A Study of Non-traditional Instruction on Qualitative Reasoning and Problem Solving in General Studies Mathematics Courses

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Abstract

In this paper we discuss pair-wise comparisons of students' performance in College Algebra and Elements of Statistics courses among three instruction formats: the traditional face-to-face lecture without technology enhancement, the blended face-to-face lecture with web-based homework, and the fully online. Overall, there was no evidence of a difference in the students' mastery of College Algebra concepts between instruction given in the traditional and blended modes. Students in the blended Elements of Statistics classes outperformed those in the traditional format. These findings are consistent with previous studies such as those reported by Barnes, Cerrito, & Levi (2004). However, students in the fully online classes performed significantly worse than those who had the face-to-face lectures in the blended and traditional formats. Our results illuminate nuances which suggest that the very attributes of face-to-face instruction with web-based homework systems and fully online classes that are beneficial to the top performing students may be detrimental to the lowest performing students. We offer some suggestions to accommodate the situation.

Introduction

Institutions of higher education are exploring the use of web-based instruction in general education science courses as the rapid development of technology continues to affect the teaching and learning of science. Several studies have shown that web-based or online homework enhances learning in general education courses in mathematics, physics, biology, and chemistry. See for example: O'Callaghan (1988), Stephens & Konvalina (1999), Hauk & Segalla (2005), Bonham, Deardorff, & Beichner (2003), Cole & Todd (2003), and Riffell & Sibley (2005). In mathematics, the options for technology usage in instruction range from the face-to-face lecture coupled with web-based homework, to fully online instruction. Web-based homework systems are an interactive environment where students learn mathematics concepts on the computer by setting their own pace, practicing problems, and receiving feedback according to their skill level. These automated systems permit more practice that provides an impetus for students to stay on top of the course material. Further, the immediate feedback on their attempt spotlights their mistakes that they correct to enhance their learning. On the one hand, the findings reported by Utts

, Sommer, Acredolo, Maher, & Matthews (2003) show that students in online classes perform as well as those in the face-to-face format. On the other hand, Leventhall (2004) and Smith & Ferguson (2005) contend that fully online mathematics instruction has inherent characteristics that lead to serious shortcomings. In fact, Fedele & Li (2008) have also shown that general studies online mathematics classes have a higher drop rate than traditional face-to-face classes. It is, therefore, of the essence to further investigate the teaching and learning of mathematics at the general studies level, by means of the various options available including those that involve technology as a teaching tool.

In the state of Florida, a student must satisfy the general studies (GS) as well as the Gordon Rule (GR) requirements in order to receive a baccalaureate degree. Those requirements in the GS/GR area of mathematics dictate that the student must take two courses at or above College Algebra level. For a variety of reasons, the two most popular choices for students to satisfy the GS/GR requirements are College Algebra and Elements of Statistics. In order to improve the teaching and learning of general studies courses, hence the retention and graduation rates, the Department of Mathematics and Statistics at the University of West Florida recently implemented a blended learning approach by means of web-based homework systems with either online or face-to-face instruction in all sections of College Algebra and Elements of Statistics during Spring 2008 with a combined enrollment of 790 students. At the end of the semester we assessed the students' qualitative reasoning and problem solving ability. In contrast, 758 students were enrolled in traditional face-to-face instruction of the two courses during Spring 2007 and a similar assessment was conducted. In this paper, we compare the Spring 2008 assessment with that of Spring 2007. Among other things our analyses will show that: (a) the students' performance in the Elements of Statistics classes improved in 2008; (b) there was no significant improvement in students' performance in College Algebra classes during this transition; and (c) the overall performance of students in the online classes in both courses was worse than that of the face-to-face classes with or without the web-based homework blend. Aside from interpreting our results, we also offer some suggestions for enhanced student learning.

Course Design and Methodology

At the University of West Florida, College Algebra is taught by graduate teaching assistants (TAs) and one faculty member, while regular faculty and adjuncts teach Elements of Statistics with the help of TAs. A Coordinator of Lower Division Courses oversees the GS/GR curriculum and helps to maintain uniformity and quality in the teaching and learning of this important GS/GR block of courses. Among other things, all sections of each course have the same syllabi with scheduled weekly topics as well as the homework assignment, similar-strength hourly tests, and a uniform final examination.

We implemented our redesigned College Algebra and Elements of Statistics courses in Spring 2008. TAs 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. Enrollment was capped at 42 per section. 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 fully online section of College Algebra using Elluminate© and the E-learning system. Students in the online section could seek help from their instructor via Elluminate© in a synchronous, two-way, dynamic live discussion with video capability. Course material and related information were posted online on the E-learning system. In Spring 2007, we offered eight sections of College Algebra with similar enrollment caps per section in the traditional face-to-face mode without technology enhancement.

In Spring 2008, three sections of approximately 130 students each were scheduled for the Elements of Statistics course in the blended learning format. We also offered two sections of fully online classes, each consisting of approximately 30 students. With the assistance of TAs, senior faculty taught all sections of the course. As with College Algebra, the blended instruction comprised of face-to-face lectures and a web-based homework system supplemented by the E-learning system. Furthermore, a computer lab staffed by TAs was reserved for 28 hours per week as a tutoring lab for students in the course. Students in these sections could do their homework or seek help in the computer lab. The online sections also used Elluminate© and E-learning for lectures, office hours, and course materials. In Spring 2007, we scheduled seven sections of Elements of Statistics in which enrollment was capped at 46, and a large section with enrollment of 110. Instruction was by means of the traditional face-to-face lecture with no technology enhancement.

Evaluation Procedure and Method

The Students' Performance

Prior to the assessment period in question, the department decided that qualitative reasoning and problem solving were the appropriate domains for GS/GR mathematics. Consequently, we set student learning outcomes for the two courses within those domains and have continued to use them as our measurable course objectives for several years. The following are the student learning outcomes:

College Algebra

On successful completion of College Algebra, student will be able to: (a) identify functions and their properties; (b) analyze and graph polynomial, rational, radical, exponential, and logarithmic functions; (c) perform operations on algebraic and transcendental functions; (d) solve exponential and logarithmic equations; (e) solve systems of linear equations; and (f) solve problems involving application of algebraic and transcendental functions.

Elements of Statistics

Student who successfully complete the Elements of Statistics course will be able to: (a) compute measures of centrality, dispersion, and location for data sets; (b) apply probability rules and calculate probabilities for discrete and continuous random variables (c) solve problems involving application of discrete and continuous random variables; (d) use probabilities rules in solving problems; (e) estimate parameters, and (f) perform hypotheses tests.

For each course, the Coordinator made a final examination consisting of 40 problems carefully chosen to assess students' performance on the learning outcomes. The examinations for the two semesters of interest were similar in thrust, strength and content. Instructors of the various sections did not have access to the examinations prior to the conclusion of formal instruction for the semester. Students in the online sections either came to the campus for the final examination or were given the same examination at an approved testing center to facilitate the proctoring of their examination.

Instructors jointly graded the examinations so that one instructor graded designated problems for all sections to enhance uniformity. We evaluated students' performance on the final examinations exclusively for the Spring 2007 and Spring 2008 to effect this comparative study. We then analyzed and compared data for several distinct groups: traditional versus blended, for each course; face-to-face versus online, for each course; and online College Algebra versus online Elements of Statistics. Furthermore, we examined the students' performance on each of the questions on the examinations so as to identify areas of strength and, more importantly, weakness.

Assessment Results

In order to compare students' performance among the groups, we first adopted a global analysis approach by classifying students who earned grades of A, B, or C on the uniform final examination as being *successful*. Accordingly, we considered students who earned lower grades (D, F) and those who withdrew from the course (W-grade) as being *unsuccessful*. Furthermore, we classified students who earned A and B grades as achieving *high success*, while those who earned an F grade were considered to be *very low performing* students. Our terminology in the sequel reflects this classification.

College Algebra: Blended format vs. Traditional Face-to-face Instruction

Table I shows the performance of the 306 students enrolled in College Algebra in the sections with blended instruction, i.e. face-to-face lectures with a web-based homework system, in Spring 2008. The performance of the 294 students enrolled in the traditional face-to-face sections of the same course but without a web-based homework system, in Spring 2007, is shown in Table II. Using the Statistical Analysis System (SAS), we performed the Fisher's Exact Test so as to compare the success rates. At a significance level of 0.05 (p-value = 0.0855), our analysis shows that the success rates for the two groups did not differ significantly. Turning to local analyses, we note that: (a) the drop rates

were 13% for Spring 2008 and 14% for Spring 2007, showing no significant difference; (b) the percentage of students who were successful was identical, at 69%; (c) the percentage of students who achieved high success increased from 45% in Spring 2007 to 50% in Spring 2008; and (d) on the other hand, the percentage of students who received a grade of F also increased from 9.5% in Spring 2007 to 12.4% in 2008. Thus, while the overall success rate for College Algebra did not change as we moved from the traditional face-to-face instruction to the blended format with face-to-face lecture and a web-based homework system, the higher rates of "extreme" grades received (A, B, and F) is noteworthy.

College Algebra: Online Instruction vs. Face-to-face formats

Similarly, we performed a statistical analysis to compare the success rates in College Algebra for the fully online section in Spring 2008 (see Table III) to the face-to-face sections (Spring 2007 and Spring 2008). The Chi-square Test with a significance level of 0.05 (p-value = 0.0001) shows that the success rates for the two groups differed significantly. Furthermore, as can be readily discerned from Tables I, II, III, and Figure I (the College Algebra Grade Distribution Chart), 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 45% and 50% for 2007 and 2008, respectively; and (e) 15.8% of students received a grade of F, a rate that is much higher than the 9.5% and 12.4% recorded by the face-to-face groups in Spring 2007 and Spring 2008. 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 bended face-to-face group with web-based homework and is even higher than 52%, the rate for traditional face-to-face group.

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 clearly 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.

Elements of Statistics: Blended Format vs. Traditional Face-to-face

Table IV shows the data for the performance of the 387 students who enrolled in sections of Elements of Statistics in Spring 2008. The format for instruction was blended with face-to-face lectures, a web-based homework

system, and E-learning support. Table V consists of the data for the performance of the 404 students who enrolled in Elements of Statistics in Spring 2007 with the traditional face-to-face instruction technology enhancement. We compared students' performance for Spring 2007 and Spring 2008 semesters with respect to the success rates as defined above. Statistical analysis was by means of Fisher's Exact Test with a significance level of 0.05 (p-value = 0.0130). Our analysis shows that the success rates for the two groups differed significantly. From Tables IV and V, one can also see that: (a) the success rate was 69% in the traditional face-to-face format in Spring 2007, compared to 77% in the blended face-to-face format with web-based homework system in Spring 2008; (b) the drop rate in Spring 2007 was 16%, compared to 11% for Spring 2008; (c) the rate of high success increased from 43% in Spring 2007 to 52% in Spring 2008; and (d) the rate of very low performance dropped slightly from 9% in Spring 2007 to 8% in Spring 2008. In fact, when we considered only those students who did not drop the course, the high success rate on the final examination rose from 51% for the traditional face-to-face format in Spring 2007, to 58% for the blended face-to-face lecture with web-based homework system. Based on these analyses, we conclude that the students in the blended format outperformed those in the traditional face-to-face instruction in Elements of Statistics.

Elements of Statistics: Online Instruction vs. Face-to-face formats

We also analyzed data for two sections of fully online Elements of Statistics sections (Spring 2008, Table VI) and compared with the data for the sections of the same course that had the face-to-face formats in Spring 2007 and Spring 2008. We utilized the Chi-square Test with a significance level of 0.05 (p-value = 0.0004) to conclude that the two groups differed significantly with respect to their success rates. Moreover, it is clear from Tables IV, V, VI and Figure II (the Elements of Statistics Grade Distribution Chart) that: (a) the success rate for the online Elements of Statistics group was 54% while those for the face-face sections were 69% and 77% for Spring 2007 and 2008, respectively; (b) the drop rate for the online group was 22%, a higher rate than the rate for either of the face-to-face sections (16% and 11% for Spring 2007 and Spring 2008, respectively); (c) the rate for high success (A or B grades) for the online group was 25%, a much lower rate than those for the face-to-face sections (at 43% for Spring 2007 and 52% for Spring 2008); (d) the percentage of students with very low performance (F grade) in the online group was 18.6% in comparison to the lower rates of 9% and 8% in the face-to-face sections in Spring 2007 and Spring 2008, respectively.

From the analyses of the data for Elements of Statistics, we conclude that the group in the blended format (face-to-face lecture and web-based homework system) outperformed the group with the traditional face-to-face instruction and the group that was fully online. Similarly, the traditional face-to-face instruction yielded better performance results in either format than the online instruction.

Online College Algebra vs. Online Elements of Statistics

Finally, we compared the students' performance for the online section of College Algebra with that of the online sections of Elements of Statistics with respect to the success rates. Employing the Fisher's Exact Test with a significance level of 0.05 (p-value = 0.1518), we observed that the two groups did not differ significantly with respect to their success rates. From Tables III and VI as well as Figures I and II, we note that the success rate for College Algebra was 50% in comparison to 54% for Elements of Statistics. The drop rates for College Algebra and Elements of Statistics were 32% and 22%, respectively. At the same time, the rates of high success were 39% for College Algebra and 25% for Elements of Statistics, while rates of very low performance were 16% and 19% for College Algebra and Elements of Statistics, respectively. Since the success rate and the drop rate favored the Elements of Statistics group but the rates of high success and very low performance favored the College Algebra group, the statistical insignificance of the overall performance of the two groups, as our test shows, is reasonable.

Comparisons of Subject Area Performance

Among the 40 problems on the College Algebra final examination, the students in the blended sections with face-to-face lecture and web-based homework did not do better than the students in the traditional face-to-face instruction on the following types of problems: (a) Finding the domain and the range of a logarithmic function; (b) Finding zeros and multiplicity of zeros, of a polynomial function; (c) Determining the composition of two functions; (d) Converting a logarithmic expression into its exponential equivalent; and (e) Evaluating a logarithmic expression using given values.

Among the 40 problems on the Elements of Statistics final examination, students in the blended platform did not do better than the group in the traditional format on the following areas: (a) Finding the variance of a discrete random variable; (b) Finding the value of a test statistic for proportion hypothesis; (c) Finding the p-value for proportion hypothesis; (d) Stating the decision for proportion hypothesis; (e) Finding the sample size to estimate the sample mean within a given error; (f) Finding the value of the margin of error; and (g) Stating the decision rule for rejecting the null hypothesis regarding two population means.

Cost of Instruction

For the sections of College Algebra, the web-based homework system was embedded in the textbooks at no additional cost. The number of sections remained the same from 2007 to 2008. Consequently, our transition from the traditional face-to-face instruction to the blended instruction did not translate into any savings for the instruction. In contract, there were eight sections of the Elements of Statistics course including one large section in which a TA assisted the instructor of record in 2007. In the redesigned course, however, we scheduled two small-sized online and three large sections of the course with TA-assistance, thus gaining a net saving equivalent to the instruction for two sections of the course.

Conclusion

Given that qualitative reasoning and problem solving skills are some of the tenets of a well-grounded college education, it is of the essence to ascertain that these are acquired in the relevant general education curriculum. In our quest to explore current trends to enhance student learning through improved instruction and student engagement, we undertook this study to compare the level of students' performance in College Algebra and Elements of Statistics in the three available formats, namely, the traditional face-to-face instruction, the blended face-to-face lecture with web-based homework, and the fully online instruction. From the foregoing, we surmise that, with respect to the domains of qualitative reasoning and problem solving:

- In College Algebra, there was no significant difference in students' performance in the traditional format in comparison to the blended face-to-face lecture with a web-based system. However, students in the face-to-face sections, irrespective of the format, outperformed those in the fully online group. While students in the blended instruction had a greater rate of high success, the same group also had a greater rate of very low performance. Put succinctly, high performing students did better as the poor performing ones did worse, in the blended format in comparison to the traditional instruction.
- In Elements of Statistics, students in the blended learning format performed significantly better than those in the traditional instruction. Similar to the results in College Algebra, the face-to-face groups had a higher rate of performance than those in the online class.
- The performance of the online College Algebra class was comparable to that of the online Elements of Statistics group. While the online Elements of Statistics group had a higher rate of success and a lower drop rate when compared with the online College Algebra group, their apparent gains were nullified by the lower rate of very high success and a higher rate of very low performance in the group.
- Regarding performance in subject areas, students in the technology-enhanced instruction did not perform better than those in the traditional face-to-face format on multistep problems.

Interpretation of results

Several factors may account for the patterns in our results but the following are rather obvious to us:

- The level of maturity and self-discipline of many students at the general studies level may not be very suitable for online instruction.
- A disproportionate majority of students in the GS/GR courses is in majors outside the sciences. Students in such majors who lack the needed motivation for success in mathematics may readily withdraw from the online classes without seeking advice or encouragement from peers, advisors, and instructors. Others who are doing poorly stay the cause and remain isolated with little chance of improving their

performance. We note that our student population consists of a high number of first-time-in-college, FTIC.

- Enrollment in these courses is by means of either a prerequisite course or attainment of minimum scores on the ACT and SAT that some students may have taken years prior to enrolling in the courses. Thus, ill-preparedness may play a greater role in students' performance in online instruction than the skillful hand and watchful eye of a seasoned instructor.
- The improvement in students' performance in the Elements of Statistics course may be attributed in part to the fact that the course is taught by regular faculty with TA support. The College Algebra course that is mainly taught by TAs did not experience significant gains in students' performance as we moved from the traditional face-to-face instruction to the blended format.
- That students in the blended instruction experienced noticeable difficulties on multistep problems may be a result of the single-step problem platform on which many web-based homework systems operate.

Recommendations

Based on this study and our overall experiences, we recommend the following:

- Through aggressive advising, students at the general studies level should be permitted to enroll in the online classes only if they have shown high achievement in prior mathematics courses or standardized tests.
- Departments should set aside a least one section of the traditional face-to-face instruction for those students deemed to be unsuitable for online and blended instruction.
- An early warning system that identifies low performing students on the very first hourly test should be used to further advise such students in order to reduce the drop rate as well as low performance.
- Instructors should use the E-Learning system to provide additional homework problems, especially those that require multistep processes. This should help to alleviate the deficiencies that students in the blended learning showed regarding multistep questions.

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Table I.
Students' performance in blended instruction of College Algebra

Spring 2008								
Section	**Enrolled**	**Withdrew**	**A**	**B**	**C**	**D**	**F**	**Pass**
1	39	5	17	10	1	0	6	28
2	41	8	8	12	7	2	4	27
3	39	12	11	10	0	3	2	33
4	40	3	2	7	18	4	6	27
5	37	1	11	13	8	2	2	32
6	29	5	4	2	11	1	6	17
7	41	3	20	4	7	2	5	31
8	40	4	10	12	5	2	7	27
TOTALS	**306**	**41**	**83**	**70**	**57**	**16**	**38**	**222**

Table II
Students' performance in traditional instruction of College Algebra

Spring 2007								
Section	**Enrolled**	**Withdrew**	**A**	**B**	**C**	**D**	**F**	**Pass**
1	42	3	10	15	7	4	3	32
2	37	7	5	9	5	7	4	19
3	39	5	10	7	10	2	5	27
4	42	7	7	13	10	1	4	30
5	40	3	15	11	7	1	3	33
6	32	9	1	10	8	1	3	19
7	21	2	5	4	4	0	6	13
8	41	6	3	8	20	4	0	31
TOTALS	**294**	**42**	**56**	**77**	**71**	**20**	**28**	**204**

Table III
Students' performance in fully online instruction of College Algebra

Spring 2008								
Section	**Enrolled**	**Withdrew**	**A**	**B**	**C**	**D**	**F**	**Pass**
1	38	12	7	8	4	1	6	19

Table IV
Students' performance in blended instruction of Elements of Statistics

Spring 2008								
Section	**Enrolled**	**Withdrew**	**A**	**B**	**C**	**D**	**F**	**Pass**
1	131	17	36	26	42	5	5	104
2	129	10	34	43	24	3	15	101
3	127	17	28	35	30	7	10	93
TOTALS	**387**	**44**	**98**	**104**	**96**	**15**	**30**	**298**

Table V
Students' performance in traditional instruction of Elements of Statistics

Spring 2007								
Section	**Enrolled**	**Withdrew**	**A**	**B**	**C**	**D**	**F**	**Pass**
1	44	5	10	9	14	4	2	33
2	42	6	18	8	8	2	0	34
3	44	7	6	5	15	5	6	26
4	41	10	6	9	5	4	6	20
5	110	18	16	24	29	6	17	69
6	32	10	11	6	3	2	0	20
7	45	5	9	7	18	2	4	34
8	46	3	16	14	12	0	1	42
TOTALS	**404**	**64**	**92**	**82**	**104**	**25**	**36**	**278**

Table VI
Students' performance in fully online instruction of Elements of Statistics

Spring 2008								
Section	**Enrolled**	**Withdrew**	**A**	**B**	**C**	**D**	**F**	**Pass**
1	29	5	1	6	9	2	6	16
2	30	8	2	6	8	1	5	16
TOTALS	**59**	**13**	**3**	**12**	**17**	**3**	**11**	**32**

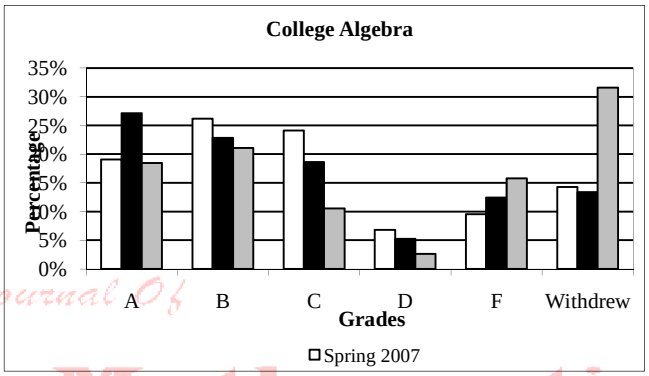

Figure I. Grade distribution chart for College Algebra

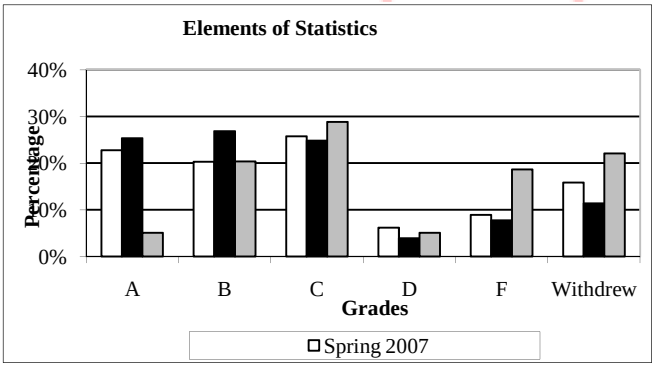

Figure II. Grade distribution chart for Elements of Statistics

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