraduate program for distance learning in 1991. This program, termed QUEST (Quality University Extended Site Telecourses), was initiated with the goal of providing working professionals with a means to continue their education without giving up their jobs (Quality University Extended Site Telecourses, 2002). Although graduate education is still a major goal of the QUEST program, QUEST has begun to be embraced by more and more undergraduate students who have special needs such as adults in the workforce and co-op students.

The QUEST program at the University of Alabama provides students with copies of videotapes of college courses taught before a live on-campus audience. The tapes are sent to students the next working day following the on-campus lecture to the students'

place of employment or a conveniently located open site. QUEST students complete the same course requirements and take the same examinations as on-campus students. They interact both with their instructor and other students via e-mail, telephone, and fax.

The Department of Aerospace Engineering and Mechanics at the University of Alabama began a master's degree program in aerospace engineering through QUEST and the College of Continuing Studies in 1994. Typically, all graduate courses taught in the Department are offered via QUEST, and it is not unheard of for a class to have as many QUEST students as on-campus students. The QUEST master's degree program in aerospace engineering is fully institutionalized, is producing graduates, and by all accounts is fully successful.

Despite the fact that the Aerospace Engineering and Mechanics Department has a successful QUEST degree program, advances in technology continue to expand the bounds of distance education. There is little doubt that the next step beyond the current distance education program at the University of Alabama is to put the degree program on the Internet. Steps have been taken in this direction—several faculty members have developed "Web-assisted" classes. Here, "Web-assisted" is interpreted to mean classes in which Web pages are used to supplement in-class materials, primarily with the distance education participants in mind (e.g., Web pages with discussion boards, supplemental materials, course notes, class-e-mail addresses, etc.).

There are many problems and issues that must be addressed when moving beyond "Web-assisted" classes to "Web-based" classes. Many of these issues are made more complex when the course is a graduate engineering class that requires students to be proficient both in mathematics and computer programming. A Web-based course in Partial Differential Equations (GES 554—Partial Differential Equations, 2002) was developed and taught in the Spring 2002 term. The course was taught in a way such that students could choose their mode of delivery (traditional or Web-based) and experiments could be conducted to gauge the effectiveness of the modes of delivery. This paper presents an analysis of how students performed during different modes of delivery of the Web-based course in partial differential equations.

Course Description

The Aerospace Engineering and Mechanics Department offers three graduate degrees: (1) M.S. in aerospace engineering, (2) M.S. in engineering science and mechanics, and (3) Ph.D. in engineering science and mechanics. Additionally, the department teaches graduate service courses in engineering mathematics; these courses are taken by students from across the College of Engineering. Partial Differential Equations (GES 554) is both a required course in each of the department's three degree programs, and a graduate service course. Thus, the class is typically relatively large for an engineering graduate course (on average approximately 30 on-campus students and 15 QUEST students) and the audience is diverse.

Partial differential equations occur in a wide variety of engineering and scientific disciplines. GES 554 examines the solution of partial differential equations by focusing on three specific equations: (1) the heat equation, (2) the wave equation, and (3) the potential equation. Emphasis is placed on the application of the method of *separation of variables*. However, partial differential equations are solved using both LaPlace

transforms and numerical techniques. Topics covered include: (1) Fouriere transforms, (2) Sturm-Louisville problems, (3) the heat equation in bounded and unbounded regions, (4) the wave equation in one- and two-dimensions, (5) the potential equation in one- and two-dimensions, (6) classification of partial differential equations, (7) Bessel functions, and (8) numerical methods for solving partial differential equations. Students in this course are required to employ either a computational environment (such as MathCad or MATLAB) or a programming language (typically FORTRAN or C++) to compute solutions to partial differential equations.

GES 554 is designed to be a stand-alone class in partial differential equations. There is an abundance of material available for the student, and students are responsible for working their way through the material. The textbook was written by the instructor; thus, much of the text material is available online. In addition, the Web-based version of the course has the following items/information online:

- Class modules—basically, "lecture" notes used in the classes and designed to be studied after students have read the associated material in the textbook.
- Homework problem solutions—students may download solutions to the homework after they turn in their assignments. The Web site has a time-stamp that indicates to the instructor if solutions to the homework problems are downloaded prior to submission.
- Class roll—contact information for both on-campus and QUEST students.
- Cyber labs—although this course does not include traditional laboratory exercises, it does rely heavily on computer programs that can generate graphical solutions to the partial differential equations. By viewing these graphical solutions, students can oftentimes quickly evaluate the accuracy of their solutions. The Web site includes several cyber labs that the students can access to experiment with alternative solutions and problem parameters.
- Electronic discussion board—organized along the lines of the textbook so that students can post questions or comments about a particular topic in an appropriate location.
- Examinations—examinations are downloaded from the typically including both an in-class and a take-home portion. Of course, the on-campus students take the in-class portion of their examinations in a classroom setting. QUEST students utilize a course coordinator to take their in-class portion of the exam.[1] Both on-campus and QUEST students download the take-home portions of their examinations from the Web site.

Method

The online version of GES 554 was beta-tested during the Spring 2002 term at the University of Alabama. The course meets three times per week for a single semester. As mentioned earlier, the class consists of both on-campus and QUEST students. Because all of the students enrolled in the course were graduate students there was some flexibility in class presentation. An attempt was made to deliver the course in such a way as to allow for a comparative study of the effectiveness of the online version. Specifically, the students in the class were divided into three tests groups: (1) traditional mode of delivery

only, (2) online delivery only, and (3) a mixture of traditional and online delivery. In addition, the performance of the students taking the class was compared to that of students from a previous semester who took the class via the traditional mode of delivery. The intent of this design was to allow for the most comprehensive comparison of the students possible.

Modes of Delivery

The students enrolled in the course were divided into three groups. The 14 QUEST students were designated group A. The 26 on-campus students were randomly divided into two separate groups (B and C). After dividing the students into groups, the class was organized into three parts (lined up with three examinations that were given in the class), where each third lasted approximately five weeks. Then, each group of students was assigned a mode of delivery (either traditional, online, or both) by which they were to take each third of the course. Table 1 below shows that Group A, the QUEST students, took the entire course using the online version. Students in Group B took the first third of the course in the traditional manner, the second third of the course in the traditional manner, and the third portion of the course with both the traditional and online version of the course. Students in Group C took the first third of the course using the traditional mode of delivery, the second third of the course using only the online mode of delivery, and the third portion of the course using both the traditional and the online modes of delivery. This experimental design allowed for a comparison between the modes of delivery given the constraints associated with offering the course. In addition, a fourth comparison group was considered: students prom a previous semester who took the class via the traditional mode of delivery.

Table 1
Students Divided into Groups and Subjected to Various Modes of Delivery

	First Third of Course	**Second Third of Course**	**Final Third of Course**
Group A (QUEST)	Online only	Online only	Online only
Group B (on-campus)	Traditional	Traditional	Traditional and online
Group C (on-campus)	Traditional	Online only	Traditional and online
Previous semester	Traditional	Traditional	Traditional

Student Demographics

Students in the course completed a survey so that the demographics of the three groups could be determined. The major points considered were: (1) students' age (considered as a gage for maturity), (2) gender, (3) degree sought, (4) experience with taking online courses, and (5) computer programming ability. As seen in Table 2, the three groups were quite similar in all areas except age.

Table 2
Student Demographics

	Group A (QUEST)	Group B	Group C	Previous Semester
Age	Avg=31.3 St.Dev=4.2	Avg=23.2 St.Dev=1.8	Avg=24.8 St.Dev=1.2	Avg=23.6 St.Dev=2.1
Gender	Male=14 Female=0	Male=12 Female=1	Male=12 Female=1	Male=26 Female=4
Degree Sought	MS=14 PhD=0	MS=10 PhD=3	MS=8 PhD=5	MS=23 PhD=7
Online Experience	Yes=14 No=0	Yes=3 No=10	Yes=2 No=11	Yes=2 No=28
Programming Experience	Yes=10 No=4	Yes=9 No=4	Yes=8 No=5	Yes=26 No=4

Comparison of Groups

Student performance of the three groups are compared and contrasted with each other, and with students from a prior semester based on three tests, a final examination, and homework assignments. The three tests and the final examination were similar to the examinations typically given in a graduate engineering mathematics course, and the homework assignments often involved in-depth computer programming projects.

Results and Analysis

This section presents data used in evaluating the effectiveness of the three modes of delivery. As indicated in Table 1, Group A consisted entirely of QUEST students while Group B and Group C consisted of randomly selected on-campus students. Also, while the QUEST students took the entire course using the online mode of delivery only, Group B and Group C took the course using various combinations of online and traditional modes of delivery. The group indicated "Previous Semester" consisted of students who took the course previously using a traditional mode of delivery only. Although the students in the previous semester did not complete exactly the same assignments and examinations, the ones they did complete are similar enough to provide a benchmark.

The four major evaluation metrics are three examinations (taken at 5-week intervals in the course and labeled "Test 1", "Test 2", and "Test 3"), a final examination (labeled "Final"), and homework (labeled "HW"). The three examinations and the final examination each included both an in-class portion and a take-home portion. The in-class portion of the examinations consisted of fairly straightforward computations. The take-home portions, however, required the students to (1) put in more abstract thought since the questions were more analytical than the in-class questions, and (2) exercise their computer programming skills. The three examinations were the most direct measure of

the effectiveness of the modes of delivery since they were given at the end of the three course segments used over the semester. The final examination and the homework, on the other hand, were used as a gage of any differences in overall performance between the three groups since the final examination was comprehensive and the homework grade bridged the three 5-week segments used in the class.

Table 3 shows performance data for the three groups. Both the average grades and the standard deviation are included for each evaluation instrument. Although Group A did slightly better than the other two groups on both the in-class and the take-home portion of the first exam, the class performance of the three groups was quite consistent. This examination was given after the first third of the course wherein Group A took the class using the online material only, and Groups B and C took the class in a traditional mode, that is, they did not utilize the online materials.

The data presented in Table 3 for Test 2 indicate that Group C, taking the class using the online mode of delivery, scored significantly better than Group B on the take-home portion of the examination. Feedback obtained from the students at the conclusion of this segment of the examination indicated that this improved performance may have been due to pressure exerted by the online mode of delivery encouraging the students to work through numerous example problems and to complete several programming assignments in the form of cyberlabs.

Table 3
Examination Scores

		Test 1		**Test 2**		**Test 3**		**Final**		**HW**
		In-class	Take-home	In-class	Take-home	In-class	Take-home	In-class	Take-home	
Group A	Avg	92.09	93.20	86.93	96.00	88.99	96.50	95.44	97.02	89.51
	St. Dev.	4.76	7.51	7.70	3.26	10.20	4.05	7.25	4.58	10.03
Group B	Avg	91.36	89.17	84.92	93.60	92.85	96.98	93.31	97.12	85.73
	St. Dev.	5.14	4.52	7.39	8.49	4.70	4.81	7.75	5.22	11.03
Group C	Avg	91.88	92.25	84.41	96.32	91.99	96.23	93.18	93.96	87.70
	St. Dev.	6.52	6.03	8.79	4.85	3.56	5.98	5.90	5.11	8.18
Previous Semester	Avg	91.92	91.03	87.25	93.10	90.23	95.87	92.88	94.32	90.11
	St. Dev.	5.32	6.51	4.32	3.89	5.65	5.10	6.15	6.78	10.34

Table 3 also indicates that both Groups B and C achieved their highest performance score in the final segment of the class. It was during this final 5-week period that students in these two groups were using both an online and a traditional mode of delivery.

Finally, Table 3 indicates that the groups' performance on the final exam and the homework was similar. Again, these two evaluation tools are considered to minimize the effects of the mode of delivery since they overarch the entire course.

Table 4
Breakdown of Group Performance with Respect to Letter Grade indicates Little Difference between the Three Groups

		Test 1	Test 2	Test 3	Final	Homework
Group A						
	A	11	9	11	11	8
	B	2	4	2	2	3
	C	1	1	1	1	3
Group B						
	A	8	7	11	10	8
	B	5	4	2	2	1
	C	0	2	0	1	4
Group C						
	A	9	7	11	10	5
	B	3	4	2	2	6
	C	1	2	0	1	2
Previous Semester	**A**	20	18	25	23	18
	B	7	9	4	4	5
	C	3	3	1	3	7

Another way to consider performance in the class is to evaluate the students' letter grade distribution (Table 4). The data indicate that both Group B and Group C achieved their best performance on the third examination.

Conclusions

Partial Differential Equations is basically a high-level mathematics course. There are several facets of the course that make it a challenge to offer in a Web-based format. First, since it is taught in the College of Engineering, GES 554 is taught with a focus on computing. Series solutions to partial differential equations are typically developed using classical techniques, but solutions are considered incomplete until students compute numerical values using computer tools. Second, the mathematics presented in the course is beyond anything the students have seen as undergraduates. Third, because the students in the class are from a variety of engineering disciplines, developing examples common to all students can be difficult. Finally, because partial differential equations serve as the fundamental type of equation solved in graduate-level engineering courses, many of the students in GES 554 are first-year graduate students.

The goal of this study was to compare the effectiveness of three modes of delivery in a graduate-level engineering mathematics course. The results presented here were gathered over a single semester, thus the sample size is limited. However, there are still some conclusions that can be drawn from data presented.

First, students performed better on the analytical portion of the course when they had used the online mode of delivery. Instructor experience and student feedback indicates that this is due to the greater consistency of online materials with this mode of delivery. Students had to "get it on their own" when they were doing the course online, and thus would have to "dig deeper to understand the material" than if they had easy access to the instructor.

Second, students taking the class via a traditional mode of delivery performed slightly better on the in-class portion of the examinations. This is most likely due to the tendency of the instructor to inadvertently drop little hints about which aspects of the class the students might expect on the examination.

Third, the two on-campus test groups both performed better when they had access to both modes of delivery, traditional and online. In this scenario, students had access to the mode from which they learned the best; students who desired the hands-on approach of the traditional mode had it and students who desired the interactive learning experience of the online mode of delivery could utilize it. Of course, presenting two modes of delivery is more time-consuming for the instructor, and this limitation must be considered when decisions about such things are being made.

Fourth, there was little measurably difference between the performance levels of the three groups. The reason for this consistent performance is likely due to the fact that each group was taking the class using the mode of delivery with which they are most accustomed to taking a class.

As a final note, the instructor of the course was initially a little disappointed that "he made no difference in the class." Perhaps the instructor felt that his teaching ability would make the difference, and student performance would indicate that the traditional mode was superior since the teacher would actually really be teaching by standing in front of the class lecturing. However, upon reflection, the instructor of the course decided that the effort and planning that went into the development of the online course was a form of teaching. The instructor finally came to terms with the idea that "the world around us is changing; why should teaching be any different?"

Note

[1]The use of a course coordinator to monitor the in-class portion of the examinations is a facet of the course that will ultimately be changed if and when GES 554 is offered entirely as a Web-based course. The most direct way to accomplish this is to eliminate the in-class portion of the examinations.

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