Web-Based Engineering Science Course Modules Overview and an Experiment in Engineering Economics

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Abstract

As curricula receive increasing pressure to reduce credit hours while including non-traditional elements, the engineering science component has sometimes been the target of cutbacks. However, knowledge of the fundamental concepts remains critical to engineering education. The existing paradigm for teaching engineering science is three credit hour blocks of material. This three-unit course depth may not be necessary, but a basic comprehension of the material is vital.

To better prepare graduates, a series of one-unit modules are being developed at the University of Arizona. Students will have the opportunity to take several of these modules in place of the currently required three unit engineering courses. Module topics include statics, engineering economics, electric circuits, mechanics of materials, hydraulics, material science, dynamics, and thermodynamics. These courses will be taught in a web-based format with opportunity to interact with faculty and teaching assistants during live and electronic office hours. The web-based materials will provide the basis for asynchronous learning and will be similar to electronic texts but allow students to question a faculty when reviewing the material. There is also interest in the materials at the community college level.

In this paper we report on the development effort and the difficulties involved, both in faculty buy-in and in course development. We have run a small experiment using the materials for engineering economics and our results are included.

1. Introduction

In Spring 1998, the General Electric Foundation (GE) granted $450,000 to the University of Arizona (UofA), College of Engineering and Mines (COEM). The project covered three main areas:

1. The development of 1-credit web based modules on various topics of engineering science.
2. The development of materials in systems/statistical thinking that could be used by faculty to develop curricula and by students to learn the content material.
3. The development of a sophomore level class that builds on our freshman design experience and covers some of the "softer" ABET 2000 criteria (communication, teamwork, ethics, contemporary issues, global environment).

In this paper, we will report on progress on the first point, the development of 1-credit modules on engineering science. The "need" for these modules is a direct result of a University mandate to reduce credit hours in all programs (or advertise as a 5-year program). Each department in the COEM was required to reduce degree requirements to 128 credits or less. The strategy of most of the programs was to simply cut out materials that were not directly related to the major. Note that the general engineering science courses at the UofA are 3 credits (45 hours of class meeting time during the semester). So, if a department wanted a breadth of engineering science - for example, material on statics, dynamics, electronic circuits, and engineering economics - then they would have to take a battery of 3-credit courses. We do not mean to say that the materials in these courses are not necessary, but for some majors, three units of one area may be less preferred to one credit (15 hours) in each of three areas. Breadth may be better than depth for some majors and some topics.

Our use of web technology is motivated by constraints on faculty time and a student body that requires time flexibility. The intent is to develop "stand-alone" modules where students can access the materials at any time, be tested for pre-requisite materials, have progress monitored, and finally be examined at the conclusion of the module. We were trying to develop materials that could be used by teaching assistants with little faculty oversight. We chose engineering science topics since this is where breadth is needed, and it is a body of material that is relatively stable. Also, our faculty that were interested in developing the content materials generally taught these classes (among others). Finally, these topics in a web based system could be easily and effectively used by advanced students as a refresher course of the Fundamentals of Engineering Exam.

The remainder of the paper is organized as follows. In section 2, we will give a brief overview of our progress on the entire set of modules. In section 3 we will use the engineering economics module to give examples of the types of materials that we include, the navigation interface, and the flexibility in the system. We have completed a test version of the site and it was used in a junior level civil engineering course. The setup of that course and the results of an evaluation by the students are covered in sections 4 and 5 respectively. We conclude in section 6 with the changes we will make based on the evaluation and directions for further experiments.

2. Background on the GE Project Modules

In the GE project, we are developing modules on the topics in Table 1. A team of faculty, students, used a development process (developed primarily by Dr. Elena Berman of the UofA Faculty Center for Instruction Improvement) to specify the content for each module. Each module starts with a content map of topics and their expected completion time. The content map is used as the primary site navigation tool. A faculty member is responsible for developing the content material and giving this material to the site development team. The site development team consists of a team leader and a crew of undergraduate students and they are responsible for putting the content on the web and ensuring that the navigation tools work.

The bottleneck in our process has been getting materials from faculty members in a timely fashion. Our goal is to be up and running with at least 6 modules by August 2001. At that time, the modules become part of the required curricula for degrees in systems engineering, industrial engineering, civil engineering, and engineering management (new degree that is starting in Fall 01). The modules can also be used to meet "engineering electives" in our BA in engineering degree. We are currently working with chemical engineering, electrical engineering, and materials science to see where the modules might be of interest.

Table 1. - Engineering Science Topics

Topic	Status
Statics	Complete - tested as help-material for 3-unit course
Engineering Economics	Complete - tested as 1-unit portion of CE 360
Mechanics of Materials	Content complete - not tested
Electronic Circuits	Content complete - not tested
Materials Science	Content 75% complete (January, 01 expected completion)
Hydraulics and Fluid Mechanics	Content 25% complete (July, 01 expected completion)
Thermodynamics	Content 50% complete (July, 01 expected completion)
Dynamics	Content 0% complete (December 01 expected completion)
Project Management	Content 0% complete (December 01 expected completion)
MATLAB	Content 1/5 complete, faculty member left UofA

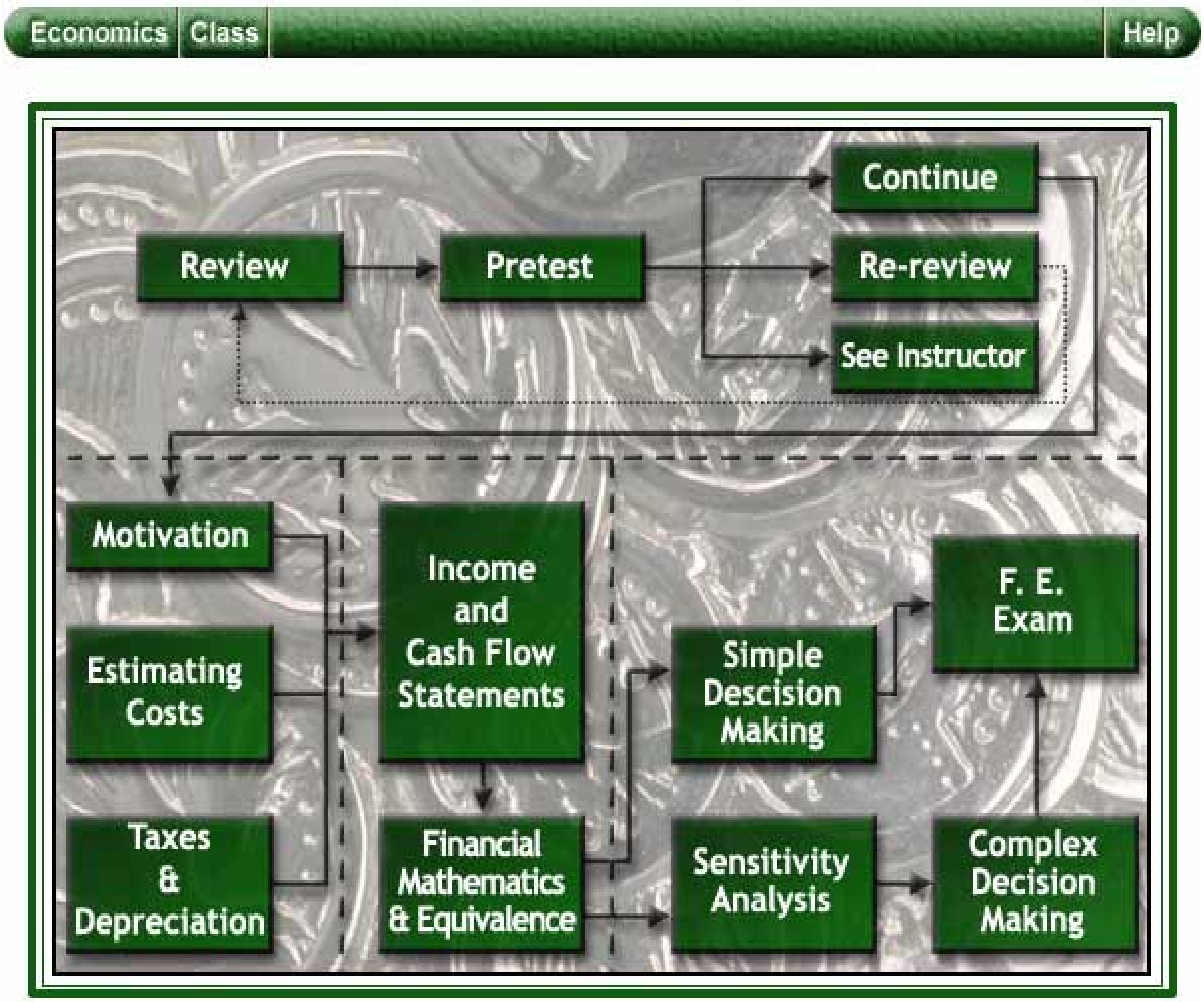
3. Engineering Economics Module

The engineering economics module can be found at gonzo.sie.arizona.edu/ge/econ and has the content map in Figure 1.

The topics are fairly standard and the notation used follows that of ***Contemporary Engineering Economics, 2nd Edition***, by Chan Park. The "dotted" lines on the map represent hurdles (quizzes) that the student must pass before moving on to the next section. For example, before starting the course material, the student must pass a pretest on basic algebra. Before moving on to income statements, the student must pass a quiz on motivation, cost estimation, and taxes and depreciation. Note that the end result of the module is sufficient information to pass the engineering economics section of the FE exam (this is constant for all modules).

Much of this material was developed for our 3-credit course on engineering economics (SIE 265). That web site has been used as an aid for a lecture-based class and was been tested in a web-only mode during summer 1998. Students favorably received the site, however, the instructor and had the ability to adapt quickly when problems arose since he was also the site developer. The development of material on cost estimation and a reorganization of the material into smaller "chunks" were required to transform the SIE 265-web site into the GE project structure. Long subsections were broken down and shortened to fit the 15-hour time constraint. Each topic has at least one numerical example and the setup is such that the student has the opportunity to work on the examples before moving to the solution screens.

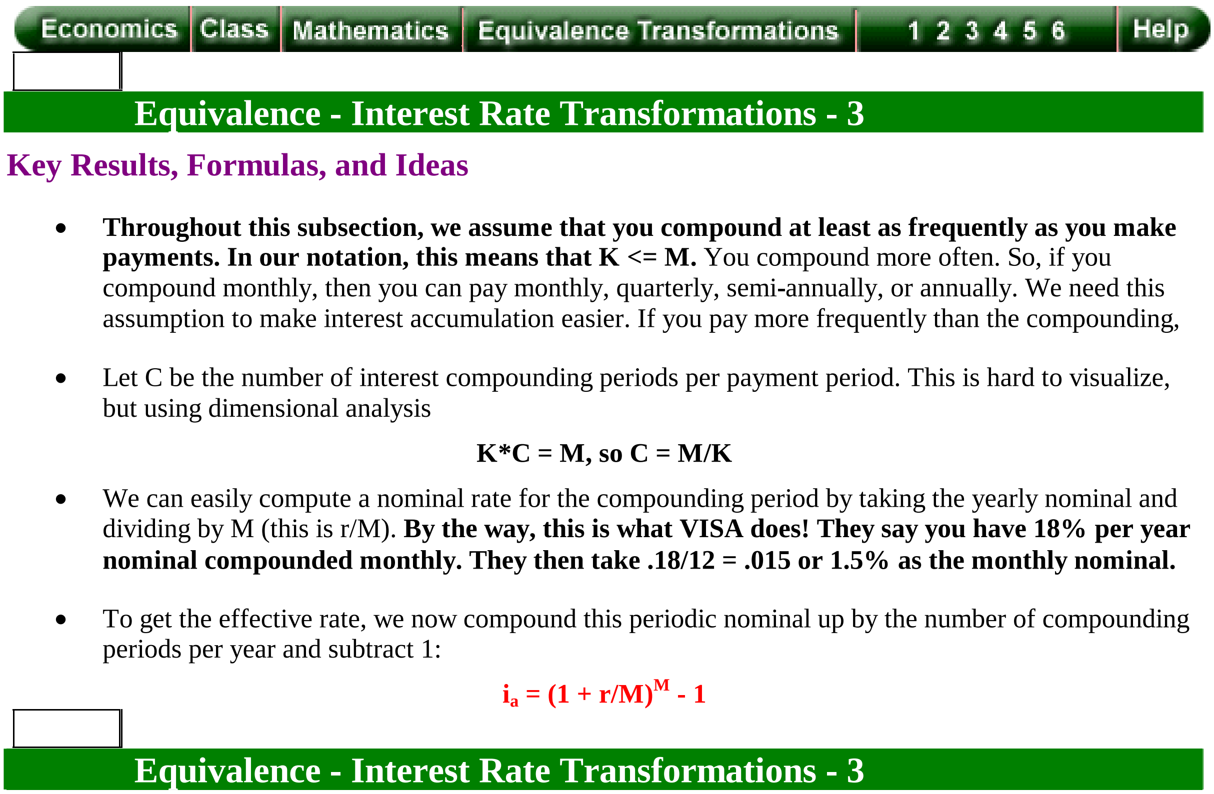
Figure 1 - Course Content Map



The site has exercises that require the use of a spreadsheet and downloadable examples are included on the site. Dialog boxes are placed strategically throughout the site to get feedback from the students and to make the learning experience more active. Navigation is done through a toolbar at the top of each screen. An example screen from the section on "economic equivalence" is given in Figure 2.

The student can return to the course map by clicking on the "Class" area. Alternatively, the student can move to the introduction page for this section (financial mathematics and equivalence) by clicking on the "Mathematics" area. Finally, the student can move to any screen in this subsection by clicking on the appropriate screen number in the area on the right of the bar. There are also "previous" and "next" buttons placed in the title bars for each page (not visible in this image.

Figure 2 - Example Screen and Navigation Bar



Each section in the content map is similarly organized. The section starts with an introduction section that motivates the need for 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 instructor's situation is described, an overview of the section is given. The overview contains links to the sub-section content material (primary navigation to get to the sub-sections) and any spreadsheets that are applicable for use in the section. After a student completes a sub-section, there is a navigation button to return to the section overview to proceed to the next topic (or they could use the navigation toolbar to return to the overview).

4. Experiment

The first draft of the module content was completed during summer 2000 and a test was set up in a Civil Engineering junior level class on transportation engineering. The course was 4 credits and 1 credit covered engineering economics. This was the plan that the Department chose when they reduced degree requirements to 128 credits.

The class was introduced to the site on the first Monday session. All students knew that the site was experimental and they were asked to participate. Problem sets were given every 2 weeks and the instructor held a problem session review every other Monday. At the start of the course, we did not have the ability to easily store dialog box answers, so this feature was disabled. We thought that we would be able to judge the progress of the class using the homework assignments, questions at the review sessions, and exam question answers. Also, no quizzes were given on the site and the students had access to the entire site at the start of the course. No pretest was given since these students were first semester juniors. Finally, the students were not locked-out of looking ahead on examples (we could have locked out movement until a dialog box question was answered) and hence some students may have moved ahead and then used example solutions to work backwards to try to understand the material.

Early in the semester, feedback was given at each review session. Typos were corrected, spreadsheets were labeled better, a missing page was constructed, and a printing utility was developed to make ease the printing of the site 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 type questions and short comment questions was given to the students so that they could evaluate the experience. The form can be obtained from the Jeff Goldberg (jeff@sie.arizona.edu).

5. Results

28 students completed the evaluation forms and Table 2 contains some of the results. All questions had a 5-point scale and we list the word descriptions for 1, 3, and 5 points.

Table 2 - Results from Site/Course Evaluation

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 web site impact difficulty	1 = Makes the course much easier 3 = No affect 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 web site was an effective tool for learning	1 = Strongly agree 3 = Uncertain 5 = Strongly disagree	2.75	1

One can see that the results are mixed. The result for question 4 is troublesome and the individual forms show that a number of the students were highly dissatisfied with the approach. It is not surprising however that a student that is used to a lecture format and face-to-face meetings with an instructor would have some difficulty initially with the approach. Their particular complaints were in navigation, the lack of a search engine on the site, and the difficulty of the examples. We intentionally restricted navigation since we wanted the students to go through the material in a set order. Even though the material was used many times before and students never complained about not knowing where to find things, this group had problems. This was the first time that we used an instructor that was not the site developer and this may have had some impact.

A total of 31 students completed the engineering economics unit. The distribution of scores for course exams and the homework are shown in Table 3, divided between the 3 credit hours of transportation engineering ("Other") and the one credit hour of engineering economics. The large percentage of homework scores below 60% are due to students who did not complete many of the homework assignments. This can be attributed to the policy that homework counts toward only 10% of the student's semester grade.

Table 3 – Scores in the Course

	Exams		Homework	
Average Score	Other	Engineering Economics	Other	Engineering Economics
>90%	19%	32%	19%	16%
80–90%	29%	32%	29%	6%
70–80%	29%	23%	16%	10%
60–70%	19%	6%	6%	23%
< 60%	3%	6%	29%	45%
Average	80%	83%	70%	61%
Std Dev	10%	14%	23%	24%
Minimum	59%	42%	8%	15%
Maximum	98%	100%	97%	99%

Again, the results appear to be mixed. Exam scores were slightly higher for engineering economics, but the variability of the exam scores was also higher, versus the other course content. It is noteworthy that the students seemed to perform equally well in the exams with the web content. However, homework scores for engineering economics were substantially lower than for the other part of the course. This was 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 complete any given economics homework (24%) versus one sixth for the other homework (17%). This 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 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 review session.

6. Conclusions and Future Work

The results of the experiment suggest that we still have a way to go before these modules can be simply turned over to TA's and students. Much of this engineering economics material was used and evaluated positively before, however issues arose that were new to this offering. It is clear that this approach does not match the learning styles of some current students and hence there can be significant student frustration. In the past, the web was one of many learning alternatives, however here we used it as the primary teaching method. It seems that we may have been a bit premature and expected too much of the students. Also, it will be important to require completion of the dialog box feedback and the progress quizzes. Requiring these features and monitoring student responses will help faculty control the learning process and will enable quick intervention when problems exist.

While the web was used as the primary teaching method, regularly scheduled class time was also useful to assess and facilitate student learning. The in-class review sessions were useful to determine what students understood from the web site, through direct questioning of the students about topics. We also asked students to solve problems in class, with the opportunity to interact with the instructor. Finally, given the more general engineering science theme of the web site, we used the classroom experience to expose students to discipline-specific issues. In our case, specific civil engineering issues in cost estimation and project evaluation were discussed within the broader context of engineering economics.

The value of running these small preliminary experiments is that we can use this information on all of the other modules. We now have specific advice for our faculty content developers and hopefully this will make development quicker with fewer feedback loops. This spring, in the engineering economics site we are including audio and video explanations for most of the examples and this will hopefully help the students understand how the examples are solved. Also, we are including a search engine in the site to help students can find specific topics easier (this will also help people that use the site as an FE exam review). Finally, we will construct a glossary for the site with links to term definitions and uses and this will be included before summer.

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Biographical Information

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Jeff Goldberg is an Associate Professor in Systems and Industrial Engineering at the University of Arizona. He also serves as director of the ELITE Program (BA in Engineering) and is an Associate Editor of ***Engineering Education***. Jeff has taught two other courses primarily using web technology and this work is a direct result of funding from the General Electric Foundation.

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