Int. J. Engng Ed. Vol. 23, No. 2, pp. 349–360, 2007
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Web-Based Engineering Economics—A Multi-Semester Experiment*

JEFFREY GOLDBERG, KEVIN LANSEY and MARK HICKMAN
The University of Arizona, Tucson, AZ 85721, USA. E-mail: jgoldberg@arizona.edu

In the face of mandated reductions in curriculum credit hours, a series of one-credit engineering science (45–60 hours for completion) modules have been developed at the University of Arizona to maintain breadth of engineering sciences and to better prepare students for passing the Fundamentals of Engineering examination. The set of modules includes engineering economics. The courses are taught in a web-based format with opportunity to interact with faculty and teaching assistants during live and electronic office hours. In this paper, we report on the development effort and the difficulties involved in faculty buy-in and in course development. We have run two experiments with the site and our results on learning and student attitudes are included.

Keywords: web-based learning; engineering economics; assessment

INTRODUCTION

IN 1996 THE UNIVERSITY of Arizona mandated all programs to reduce the required number of credit hours for a degree (or advertise as a five-year program). Each department in the College of Engineering (CoE) was required to reduce degree requirements to 128 credits or less, typically a loss of eight units. A strategy of most of the programs was to reduce the number of engineering science credits outside of their major discipline. Soon thereafter, with a grant from the General Electric (GE) Foundation, the CoE began the development of one-credit web-based modules on various engineering science topics.

These courses allow flexibility in how students earn their engineering science credit and provide needed breadth. Students continue to take a number of courses in engineering science, but in the form of one-credit modules instead of three-credit courses. Some depth is sacrificed, but overall we believe that this is a stronger alternative when total hours are limited. The courses also prepare students for engineering practice as they are framed around the material on the Fundamentals of Engineering (FE) examination and may be used by advanced students as a refresher course for the FE exam.

Our decision to use web technology was motivated by constraints on faculty time and a student body that appreciates time flexibility. The goal was to develop 'stand-alone' modules where students can access the materials at any time, be tested for prerequisite materials, have progress monitored, and be examined at the conclusion of the module. We were striving to have materials that can be used by teaching assistants with little faculty oversight. Since engineering science topics are relatively stable, the majority of the developed materials required little change after initial web construction under the direction of faculty members who taught these classes.

The purpose of this paper is to present the UA web approach to teaching engineering economics and an evaluation experiment that examined student learning in the courses. Thus, the web-based instruction literature is summarized, followed by the course materials and the delivery approach for the UA courses. Learning (grades) and student attitudes from both web-based and traditional lecture courses are then analyzed to describe the impact of the web-based instruction. Conclusions based on the results of the experiment complete the paper.

BACKGROUND

Classification of on-line courses/programs

Several levels of hypermedia-supported courses can be identified. Generally, all on-line supported courses provide web-based communication with faculty or teaching assistants. The first-level course is a traditional lecture course that has support materials on the web that may also be used in the classroom to provide better examples and demonstrations [1, 2]. These courses take advantage of web materials to reinforce concepts that are difficult to present in a typical blackboard presentation. They often include animations and opportunities to perform 'what if' analyses through web-based modules. For example, Yap and Mannan [2] have used web materials to support a thermodynamics course by providing lectures including pre-lab explanations, animations and videos providing further explanation on concepts.

The second-level courses are teleteaching or

* Accepted 14 August 2006.

on-line or television-based recorded lectures that may be supported by web materials (e.g. lecture Powerpoint slides). An advantage of the second level is the student's ability to rewind and listen to the lecturer several times at a convenient time [3–5]. This type of delivery has been used for individual courses and for full programs [4]. Kandzia and Ottmann [5] describe a virtual university that extends teleteaching to multimedia-supported teaching by combining resources from several traditional universities. Traditional lectures are enhanced by use of whiteboard technology and multimedia modules. All are recorded for future use to avoid losing the resource. Development costs, long-term archiving and accessibility of materials and changing how instructors teach courses are issues in implementation.

The third-level course has no formal lectures and is often an introductory-level course in a field (e.g. economics). The course relies on a traditional text as the main information source and support is given to the students in the form of links to other web-based materials, and possibly summaries of text materials that are typically Powerpoint slides [6, 7]. Tailored web courseware (a sort of webtext) are also third-level courses but are seen less frequently due to development costs. This type of course often includes other materials for alternative learning types [8]. Kaderali *et al.* [9] discuss an undergraduate electrical engineering program based on the third-level implementation. Being a full program and the desired product, a support center was organized to assist with web content development. The main texts were provided as PDF files with interactive elements for quizzes, exercise hints, and online simulations. Virtual events including laboratories were also provided. Students were in dispersed locations and took advantage of newsgroups and on-line tutors for educational support. Second- and third-level courses are fairly common to distance-learning programs and are described as 'traditional' online courses [10].

Evaluation of on-line courses/programs

The literature is extremely clear on the advantages and disadvantages of using web-based distance materials:

Advantages of using web-based materials:
- Opportunities for working students—flexibility
- Accessibility to best course materials in the world
- No physical plant needed
- Controlled rate of learning
- Increased diversity, since students from a variety of places can participate
- Lots of information in a variety of sources and styles (one can tailor materials to different learning styles)

Disadvantages of using web-based materials:
- Feelings of isolation for the students [11]
- Lack of guidance in the class [11]
- Feelings of helplessness [11]
- Lack of knowledge when something in the site goes wrong, causing frustration [12]
- Difficulty in motivating students (30–50% drop-out rate) [13]
- Expensive to get the site going [5, 9]
- Must be tailored to the hardware available to students

Formal and rigorous evaluations of student learning in web-enhanced courses are not common. Some results are summarized here. For first-level courses, Regan and Shepard [14] show that interactive graphics, video, and sound have been shown to enhance student learning. Paterson [15] was based on an undergraduate class that has a mix of class- and web-based materials. Electronic copies of notes, an electronic bulletin board and discussion group, multimedia assignments, and space for peer review of term paper reports are included in the website. These resources were all well liked by the students; however, they also thought that the web materials should not totally replace the live portions of the class. Williamson *et al.* [18] discussed a graduate electrical engineering course from the perspectives of the student and the instructor. The course consisted of a virtual classroom (using LearnLinc) that had Powerpoint slides attached to a whiteboard. The instructor and the students communicated through a two-way audio link. Students thought that the course was good but missed the personal interaction. To examine impacts of introducing demonstration oriented/active learning materials, Zwyno *et al.* [1] compared student attitudes and success in a 'controls' course for students. Part of the class was provided by supporting hypermedia materials. The results showed an improvement in learning compared to not using the materials. Zwyno *et al.* [17] extended the analysis from the above study by reviewing the impact on different learning levels as defined in Bloom's taxonomy. Introducing more demonstration-type materials had a significant effect on Bloom levels through 'application' and 'analysis.' 'Synthesis' and 'evaluation' abilities for the students were not significantly different for the conventional and hypermedia-enhanced courses.

Second-level courses are more common at graduate level in part-time distance learning programs. Again, evaluations are not common. Evans *et al.* [3] tested materials in a multi-section graduate student operations management course. The web-based group basically used a text, notes, and a Powerpoint/audio system. Their student group thought that the site was an effective learning tool. Dutton *et al.* [18] reported on a freshman C++ course where 312 students were split into two groups. The first group took the traditional lecture class with web supplements and the second group only used the web supplements. They found that the non-lecture students did better on the final exam and the course grade. When one accounts for maturity level of the students and the effort put into homework, the result is softened a bit. It was also found that the non-lecture students dropped out in significantly higher numbers.

Given the demand for problem-solving skills, third-level courses are relatively rare in engineering as students. Courses in engineering science and basic principles are more likely to be developed [6–8]. Varde and Fogler [7] compared student perceptions in a first-level course compared to traditional delivery in a four-semester hour credit chemical reactions course. This class is in an introductory problem-solving course with a strong emphasis on mathematics. Materials for higher-level learning and open-ended thinking were incorporated into the site. Student attitudes were consistent with the above summary, with the further advantage of students taking ownership for their learning. Difficulties for students to achieve success in open-ended questions were also noted.

Two other groups, Sullivan and Terpenny [19] at Virginia Tech (VT) and Lohmann and Sharp [20] at Georgia Tech (GT), have incorporated hypermedia into engineering economics courses. Their courses and sites are structured quite differently than ours. One course is primarily lecture-based and design-oriented and is enhanced with web materials (first level—VT), while the other makes use of streaming video and PowerPoint presentations (second level—GT). The VT study did not show any improvement by adding web materials. The course considered herein is completely web-based and intended to be taught with a graduate student 'coach' rather than regular faculty. It is completely web-based, with the TA holding recitation sessions and being available for consultation and questions.

ENGINEERING SCIENCE MODULE STRUCTURE

As noted above, the engineering science modules are intended to provide program breadth and to cover material found on the FE exam. Since most students take three or more of the courses, the module format is consistent between courses to reduce a student's time to learn site navigation. The modules are structured to guide students through the material and provide feedback regarding their learning. It is well documented (e.g. [21]) that gearing material to learning styles improves learning. Since modules are studied in an independent mode, these are provided materials in multiple formats: visual, audio, and applications through spreadsheets. An overview of that format using the engineering economics course as an example is provided in this section to demonstrate the tools applied to overcome some of the weaknesses of web-based classes noted above.

The front page for the eight-course modules can be found at http://gecourses.sie.arizona.edu/GE. To access the sites, a username and password are required (to access the sites or the evaluation form noted later, contact Jeffrey Goldberg at jgoldberg@arizona.edu). Each module starts with an initial page called the 'course wheel', which contains information on course structure, the instructor, navigational help, course newsgroup, and course material (Fig. 1). The student creates a username and password at the 'Start Here' button. The site is password protected and students may only access modules for which they are registered.

The class is organized using a 'course map' and each topic is a block on the map (Fig. 2). Students proceed through the material at their own pace. To assist with course organization and navigation, links to a print engine, a search engine for looking up topics, the class syllabus, the class newsgroup, a sheet of formulas, and email to the instructor/TA are located on the bottom navigation bar on every page within the module. All eight modules have the same interface and organization style, so there is no additional learning required to access other modules.

The topics in the engineering economics modules are fairly standard and the notations follow that of the third edition of ***Contemporary Engineering Economics*** [22]. The 'dashed' lines on the map represent milestones that the student should reach before moving on to the next section. For example, before starting the course material, the student should master and pass a pre-test on basic algebra. Before moving on to sensitivity analysis, the student should pass a quiz on financial mathematics and equivalence. Portions of the modules can be 'locked-out' until the student records a passing grade on the quiz. However, this feature can be turned on and off, depending on how the instructor wants to run the class (our students have strongly preferred that we do not use the lock-out feature and simply always provide access to the entire site).

The interface is designed to make things easy for the student and is broadly consistent. For example, common colors are used for different functions (all active links are blue and underlined in every module; there is no other blue or underlining). Most pages fit on one screen, so little or no scrolling is necessary (designed for a 15-inch monitor). Downloads are small and can be handled by a 56K connection (for videos, an option is given to download with a high-speed connection if that is available).

Figure 3 shows a typical page within a block. The top bar allows students to get to the module wheel ('Economics' button), the course map ('Class' button), the block's first page ('Taxes and Depreciation' button), and the pages within this particular subsection (buttons numbered 1 through 10). 'Next' and 'Previous' navigation buttons on the label bars move the reader a single page (this is the first page in the subsection, so there is no previous page). This page has a video clip, denoted by the music/video icon. All video clips have been created using Windows Media and are tailored to the Internet Explorer browser. A

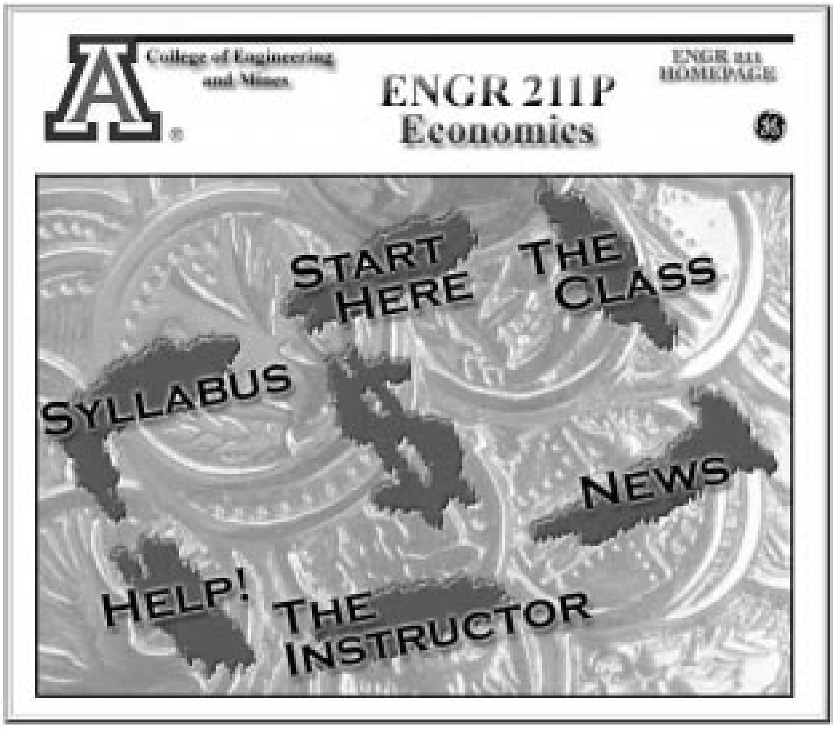

Fig. 1. Course wheel.

video clip is included at each major section to introduce the material and highlight the most important concepts. The bottom bar is the same on all pages and has been described previously.

This module also has exercises that require the use of downloadable spreadsheets. Since all material is on the website, these tools are immediately accessible by the student when the material is reached rather than moving between resources in other settings. Dialog boxes are placed strategically throughout the site to obtain feedback from the students and to make the learning experience more active. Quizzes are included at the end of many content blocks. Presently, these quizzes are not counted in the course grade and are only for student self-assessment. The students receive immediate feedback on quiz solutions, including text and audio explanations of the solutions. Any responses given by the students (quizzes, dialog box answers, end of section feedback) are anonymously stored

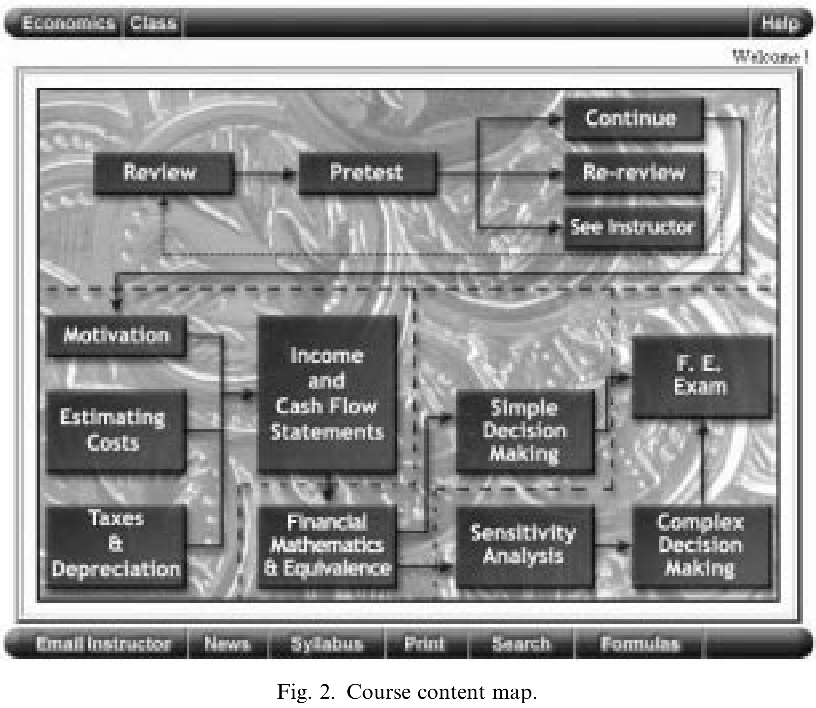

Fig. 2. Course content map.

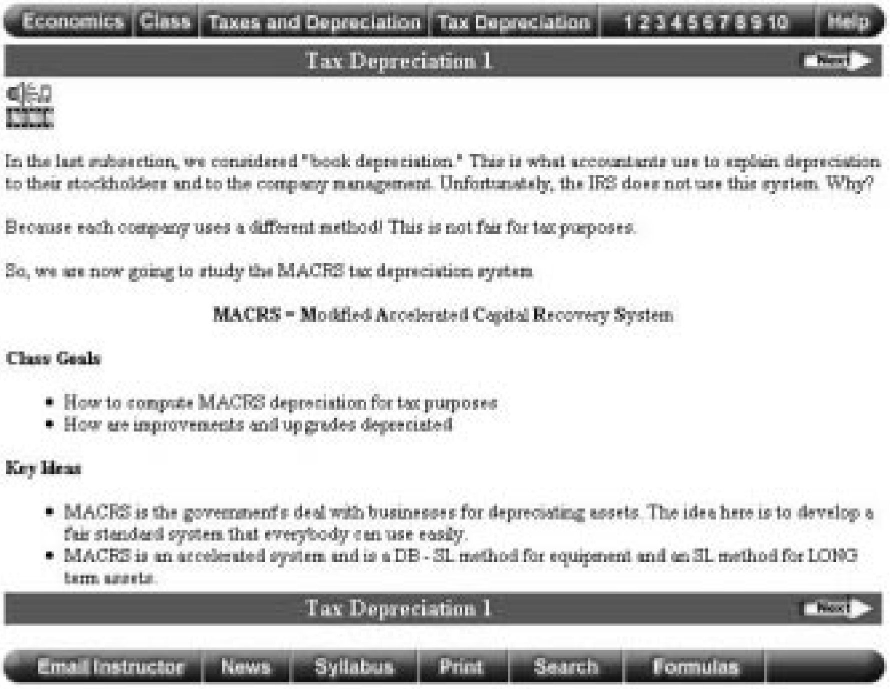

Fig. 3. Typical module page with navigation bars and audio/video button.

in the course database for faculty and TA review to identify specific module sections where improvements may be needed.

The content in each block is similarly organized. The block starts with an introduction section that presents motivation for understanding the topic. Usually, an example is presented that requires the student to think of a real situation where the material might be applied. After the situation is described, an overview of the block is given. The overview contains links to the block's content material. Since time management is critical for student success, the top bar informs the student how many screens are in each block so the student can estimate the time required for completion. In addition, the course syllabus (bottom bar) lists the expected time needed to complete each block. To move to the next block a student returns to the course map. The map is intended to give students a perspective on the 'big picture' (course structure) and how topics (blocks) link and build upon one another.

In terms of course operation, each semester students registered through the UA student information system are manually entered in the class database, since security issues prohibit linking directly to the UA system. The students are then informed via email that they must go to the course site and set up their username and password. During identification setup, baseline evaluation data is collected from each student (major, standing, email, GPA, experience level with web courses, home PC). A single introductory meeting with all students, a single faculty member, and the course TA is then held to acclimatize students to the course environment, answer questions, and provide advice on course success.

Currently, one TA working 13.3 hours per week runs several one-credit modules in parallel in five-week periods during a 15-week semester. Modules are scheduled once or twice a semester such that most students only take one module in each five-week period. The TA provides course management, office hours, review sessions, and exam and homework grading. Exam and homework questions have been formulated by faculty or by the TA with faculty review. After several offerings, a reasonably large bank of questions is available. A faculty member is consulted only when the TA has questions about the material or the course operation. The exams are given live in a large group (prescheduled on the first day of the semester) or by using a proctor if the student is remote from campus.

LEARNING EVALUATION

The Engineering Economics module has been used in two settings. First, the module was 'co-taught' with an instructor for a group of civil engineering juniors. Experience with previous web-based courses suggested that it was better to have an instructor available during the first offering as the site often had areas where the developer understanding was quite a bit different than the student understanding. After the first offering and since spring 2001, the module has been offered as a 'stand-alone' course with TA support. The students come from a mix of departments and take the class because they are interested in the material or it is required for their degree program. Results of learning outcomes and student satisfaction are reported for both the stand-alone and instructor-assisted offerings.

Civil engineering course

The first test was in a civil engineering junior-level class on transportation engineering. The four-credit-hour semester course included one credit hour in engineering economics. The website was introduced to the students on the first Monday session of the semester. The students were asked to participate knowing that the site was experimental. Problem sets were given every two weeks and the instructor held a problem session review every other Monday during the 15-week semester. At the start of the course, the dialog box feature of the site was disabled, since this information was not capable of being stored. Class progress was judged from the homework assignments, questions at the review sessions, and exam question answers. Since required background material is basic algebra, no pre-test on prerequisite material was given to these students, who were first-semester juniors (they had already taken differential equations, so there was no need to test on basic algebra). The remaining three credits of the class were offered in a traditional lecture style.

Early in the semester, feedback was given to the web development team after each review session. Typographical errors in the site were corrected, spreadsheets were labeled better, a missing page was constructed, and a printing utility was developed to simplify printing of the module materials. This feedback stopped midway through the semester and nothing was changed on the site for the rest of the semester. At the end of the semester, an evaluation form that contained both ranking and short comment questions was given to the students so that they could evaluate their experience. Twenty-eight students completed the evaluation forms. All questions had a five-point Likert scale and word descriptions for 1, 3, and 5 points are given in Table 1 with some results.

The results were varied. There were clear indicators that the site was working somewhat. However, the result for question 4 was troublesome, and the comments and rankings on a small number of forms showed that some students were highly dissatisfied with the modules. Their particular complaints were in navigation, the lack of a search engine on the site, and the difficulty of the examples. We note that we intentionally restricted navigation, since we wanted the students to go through the material in a set order and this may have been a poor decision. Also, these comments are all usability issues rather than problems with the lack of instructor help in the learning process. Since this initial offering, the site has been improved by adding the search engine, adding the print engine to facilitate printing all site pages without going through one screen at a time (mid-semester addition), adding the formula sheet and glossary for easy reference, and adding more examples and quiz problems. The call for more examples has been a continuing response for all modules.

To measure the amount of learning achieved, the primary metric used is test score results. A total of 31 students completed the engineering economics unit. The score statistics for course exams and the homework assignments are shown in Table 2 for the three credit hours of transportation engineering assignments ('Other') and the one credit hour of engineering economics graded work. Fig. 4 shows the distribution of scores. The large percentage of homework scores below 60% is due to students who did not complete many of the homework assignments. This result can be attributed to the policy that homework counts toward only 10% of the student's semester grade in both parts of the class.

Table 1. Results from site/course evaluation from first offering of Engineering Economics to civil engineering juniors.

Question	Answers	Average	Standard Deviation
1. How much do you feel you have learned?	1 = An exceptional amount 3 = About as much as usual 5 = Almost nothing	2.86	0.71
2. Overall rating of this part of the course	1 = One of the best 3 = About average 5 = One of the worst	2.86	0.71
3. The difficulty in this part of the course is:	1 = Among the easiest 3 = About average 5 = Among the most difficult	3.00	0.54
4. How does the website impact on difficulty	1 = Makes the course much easier 3 = No effect on difficulty 5 = Makes the course much harder	3.36	0.95
5. This part of the course was organized effectively	1 = Strongly agree 3 = Uncertain 5 = Strongly disagree	2.46	0.88
6. The website was an effective tool for learning	1 = Strongly agree 3 = Uncertain 5 = Strongly disagree	2.75	1

The results here are also mixed. Exam scores were slightly higher for the engineering economics section, but the variability of the exam scores was also higher. It is noteworthy that the students seemed to perform equally well in the exams over the web content and over the lectured materials. The t-statistics comparing the engineering economics versus lectured materials in mean exam and homework scores were 0.971 and 0.167, respectively. This implies that the hypothesis that the mean scores are the same cannot be rejected for both exam scores and homework scores (n = 60, $t_{=95\%,n=60}$ = 1.645 for a one-sided pooled sample t-test).

Despite not being able to reject the hypothesis that the homework scores differ significantly, the data shows homework scores for engineering economics to be substantially lower than for the other part of the course (high standard deviations cause the small t-statistic). We believe that this was likely due to two effects. First, students were less likely to complete the engineering economics homework versus the other homework: almost one-quarter of the students did not entirely complete any given economics homework (24%) versus one-sixth for the other homework (17%). This lack of effort may be due in part to a seeming lack of accountability for completing the web content. Second, scores on the completed economics homework were also lower. This trend continued even after we changed our homework policy halfway through the semester to allow students to turn in the engineering economics homework *after* the review session, rather than before. The implication is that the students either did not complete homework prior to the exam or did so in preparing for the test, but after the homework due date.

Based on all of the above results, we felt that students were reasonably comfortable with the web module but sought a more structured easier-to-use site. The resulting grades were consistent with student ability, giving some indication that a similar level of learning was achieved. Differences in the level of the material muddle this conclusion. Clearly, given the difference in course materials and the problem sessions, no definitive statement can be made regarding the module's effectiveness. At a minimum, however, the students did learn the desired engineering economics material.

ENGR 211-P course

After the first experiment with civil engineering juniors, student evaluations/suggestions led to site modifications (primarily with additional interactions, audio explanation, and examples) and the course was then run in a stand-alone mode as an engineering economics class (ENGR 211-P). To examine student learning results on ENGR 211-P, final exam questions were compared with results on exam questions from the traditional three-credit lecture-based course (SIE 265—Engineering Management I). SIE 265 had approximately 10 weeks of engineering economics materials.

We note that this experiment structure may have some bias for two reasons. First, the abilities, maturity levels, and educational goals of the students in the traditional classes are different than the students in ENGR 211. The ENGR 211-P students are likely more mature, since they are usually civil engineering juniors and seniors. On the other hand, SIE 265 students are systems and industrial engineering and engineering management sophomores. This material is a core requirement for SIE and engineering management, so one might think that the SIE 265 students should be better motivated. In addition, in SIE 265, more material has been taught to provide more perspective on engineering economics

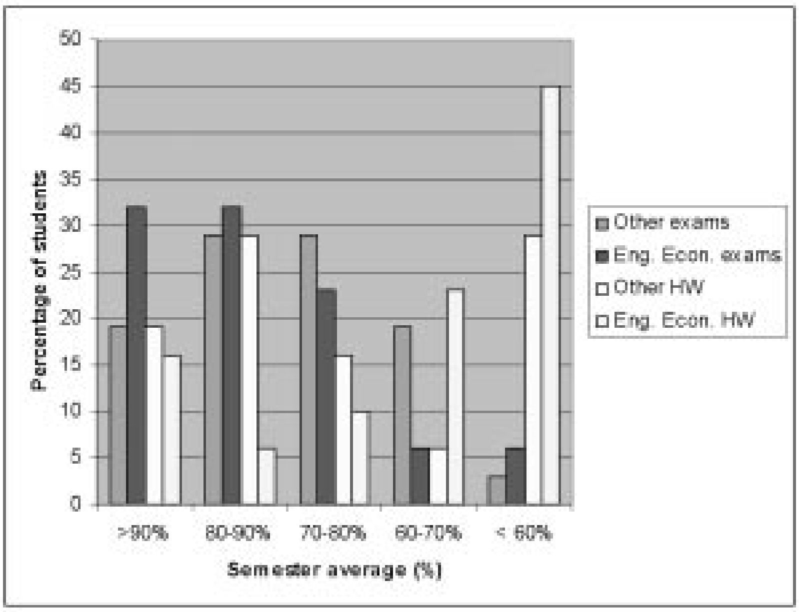

Fig. 4. Distribution of scores from civil engineering course offering with engineering economics module.

Table 2. Summary statistics scores for Civil Engineering course

	Exams		Homework	
	Other	Engineering Economics	Other	Engineering Economics
Average	80%	83%	70%	61%
Std Dev	10%	14%	23%	24%
Minimum	59%	42%	8%	15%
Maximum	98%	100%	97%	99%

content. Second, scores on exam questions are not independent, since the exams have a time limit. Here, scores are compared on a question by question basis, but the questions were not administered in the same test format. The comparison questions comprised the majority of the ENGR 211-P exam, while this material is spread throughout the semester on the SIE 265 exams. The problem is that a score on a question could be lower if it is on an exam with more difficult or with more time-consuming questions.

If the ENGR 211-P students are doing substantially worse than the traditional classes on questions that are important, this would suggest that the web-based approach is not working well for this group. Thus, we test if the students in the web course are learning the material to a satisfactory level using the SIE 265 students as the control, neglecting any potential bias.

Results are reported for two sets of courses. In fall 2002, the ENGR 211-P exam consisted of six questions and all six were used in SIE 265 exams the following spring (two questions from each of the three course exams). The questions are typical engineering economics exam questions covering economic insight (question 1), developing income and cash flow statements (question 2), cost estimation and inflation (question 3), break-even problems (question 4), equivalence and loan computations (question 5), and rate of return computation and analysis (question 6). The problems require skills in recognizing the correct approach, using the appropriate problem data, correctly implementing the approach, and making the appropriate conclusions. Results from the comparison are listed in Table 3.

The total scores as well as the scores on individual questions from the two groups are similar and indicate that the web-based approach seems to be working for the fall 2002 ENGR 211-P group. The t-statistic is given for each question based on the hypothesis that the mean of the two scores is the same. In all problems, the two-sample pooled t-test result is that this hypothesis is not rejected. In addition, if the two weakest scores in the SIE 265 sample group are deleted (both students scored below 65 total points), then the two groups yield almost identical statistics. Since it is possible that the ENGR 211-P students in this group are just better students, the cumulative GPAs of the two groups were also compared. As listed in Table 4, the average GPAs and standard deviations are similar between the groups. The t-statistic for the null hypothesis of identical means is 0.37 and the 97.5% confidence limit t-statistic is 2.02. Thus, the null hypothesis cannot be rejected, giving more credibility that the closeness of the scores suggests that the students were learning similar amounts in these two settings.

This experiment was repeated in spring 2003 and the results are summarized in Table 5. Here five questions were used in both classes during the course of the semester. As seen, the t-statistics for all problems were below the 97.5% confidence level for rejecting the null hypothesis that the means in the two samples were the same.

In fall 2002, eight of the ten ENGR 211-P students filled out the attitude evaluation and course satisfaction survey. The results are shown in Table 6 (along with the results from Table 1 for comparison). Excluding course difficulty, comparing the average values for the two samples, all measures moved in the positive direction including the impact of web learning on course difficulty. The students still perceive that the class is difficult (and this contradicts a similar question that is given to the students in the three-unit course SIE 265 (data not shown)) and the use of the website instead of a traditional format makes the course more difficult. The differences in attitude between the two study groups may be influenced

Table 3. Exam results for engineering economics for academic year 2002 for web module and traditional three-unit course

Problem	1	2	3	4	5	6	Total
Maximum Score	24	50	40	30	25	35	204
SIE 265—34 students (Spring 2002)							
Average	18	38	35	21	16	23	150
Median	19	44	37	26	17	25	152
Standard Deviation	4	13	7	9	7	9	34
ENGR 211 P—10 students (Fall 2002)							
Average	16	39	37	25	16	22	155
Median	18	45	39	28	17	23	163
Standard Deviation	6	14	3	6	6	9	27
t-statistic	0.99	−0.20	−1.31	−1.64	0.0	0.31	−0.48
$Z_{0.975}$	2.02	−2.02	−2.02	−2.02	2.02	2.02	−2.02
		Cannot reject hypothesis that means are not the same					

Table 4. Comparison of grade point averages for SIE 265 and ENGR 211-P student samples (fall 2002)

Class	Average Cum GPA	Sample Standard Deviation	Sample Size	Standard error of the sample average
SIE 265	2.67	0.523	34	0.090
ENGR 211-P	2.74	0.481	10	0.152

by the self-selection of those taking the web courses in 2002. At that time, the majority of the students were CE students who had the option of taking three one-unit modules or one three-unit traditional engineering science course to satisfy their engineering science elective. Students electing to take the web-based modules may be better learners in this setting or at least perceive the benefits of learning in this fashion.

LESSONS LEARNED

This paper describes an initiative to take a traditional class in engineering economics and move it to an electronic course. Seven similar engineering science modules have been developed and taught for several semesters. Many of our comments result from the broader experience with all eight modules. The advantages in this transition include reduced operating costs (TA versus faculty), more flexible scheduling for the students, and an ability to reach students with different learning styles. The disadvantages are that students sometimes feel lost and confused

In a typical course, the web may be one of many learning alternatives; however, here it was used as the primary teaching method. Overall, the project has been successful, the modules are now well established, and benefits are beginning to accrue. As expected in web course development, a large fixed cost was incurred both in dollars and in development time. In terms of development costs, in addition to the GE Foundation grant, further project support was provided by the CoE and the Arizona Board of Regents. A rough estimate on direct costs for development of the entire suite of eight courses (statics, mechanics of materials, fluid mechanics, dynamics, thermodynamics, circuits, materials science, and engineering economics) and the offerings to date is $500,000. This amount does not include faculty time that has been donated during the course offerings or time beyond what was funded for development. As noted, a teaching assistant (13.3 hours/week) leads two or three courses at a time in three five-week blocks during a semester. At present, 110–120 student credit hours are taken during each semester with students generally taking one course per block.

The transition to web courses was not always smooth and a number of lessons have been learned. During the first course offerings, student feedback was predominantly negative. Common comments were: the interface is not good enough, the material is confusing, there are not enough examples, etc. Much of this criticism is valid but some is due to the newness of this type of learning experience. It is clear, however, that this approach does not match the learning styles of some students; hence, there can be significant student frustration. Students that have had experience with other web classes have done better. Using student data collected during registration, correlations were sought between course success (grade) and student characteristics, including major, academic year, web and web course experience and learning style. None of these factors was a significant indicator of student success in ENGR 211-P or in other modules [23]. This suggests that the modules do not show bias against any particular student learning style.

Student frustration levels can be exceedingly high, so instructor flexibility and understanding is required. During initial offerings, retention was a major problem. Students invariably waited until the final weekend before the exam to cover the material, which was simply not enough time to

Table 5. Exam results for Engineering Economics for spring 2003 for web module (ENGR 211-P) and traditional three-unit course (SIE 265)

Problem	1	2	3	4	5
Maximum Score	20	30	20	30	20
SIE 265—35 students (Spring 2003)					
Average	11.4	25.5	16.8	17.2	20.0
Standard Deviation	4.06	3.70	7.09	7.18	5.53
ENGR 211-P—11 students (Spring 2003)					
Average	10.3	26.6	17.6	15.6	16.2
Standard Deviation	4.00	4.01	2.06	3.61	7.81
t statistic	0.81	−0.84	−0.62	0.96	1.51
$Z_{0.975}$	2.02	−2.02	−2.02	2.02	2.02
Result	Cannot reject hypothesis that means are equal				

Table 6. Summary of results from attitudinal survey of ENGR 211-P students (fall 2002) and CE students (fall 2000)

Question	Answers	Fall 2002 ENGR 211-P		Fall 2000 CE group	
		Ave	Dev	Ave	Dev
1. How much do you feel you have learned?	1 = An exceptional amount 3 = About as much as usual 5 = Almost nothing	2.25	0.88	2.86	0.71
2. Overall rating of this course	1 = One of the best 3 = About average 5 = One of the worst	2.38	0.52	2.86	0.71
3. The difficulty of the course is:	1 = Among the easiest 3 = About average 5 = Among the most difficult	3.63	0.52	3.00	0.54
4. How does the website impact on difficulty	1 = Makes the course much easier 3 = No effect on difficulty 5 = Makes the course much harder	3.12	0.83	3.36	0.95
5. The course was organized effectively	1 = Strongly agree 3 = Uncertain 5 = Strongly disagree	2.00	0.00	2.46	0.88
6. The website was an effective tool for learning	1 = Strongly agree 3 = Uncertain 5 = Strongly disagree	2.13	0.64	2.75	1

master the material. Signing drop forms on the day of the final exam was common. Notes from students in the fourth week of the course period saying 'What am I supposed to do for this class?' were also common. Most of these problems have been solved by extensive communication processes between the TAs and the students. Emails to students every few days, announcements to the class before the semester starts, the beginning of semester meeting, an emailed syllabus and the navigation write-up, and direct links to the class site from the university catalog are necessary to ensure that students have the information needed to be successful in the class. In addition, two homework assignments are now required, which forces students to begin the material early. The module schedule is prepared and posted two months before the start of the semester, including the timing of modules to be offered, the homework due dates, and the final exam date. Advanced planning helps faculty and students.

It is also clear that students look for additional support on their own. Study groups are common and announcements are posted that groups are forming. Also, as engineering science courses are typically problem-solving courses, committed students seek other problem sets to improve those skills. As one goal of the modules is to teach to the FE level, FE exam preparation manuals are invaluable.

Much of the modules' financial benefit comes from having graduate students primarily responsible for running the class, as they are lower in cost than tenured faculty. It is critical that the TAs be highly ethical, have good communication skills, have a breadth of technical skills, and be well organized. It requires time to organize exams and homework and, if the TA does not have good foresight and scheduling ability, there is a risk of a last-minute rush. After operating these courses for several years, a set of well-defined processes and schedules are in place for the TA. However, it took time and effort to reach this point. Still the TAs are the key factor in the solution, as they implement the process. They are also critical to student success by providing help for homework and a sounding board for questions. The materials enable the TAs to take on the role of 'learning coach.'

CONCLUSIONS

The development of a web-based course for engineering economics is unique in that the module is fully web-based and is text oriented, with other media included to assist different learners, compared to video/Powerpoint sites. The resulting course has reinforced many of the advantages and disadvantages that have been identified in the past, such as expense and need for extensive planning. Providing a human connection to the material by a teaching assistant (learning coach) was seen as a critical element in student success and overcomes many of the student-based disadvantages, including feelings of isolation and frustration. Based on our evaluation of student success and feedback, student learning is being achieved at levels that are similar to lecture-based classes on the same material. The success in implementation and learning is attributed to teaching stable material at fundamental levels.

REFERENCES

1. M. Zywno, W. Brimley and W. White, Effective integration of multimedia courseware in engineering education at Ryerson Polytechnic University, *Global Journal of Engineering Education*, **4**(1) (http://www.eng.monash.edu.au/uicee/gjee/vol4no1/Zywno.pdf) (2000).
2. M. Yap and M. Mannan, A WWW-based course structure for teaching a Thermodynamics and Heat Transfer Course, *International Journal of Engineering Education*, **17**(2) (2001), pp. 176–188.
3. R. Evans, S. Murray, M. Daily and R. Hall, Effectiveness of an internet-based Graduate Engineering Management Course, *Journal of Engineering Education,* **90**(1) (2000), pp. 63–71.
4. W. Winer, W. Wepfer, J. Digregorio, G. Wright and J. Boland, Online delivery of the MSME program from Georgia Tech, *International Journal of Engineering Education,* **17**(2) (2001), pp. 131–137.
5. P-T. Kandzia and T. Ottmann, How real is the virtual university in the Upper Rhine Valley?, *International Journal of Engineering Education*, **17**(2) (2001), pp. 138–144.
6. S. Myers and M. Nelson, Do on-line students in a mastery based principles course analyze, synthesize, and evaluate better than face-to-face students?, presented at the OLN conference on The Convergence of Learning and Technology (2003).
7. N. Varde and H. Fogler, Asynchronous learning of chemical reaction engineering, in *Proceedings of the 2002 ECI Conference on e-Technologies in Engineering Education: Learning Outcomes Providing Future Possibilities*, paper 32 (2004) (http://services.bepress.com/cgi/viewcontent.cgi?article=1033&context=eci/etechnologies).
8. J. Goldberg and K. Lansey, Web-based alternatives for learning engineering science, *Computers in Education Journal*, **14**(4) (2004), pp. 2–11.
9. F. Kaderali, G. Steinkamp and B. Cubaleska, Studying electrical engineering in the virtual university, *International Journal of Engineering Education*, **17**(2) (2001), pp. 119–130.
10. C. Twigg, Innovations in online learning: Moving beyond no significant difference, pew learning and technology program (http://www.center.rpi.edu/PewSym/Mono4.pdf) (2001).
11. R. Schwartz, The virtual universe, *ASEE Prism*, **5** (1995), pp. 22–26.
12. L. Schrum, Professional development in the information age: An online experience, educational technology, **32**(12) (1992), pp. 49–53.
13. M. Moore and G. Kearsley, *Distance Education: A Systems View,* Wadsworth, Belmont, CA (1996).
14. M. Regan and S. Sheppard, Interactive multimedia courseware and the hands-on learning experience: An assessment study, *Journal of Engineering Education*, **85**(2) (1996), pp. 123–131.
15. K. G. Paterson, Student perceptions of internet-based learning tools in environmental engineering education, *Journal of Engineering Education,* **88**(3) (1999), pp. 295–304.
16. C. Williamson, J. Bernhard and K. Chamberlin, Perspectives on an internet-based synchronous distance learning experiment, *Journal of Engineering Education,* **90**(1) (2000), pp. 53–61.
17. M. Zwyno, Hypermedia instruction and learning outcomes at different levels of Bloom's Taxonomy of Cognitive Domain, *Global Journal of Engineering Education*, **7**(1) (http://www.eng.monash.edu.au/uicee/gjee/vol7no1/Zywno.pdf) (2003).
18. J. Dutton, M. Dutton and J. Perry, Do online students perform as well as lecture students? *Journal of Engineering Education,* **89**(1) (2001), pp. 131–201.
19. W. Sullivan and J. Terpenny, A virtual classroom experiment for teaching engineering economy, *Engineering Economist,* **49**(4) (2004), pp. 279–306.
20. J. Lohmann and G. Sharp, The evolution of an electronic-only course delivery method in engineering economy for on-campus sudents, in *Proceedings of the 2002 ASEE Conference,* Montreal, Canada (June 2002).
21. D. Jensen, J. Wood and K. Wood, Hands-on activities, interactive multimedia and improved team dynamics for enhancing mechanical engineering curriculum, *International Journal on Engineering Education*, **19**(6) (2003), pp. 874–884.
22. C. Park, *Contemporary Engineering Economics,* 2nd edition, Addison Wesley (1997).
23. A. Bheda, Web education and different learning styles, M.Sc. thesis, Department of Systems and Industrial Engineering, University of Arizona, Tucson, Arizona (2003).

Jeffrey Goldberg is currently the Associate Dean for Academic Affairs in the College of Engineering at the University of Arizona (UA) and the Director of the Bachelor of Arts in Engineering program. He has been a member of the Systems and Industrial Engineering faculty at the UA since 1985. Dr. Goldberg received his Ph.D. from the Michigan, in IOE 1984, and the M. Engr. and B.Sc. from Cornell in ORIE in 1980 and 1979, respectively. His research interests include designing and operating emergency vehicle systems, and using mathematical models to help solve decision problems. He is an active member of the American Society for Engineering Education, and has been a national leader in the development and design of effective engineering educational systems. He has received a number of awards, including the El Paso Natural Gas Foundation Faculty Achievement Award, the University-wide Teaching Award as part of Team 102, the Anderson Consulting Teaching Award, and the Shingo Prize for Excellence in Manufacturing. His textbook ***The Design and Analysis of Lean Production Systems*** won the Book of the Year Award from the Institute for Industrial Engineering in 2003.

Kevin Lansey is a Professor in the Department of Civil Engineering and Engineering Mechanics and an adjunct faculty in the Department of Hydrology and Water Resources at the UA. He has conducted research on a range of water resources problems, with emphasis on water distribution and systems analysis. This work has resulted in over 110 publications, including two textbooks. Based on his contributions, he was awarded the ASCE Huber Civil Engineering Research Prize for Young Researchers in 2002. Dr. Lansey has received a university-wide teaching award and has been recognized by the UA students with three teaching awards.

Mark Hickman earned his B.Sc. in Civil Engineering, M.Sc. in Transportation, and Ph.D. in Transportation Systems from the Massachusetts Institute of Technology (MIT). Currently he is an Associate Professor in the Department of Civil Engineering and Engineering Mechanics at the UA in Tucson, Arizona. He has had previous academic positions with Texas A&M University and the University of California—Berkeley. His areas of interest include quantitative analysis of transportation systems, remote sensing of transportation flows, and public transit planning and operations. He is a member of INFORMS, ITE, ASCE and TRB. He has also won numerous teaching awards at the University of Arizona.