ASSESSING TEACHING METHODS FOR A COURSE IN NUMERICAL METHODS

Abstract

Effectiveness of four instructional delivery modalities – 1) Traditional lecture, 2) Web-enhanced lecture, 3) Web-based self-study, and 4) Combined web-based self-study & classroom discussion, was investigated for a single instructional unit (Nonlinear Equations) over separate administrations of an undergraduate course in Numerical Methods. Two assessment instruments – 1) student performance on a multiple-choice examination, and 2) a student satisfaction survey were used to gather relevant data to compare the delivery modalities. Statistical analysis of the assessment data indicates that the second modality where web-based modules for instruction were used in conjunction with a face-to-face lecture delivery mode resulted in higher levels of student performance and satisfaction.

Background and Rationale

Web-based modules have been developed for a junior-level Numerical Methods course delivered in the College of Engineering at University of South Florida, Tampa.

The features of the web-based modules are addressed indirectly since the complete details are readily available in Ref[1, 2]. Stating in brief, the unique features of the web-based modules are that they are both *holistic* and *customized*. *Holistically*, the web-based modules review essential course background information; present numerical methods through several options - textbook notes, lecture videos, PowerPoint presentations, simulations and assessments; show how course content covered is applied in real life; tell stories to illustrate special topics and pitfalls; and give historical perspectives to the material[1,2]. Faculty and students are able to choose a customized view based on their preferred computational system - Maple[3], Mathcad[4], Mathematica[5], Matlab[6], and choice of engineering major - Chemical, Civil, Computer, Electrical, General, Industrial, and Mechanical.

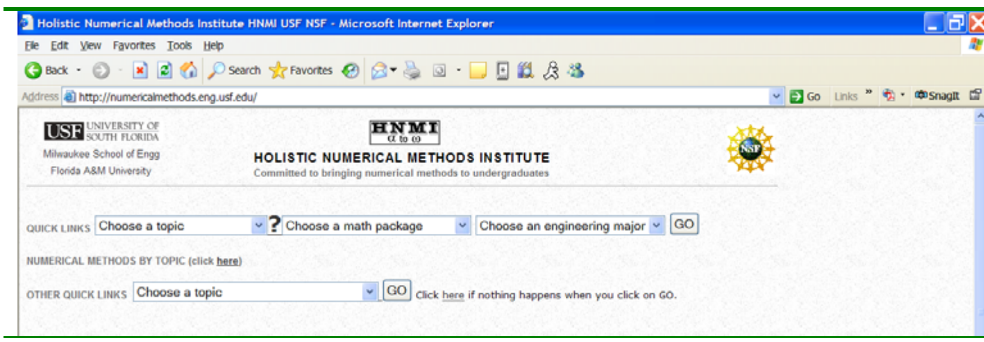

Figure 1: Home page of the Holistic Numerical Methods Institute - Committed to Bringing Customized Numerical Methods Holistically to Undergraduates.

The focus of this research is to compare four different modes of instructional delivery, namely

1) Traditional lecture,
2) Web-enhanced lecture,
3) Web-based self-study, and
4) Web-based self-study/discussion

The present study is a follow-up of findings reported in a previous paper[7] where we addressed only the first two modalities. Since the previous study was completed, the course has been delivered twice more, once with a web-based self-study and another with combined web-based self-study followed by a classroom discussion.

In recent years, there has been a substantial amount of research exploring how to enhance student learning across disciplines, including science, mathematics, engineering, and technology (SMET) courses. Research in this area spans academic disciplines and professional preparation, from medicine[8] to education[9] and computing to business[10]. Furthermore, the research base is exploring how e-learning, as internet-based education is often referred to, has different benefits based on characteristics of the individual student. The British Journal of International Technology devoted an entire edition to this issue alone[11] addressing, among other things, the need to be cognizant that distance learning has a unique ability to provide students with different learning modalities with varied resources and strategies. Techniques and tools to be used to enhance learning using the web include effective and adaptive navigation as well as addressing multiple and diverse needs and interests of the student[12].

The text, *How People Learn*[13] provides a foundation for many of the issues facing current educators who are encountering an increasingly diverse and multi-faceted student population. This literature was foundational to the exploration of various modalities of course delivery considered in this study. According to *How People Learn*, experts (in this case, faculty) "*often forget what is easy and what is difficult for students*[13, p. 32]." Relative to this issue, the modules and instructional materials developed through this study offer both students and faculty a comprehensive instructional package for simplifying and enhancing the teaching of numerical methods across the engineering curriculum.

Further, research has demonstrated that it is beneficial to provide "*instruction that enables students to see models of how experts organize and solve problems*" and that "*the level of complexity of the models must be tailored to the learners' current levels of knowledge and skills*[13, p. 37]." The design and format of the web-based modules helps students see how experts apply fundamental numerical methods to solve real world engineering problems both within and across different engineering disciplines.

And finally, citing again from this same synthesis of research findings, we know that "*A major goal of schooling is to prepare students for flexible adaptation to new problems and settings*[13, p. 65]" and that "*knowledge that is taught in only a single context is less likely to support flexible knowledge transfer than is knowledge that is taught in multiple contexts*[13, p. 66]." Our effort was to provide instruction opportunity to suit different learning styles[14]. By enabling students to select both a preferred computational system as well as to select one or more illustrative examples drawn from seven popular engineering majors within each topic area, these interactive instructional modules maximize the likelihood of lasting and flexible learning transfer of essential numerical methods course content.

Implementation & Assessment Instruments

The previous study[7] compared the first two modalities 1) Traditional lecture, and 2) Web-enhanced lecture for the two topics of Nonlinear Equations and Interpolation. In this paper, the focus is narrowed to the topic of Nonlinear Equation, but the scope of data is broadened by looking at four modes of delivering the content. The four modalities were implemented in four separate semesters - Summer 2002, Summer 2003, Summer 2004 and Spring 2005[1] semesters, respectively.

In Summer 2002 semester, students in the Numerical Methods course were instructed on Nonlinear Equations using the traditional, face-to-face lecture method without the use of the web-based modules, hereafter referred to as the *Traditional Lecture* mode of delivery. We used a popular engineering numerical methods textbook[15] for reading assignments and problem sets.

In Summer 2003 semester, students were instructed on the same topic of Nonlinear Equations using both lecture and the web-based resources that were developed for the course, hereafter referred to as the *Web Enhanced Lecture*. Before discussing numerical methods for a mathematical procedure, we conducted an in-class and informal diagnostic test on the background information via several multiple-choice questions. This allowed us to review specific material that most students struggle with. We used PowerPoint presentations to present the topics. These presentations were continually supplemented with discussions based on spontaneous instructor and student questions. Several times during the presentation, students were also paired in class to work out an iteration or two for a numerical problem. We also met during the weekly computer laboratory session where each student had access to a computer. Simulations for various numerical methods were conducted. Reading assignments were based on textbook notes written by the first author, and problem sets included questions based on Bloom's taxonomy[16].

In Summer 2004 semester, students received instruction through a distance format without a classroom lecture component, hereafter called the *Web-Based Self Study* mode. Same resources were available to students as they were in Summer 2003. In addition, lecture videos that were video recorded in a studio were available online. Since the students were learning the material themselves, regular class periods and the weekly lab session that were devoted to the topic of Nonlinear Equations as in Summer 2003 were cancelled. At the end of the week, as part of their graded homework assignment, students were asked to submit answers to 18 short questions (6 on each of the 3 subtopics of Background, Bisection Method, and Newton-Raphson Method) that were based on six levels of Bloom's taxonomy. The reading assignments and problem sets were the same as in Summer 2003.

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[1] We were planning to implement the fourth modality in Summer 2005. However, due to certain circumstances, it was co-taught by two instructors and hence assessments were not conducted like in previous semesters. The fourth modality will be implemented again in Summer 2006.

In Spring 2005 semester, students used the same self-study methods as those in Summer 2004 but were required to meet in the weekly lab session to discuss the lesson. This mode hereafter is called *Web-based Self Study/Class Discussion.* Although attending the weekly lab session was mandatory, they were not required to ask questions. Before the weekly lab session, as part of their graded homework assignment, students were asked to submit answers to 9 short questions (3 on each of the 3 subtopics) based on **first** three levels of Bloom's taxonomy. After the weekly lab session, they were asked to submit answers to 9 more short questions (3 on each of the 3 subtopics) based on **last** three levels of Bloom's taxonomy. The reading assignments and problem sets were the same as in Summer 2003.

To measure the student performance, four[2] questions were asked in the Nonlinear Equations portion of the final examination. Two of the four questions were selected at the lower levels of Bloom's taxonomy, while the other two were chosen from the upper levels of Bloom's taxonomy. Student performance on these four questions was examined as a function of the four course delivery modes.

To measure student satisfaction, a survey that gathered information on students' perceptions of the *presentation* and how it impacted their learning of the material was developed. This data was both quantitative and qualitative in nature, thus permitting exploration of the reasons behind student ratings. The instrument consisted of eight Likert[17] items (see Table 4) using a scale from 1 (truly inadequate) to 7 (truly outstanding). Instruments for the selected response options was consistent across semesters, however, qualitative data varied based on the mode of delivery. No qualitative data was gathered in the initial (Summer 2002) year of course delivery. For the other three years, questions varied slightly, based on delivery mode. While in Summer 2003, only one open-ended question was asked, "In what way can the class presentations be improved for Nonlinear Equations". In Summer 2004 and Spring 2005, four questions were asked. In addition to the question asked in 2003, the other three questions for 2005 were: "How did you learn the material for Nonlinear Equations?" What did you like most about the web-based and class presentation for Nonlinear Equations?", and "What did you like least about the web-based and class presentations for Nonlinear Equations". The 2004 questions were similar but did not address class presentations since they were not a part of the instruction in 2004. The answers were analyzed thematically to identify trends as well as strengths and weaknesses of the course as perceived by the students.

To evaluate the effectiveness of the various modes of delivery, the same sources of assessment data was used across the four years as well as the survey data previously discussed. Student performance was examined relative to their starting abilities, as reflected in their combined GPA across four prerequisite courses, Calculus I, Calculus II, Calculus III, and Differential Equations.

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[2] In the previous study[7] that examined results from two of the four delivery modalities, student performance was measured using results from 12 multiple choice questions (6 questions each from Nonlinear Equations and Interpolation) as part of the final examination. The six questions of each topic were based on the corresponding six levels of Bloom's taxonomy[16]. Since Summer 2004, only 4 questions are asked in the final examination on each topic, two at the lower level of Bloom's taxonomy, and two at the higher level of Bloom's taxonomy. This was done as the whole final examination was made multiple-choice since Summer 2003.

Assessment Results

Students in each of the four classes were typically in the later stages of their academic career and were identified as coming from three different sources. They were identified as either transfer students from the Community College (CC), First Time in College (FTIC), or Other (OT[3]). Since the Mean GPA (MPGPA) of the four prerequisite courses was of interest as a predictor, there was a concern about the equity of class composition as a function of where the students might have taken the four prerequisite courses. Chi-Square Goodness of Fit tests were conducted to determine if each of the classes delivered under the four different modalities contained similar students. The results of these analyses revealed that there were no statistically significant differences (using a Type I error rate of 0.5) across classes based on gender or location of previous course work (χ^2= 1.07, p=0.7849 for gender and χ^2= 18.96, p=0.4410 for location of previous course work).

Two assessment instruments[7] were used to explore the impact of course delivery mode on student achievement and satisfaction.

1. multiple choice question final examination[7] based on Bloom's taxonomy, and
2. student satisfaction survey[7].

The summer semesters of 2002 and 2003 were 6 weeks long, the summer 2004 semester was 10 weeks long, and the Spring 2005 semester was 16 weeks long. As such, results must be considered with regards to this potentially influential factor.

A. Multiple-Choice Final Examination Based on Bloom's Taxonomy

Four multiple-choice questions on Nonlinear Equations were used to gauge how well students performed in this area of the course delivered under the four different modalities. Two questions were asked at lower levels *(Knowledge, Comprehension, and Application)* of Bloom's taxonomy and two questions were asked at upper levels *(Analysis, Synthesis, and Evaluation)* of Bloom's taxonomy.

Each correct answer was given a score of one while an incorrect answer was scored as a zero, for two possible points for each of the lower and upper level sets of questions. For each of the four classes, Table 1 contains the sample size and the means for the incoming GPA on the four prerequisite courses (Calculus I, Calculus II, Calculus III and Ordinary Differential Equations) as well as the mean scores on the two point upper and lower Bloom's Taxonomy questions. For three of the four classes, the sample size was similar (42 in 2002, 49 in 2004 and 41 in 2005) while the other class was notably smaller (N=27 in 2003). Incoming MPGPA also varied, with the lowest MPGPA of 2.59 in the 2002 group and the highest MPGPA of 2.81 in the 2003 group. It is important to note that the highest MPGPA is in the group that had the smaller sample size. Additionally, the variability for MPGPA, as evidenced by the standard deviation was more pronounced in the 2003 student group than in the other three, which is an expected occurrence with a smaller sample size.

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[3] Other (OT) category includes students transferring form other universities or community colleges without having received a formal degree from those institutions.

Table 1 – Sample Size and Means of Incoming GPA(MPGPA) and Final Examination Score

Class	N	MPGPA		Upper Bloom		Lower Bloom	
		Mean (max=4)	SD	Mean (max=2)	SD	Mean (max=2)	SD
2002	42	2.59	0.763	0.86	0.647	1.29	0.457
2003	27	2.81	0.916	0.96	0.808	1.56	0.506
2004	49	2.75	0.606	0.80	0.707	1.47	0.581
2005	41	2.63	0.785	0.51	0.675	1.32	0.521
Total	159						

To test the potential for different modalities of delivery to impact student performance, a two-factor Analysis of Variance (ANOVA) was conducted. Students were classified into one of three groups: low, medium, and high ability. Classification into a category was based on incoming GPA on the four prerequisite courses. The low category was comprised of student in the 25th percentile of the sample, the medium category was comprised of students who scored in the middle half of the percentile scores, and the high category was comprised of students in the 75th percentile or higher. The distribution of these students is presented in Table 2.

Table 2 – Sample Size of Students in Each Ability Level by Cohort

	2002	2003	2004	2005
Low	9	9	8	11
Medium	23	5	30	18
High	10	13	11	12

The results of the two-factor Analysis of Variance (ANOVA) using the MPGPA and Course Delivery Modality was used to examine student performance on the two sets of questions representing the lower and upper levels of Bloom's Taxonomy are presented in Table 3. The *F* statistics used in the ANOVA analysis are used to draw conclusions about mean differences in the population based upon the observed data. Each *F* statistic is the ratio of a variance estimate based upon differences among group means and an estimate based upon differences among scores within groups. Large values of *F* are associated with group mean differences that are greater than would be expected from only sampling error. The *p*-value is the probability of obtaining an *F* statistic as large as the one observed or larger, if the null hypothesis (that is, equal means in the population) is true. The smaller the *p*-value is, the less we believe that the null hypothesis is true. When the *p*-value is smaller than a pre-specified criterion (called α), we officially declare the null hypothesis false and conclude that the population means are not the same. Conversely, if the *p*-value is larger than α, we declare that we fail to reject the null hypothesis. The pre-specified value, α, is the probability of rejecting a null hypothesis when it is true (a decision that is called a Type I error).

These results of the two-factor, with interaction, design of experiment are interpreted relative to a level of confidence of α=0.10 (or 90% confidence that the claim can be made) in the results[18, chapter 10]. This Type I error rate is consistent with the baseline study[7] to determine statistical significance of findings. Similar to findings in the previous study[7], and as might be expected, the MPGPA was a significant predictor of student performance. The method of delivery was not statistically significant as a main effect. However, an interaction between MPGPA and mode of delivery was evident for the scores on the lower level taxonomy questions. Further follow-up tests identified that students in the 2002 and 2005 classes performed similarly, but the 2003 cohort performed significantly higher than the students in the 2002 and 2005 classes. The results of the contrast tests of significance between the groups revealed that, using an alpha of 0.10, the students in 2004 performed similar to the remaining three groups.

Table 3 – Results for a Two-Factor ANOVA Design of Experiments.

Final Examination Score	Source of Variation	F	p value
Upper Level Bloom	Course Delivery	2.02	0.1130
	MPGPA	5.86	0.0019*
	MPGPA & Course Delivery	0.77	0.5929
Low Level Bloom	Course Delivery	0.92	0.4316
	MPGPA	16.56	<.0001*
	MPGPA & Course Delivery	2.92	0.0101*

* Statistically significant at α = 0.10

The results in Table 3 can be summarized as follows:

- <u>Effect of pre-requisite GPA (Factor A)</u> **–** The effect of the pre-requisite GPA (MPGPA) on the final examination score is significant with a 90% confidence level (α = 0.10) for Nonlinear Equations upper and lower level Bloom scores. Students with prerequisite GPA higher than MPGPA perform better on these scores.
- <u>Effect of course delivery mode (Factor B)</u> **–** The effect of course delivery mode on the final examination score was not significant at the 90% confidence level (α = 0.10) for Nonlinear Equations upper and lower level Bloom scores. Thus, students receiving instruction under the different modalities did not vary significantly across the different methods of instruction.
- <u>Effect of pre-requisite GPA and course delivery mode interaction</u> **–** The effect of the interaction between GPA and delivery modality on the lower level Bloom questions was significant (α = 0.10). This indicates that different ability level students may perform better based on mode of course delivery.

Based on the findings reported above, as well as an examination of the mean scores (see Table 1), there is support that the use of web-based modules positively impact student performance. Although not all statistical analyses had statistically significant findings, students in the 2003 cohort consistently outscored their peers in the other classes. Furthermore, the interaction between mode of delivery and incoming ability level suggests that the use of web-based modules provides students coming in with a lower ability (as indicated by GPA on the four prerequisite courses) with an enhanced ability to be successful on the material presented.

B. Student Satisfaction Survey

Student satisfaction surveys were given on the presentations used to teach Nonlinear Equations. The survey consisted of eight selected response questions, and, depending on the class, included zero to four open-ended questions.

Quantitative Analysis

A seven-point Likert scale was used for the eight selected response items, ranging from 1 (Truly Inadequate) to 7 (Truly Outstanding). In addition, an Analysis of Variance was conducted on each of the items. The results of these analyses are provided in Table 4. The results of all eight items are statistically significant at the set Type I error rate of 0.10. In all cases, students in the 2003 cohort had notably higher scores than in the other three classes of modality delivery. Contrast statements support the contention that this group of students rated these items higher than their peers in the other classes at an alpha level of 0.05.

Table 4 – Results of Presentation Items on Surveys on Nonlinear Equations (number of samples, means, F-values, and p-values)

Questions	Mean* (SD)				F	*p*
	2002 (N=38)	2003 (N=27)	2004 (N=43)	2005 (N=38)		
In terms of their value in helping me acquire foundational knowledge and skills, I'd say that the presentations were	4.63 (1.21)	5.86 (1.06)	4.53 (1.32)	4.92 (1.01)	7.83	<.0001
In terms of their value in reinforcing information presented both in the reading assignments and in the problem sets, I'd say that the presentations were	4.71 (1.19)	5.86 (1.03)	4.49 (1.25)	5.08 (0.93)	8.55	<.0001
In terms of their value in helping me learn to clearly formulate a specific problem and then work it through to completion, I'd say that the presentations were	4.37 (1.40)	5.86 (1.09)	4.30 (1.25)	4.89 (1.10)	10.05	<.0001
In terms of their value in helping me develop generic higher-order thinking (e.g. analysis, synthesis and evaluation from Bloom's taxonomy brochure I gave you) and problem solving skills, I'd say that the presentations were	4.34 (1.27)	5.61 (0.98)	4.14 (1.37)	4.74 (1.12)	8.69	<.0001
In terms of their value in helping me develop a sense of competence and confidence, I'd say that the presentations were	4.58 (1.25)	5.68 (1.20)	3.95 (1.24)	4.76 (0.90)	13.22	<.0001
Overall, I'd say that the clarity of the explanations contained in the presentations were	4.55 (1.32)	6.04 (0.94)	4.35 (1.33)	5.16 (1.04)	12.75	<.0001

In terms of helping me see the relevance of the course material to my major, I'd say the presentations were	4.18 (1.27)	5.79 (1.08)	4.02 (1.37)	4.82 (1.07)	12.20	<.0001
Overall, I'd say that the helpfulness of the illustrative examples and practical applications contained in the presentations were	4.47 (1.40)	5.71 (0.96)	4.28 (1.25)	5.03 (0.90)	9.25	<.0001
* 1=Truly Inadequate, 2=Poor, 3=Adequate, 4=Good, 5=Very Good, 6=Excellent, 7=Truly Outstanding						

Qualitative Analysis

A series of open-ended questions were asked each year. In two of the four years (Summer 2004 and Spring 2005), there were four similar items. In Summer 2003, there was only one item, and in Summer 2002, no qualitative data was gathered. The responses to these items were reviewed and thematically analyzed.

Question One (2004 and 2005): How did you learn the material for Nonlinear Equations?

There were four common resources or methods identified by students as strategies for learning the Nonlinear Equations material: (1) Textbook Notes, (2) Lecture Videos, and (3) Activities (including simulations). Only 12% students in 2004 and 16% students in 2005 identified only one method of learning the material, typically either Textbook Notes or Lecture Videos. The majority of other students cited some mixture of methods, with the most prevalent listed in Table 5. Additionally, 9% students in 2004 commented that they had used online quizzes as a learning method.

Table 5 – Results of How Students Learned Material for Nonlinear Equations

Method/Source	2004	2005
Textbook Notes and Lecture Videos	42%	28%
Textbook Notes, Lecture Videos, and Assignments	23%	28%

Often, students cited the variety of resources as beneficial or related a specific process that they followed utilizing multiple resources. For example, one student in 2004 related, "I watched the videos first, and then I went back and read over the notes. I then proceeded to do the homework and then checked my answers with the online quizzes". Other students explained how they used the different resources to back up weak areas. One student (also in 2004) stated, "First, I watched the videos and then I looked over the text that pertained to the material I was still a little 'murky' on". Similar tendencies about using the varied resources were noted in 2005, as illustrated by this response: "I first watched the videos. Then I looked at the notes. I like how the videos reinforced the notes".

Question Two (2004 and 2005): What did you like most about the web-based (and class-2005 only) presentation for Nonlinear Equations?

Students in both classes consistently identified two major areas that they liked about the course presentations. The first was the ability to review the materials and work at their own pace (20% in 2004 and 31% in 2005) and the second was the quality, relevance, and utility of the materials (31% in 2004 and 33% in 2005). Other areas mentioned by more than one person included convenience (16% in 2004 and 18% in 2005), examples/simulations (7% in 2004 and 10% in 2005), not having to come to class on site (7% in 2004), and the organization/navigation online (7% in 2004).

Convenience as well as the ability to reinforce learning was prevalent and obvious responses across both years. For example, in 2004 one student wrote "I could do it at any time and at my own pace" and another stated, "Nice to watch the videos instead of being in class, could play it again if there was something you did not understand. Similar comments were provided from the students in the 2005 section. One student in this cohort replied, "I liked the fact that I could rewind the video or pause the presentation at any time, to go over problems or compare to problems I already did."

Question Three (2004 and 2005): What did you like least about the web-based (and class-2005 only) presentation for Nonlinear Equations?

A small but notable number of students (9% in 2004 and 22% in 2005) stated that there was nothing that they liked *least* about the class. Few strong themes among responses were noted although there were some areas of commonality. The most prevalent area noted was concerns about not being able to ask questions real-time with 24% students in 2004 citing this as an area of concern and 22% in 2005. The other area that spanned both classes was the lack of sufficient numbers of examples (11% in 2004 and 11% in 2005). Other areas noted by more than one person in a class included needing more time (7% in 2004 and 5% in 2005), the quality of the audio or video (9% in 2004 and 5% in 2005), and size/type of files to be downloaded (7% in 2004, 5% in 2005). Two individuals in 2005 noted that it was hard to stay motivated on task and that the online format hurt their eyes.

The issue of not being able to ask questions was obvious and, at times, the responses relayed frustration over this issue. One student 2005 wrote this response "I DID NOT HAVE SOMEBODY TO ASK QUESTION AT THE MOMENT" (emphasis from student's written response). Another individual in 2004 wrote, "It was hard to motivate yourself to go through it. There was no chance to ask a question while watching the videos. If you could have asked questions it would have been nicer, but there is no way that is possible." The students in the 2004 cohort had similar concerns with availability of timely feedback with one student stating "No instant feedback in case of a problem or concern."

Question Four (2003, 2004 and 2005): In what way can the (web-based, class) presentations be improved for Nonlinear Equations?

Similar to the question about what they liked least about the course, many of the respondents answered that there was nothing that they would suggest to improve presentations. This was especially notable in the responses from students enrolled in the 2003 group of students who received instruction through the web-enhanced lecture modality. Of the 26 students who responded to this question, 50% answered either *nothing* or made a laudable comment. For example, one student wrote, "Certainly no improvements are necessary as far as I can see. I always feel very well prepared to do the homework after class. I think that the class presentations are very clear". Of the remaining 13 students, one simply wrote 'not sure'. Although not as strong in the other delivery modalities, a few students also replied with no suggestions for improvement (20% in 2004 and 11% in 2005).

Of those who did provide feedback, there was one dominating theme, regardless of delivery modality, and that was a request for more examples with approximately one-third of students in each class identifying this as an area of potential improvement, including comments about variation in the examples (29% in 2003, 35% in 2004, and 30% in 2005). Many suggestions were very specific in nature and the subject was addressed by only one student. For example, in both 2003 and 2005 one student in each section expressed interest in learning more about MAPLE. In 2004, a student suggested making hard copies available on CD. However, with the exception of the request for more and varied examples, there were no other notable themes.

Conclusions

The findings of both the cognitive assessment data as well as the survey data suggests that the use of web-based modules provides students with enhanced likelihood to succeed in the course. Students consistently performed better on achievement measures as well as survey items from the 2003 cohort as compared to the other three groups of students. Students in the cohort that received their instruction in the more traditional, face-to-face mode, without benefit of either supplementary or primary web-based materials, consistently performed lower than the other three groups, both on achievement measures as well as satisfaction measures. The findings of the qualitative data support the contention presented by other research that students find different and varied resources helpful. The use of multiple methods within the web modules created, e.g., textbook, notes, lecture videos, simulations and exercises, provides a variety of resources that maybe more or less helpful to specific student depending on their learning style.

Future Study

With renewed funding from National Science Foundation of USA until March 2007, we are adding web-based modules for four more topics - Simultaneous Linear Equations, Regression, Integration, Differential Equations. In 2006, we are seeking funding for three more modules – Differentiation, Fast Fourier Transforms, and Fundamentals of Scientific Computing to complete the resources for a typical undergraduate course in Numerical Methods.

Since Fall 2004, we are using the three assessment tools for a study not only at University of South Florida, but also at Florida A&M University (FAMU) and Milwaukee School of Engineering (MSOE). This partnership among three universities is allowing us to measure the effectiveness of the web-based modules in a diverse student population:

- underrepresented minorities and women in engineering (FAMU),
- transfer and over traditional-age adult students (USF),
- diverse engineering majors – Mechanical, Electrical, Chemical, and Biomedical,
- class sizes – small (FAMU), medium (MSOE), and large (USF),

- computational systems (Matlab at FAMU and MSOE, and Maple at USF).

We anticipate formally presenting and publishing the assessment results for the full course in 2008.

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