AC 2007-2641: ENHANCING THE LEARNING OF ENGINEERING ECONOMY WITH INNOVATIVE TECHNOLOGY AND TEACHING

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Enhancing the Learning of Engineering Economy with Innovative Technology and Teaching

Abstract

As one migrates from the traditional classroom instruction using black or white boards to the use of computers, many other forms of technology have become available—both as hardware and software—that can enhance teaching and learning. This paper discusses the incorporation of several such innovations, including information transfer, application of spreadsheets (Excel) as a problem-solving tool, and pedagogical adaptation to current needs, into the teaching of engineering economy, a course required in many engineering programs.

During the last decade, engineering economy text books have gradually introduced the use of Excel in solving these problems. However, most solved examples shown in these books still use formulas or factors and interest tables. Over the semester, the course discussed in this paper moves gradually from solving problems using a combination of traditional methods and Excel to using only Excel. By the end of the semester, students take exams and solve even complex problems using Excel only. This approach should prove to be valuable to the students when they enter the working world, where finding textbooks and business calculators are an exception for the engineer, but having computers with Excel or any other spreadsheet software is common place. With an eye toward the needs of a changing student population, presentation and delivery of course materials have also been redesigned to enhance interest and learning, and to make course materials more accessible than previously possible. This paper discusses the need for change in the teaching of engineering economy, specific technological and pedagogical methods used, the quantitative and qualitative testing and results of changes, plans for ongoing research, and recommendations.

Introduction

During the last millennium, the methods of instruction in the classroom did not experience much change. The instructor would use the chalkboard (which now has been converted to the white board), the overhead projector (which has been replaced with the document camera), and overhead transparencies (now replaced with PowerPoint presentations on the laptop). Students would attend lectures and multi-task as efficiently as possible. On the one hand, they wanted to copy down every word on the blackboard or screen; on the other, they wanted to soak up all the words of "wisdom" that the professor uttered. Something had to give—either their note taking or their understanding of the lecture. Students absent from a lecture because of illness, outside obligations, or just laziness had to rely entirely on a classmate for notes—a usually unsatisfactory method.

Today's students face several challenges which their predecessors did not. During the last two decades, the rapidly rising cost of higher education has placed an additional burden on many students who now have to work to make ends meet. Other students are returning to college after having been in the workplace for several years. Those who work full-time and wish to pursue a degree usually have to take one or two evening or early morning classes during a semester; these classes are almost always several hours in duration. After a full day of work, these students are often quite exhausted. For them, it is a major challenge to remain as focused during the entire lecture as would a traditional full-time student. Because of these changes, many earlier methods of instruction are not as effective for today's students as they were for their predecessors.

Since the start of the new millennium, we have seen rapid changes in technology, and these changes are growing exponentially. In 2003, the College of Engineering and Applied Sciences at Western Michigan University moved into a new 300,000 square foot building where each one of the 15 classrooms is equipped with the latest technology: a VHS tape player, a DVD player, an electronic document camera, the ability to easily plug in a laptop computer, and an audio system, all connected to a projection system mounted on the ceiling. The instructor can select and use any delivery device with the capability of easily switching back and forth between them. Besides a wireless environment, each seat in the classroom also has the ability to connect a laptop computer to the university computing system using a cat-5 cable. The University has also made WebCT-Vista available to all instructors.

The engineering faculty has gradually started incorporating various forms of technology in their classroom instruction. The primary author has further incorporated several new innovations into the teaching of engineering economy, a course required in many engineering programs.

Improved PowerPoint Presentations

As a first step, he has introduced animation and color into all of his PowerPoint slides, thus making the learning of the material easier and enjoyable. All key points where students are apt to fumble are also highlighted in the slides, making it easier for them to grasp these critical points. All the solved problems in the slides use cash flow diagrams drawn using Excel. Before developing these slides, the author reviewed several methods, including Notepad, various types of CAD software, and Visual Basic, but found that using the "drawing" toolbar in Excel was the easiest and most effective method for drawing such diagrams. Each arrow representing a cash flow in the diagram can be assigned a different color which matches the appropriate part of the equation. This allows the student to correlate each element of the equation with the appropriate part of the cash flow. All the PowerPoint slides for the entire course are made available in pdf format to the students at the start of the semester through WebCT so that they can focus on the lecture instead of note taking.

Background on Spreadsheet Use in Engineering Economy

A major change made in teaching the course is the incorporation of spreadsheet analysis throughout all aspects of engineering economics problem solving. Historically, engineering economy had been taught using formulas, or factors and interest tables, or business calculators. All problems dealing with time-value-of-money were traditionally solved by any one of these methods. (See Thuesen and Fabrycky, 1989 [1] for example.)

In the early 1990s, as computer technology advanced, spreadsheet use gradually found its way into engineering economy classrooms, pedagogy, and textbooks. Very early presentations on including spreadsheets in the teaching of engineering economy included White (1988) [2], Eschenbach, Wiebe, and Yazici (1991) [3], and Eschenbach and White (1992) [4]. Noting the increasing discussion on spreadsheet use in the engineering curriculum, Alloway (1994) [5] advocated the electronic spreadsheet as frequently being "the best choice for both learning and applying engineering concepts." He suggested that the structure imposed by spreadsheet use typically resulted in more complete problem formulation, and that spreadsheet solutions were appropriate for the vast majority of engineering economy problems. Eschenbach [6] noted in 1995 that spreadsheet packages at that time did not include functions for arithmetic gradients, but, as all engineering economy texts included factors for these gradients, adaptations could easily be made. In 1996, Lavelle [7] supported spreadsheet assignments as good pedagogy because they promote students' understanding of engineering economy principles and skill development in basic engineering analysis. A 1999 report found that by 1997, 75% of instructors were using spreadsheets in their engineering economy course (Nachtmann, Needy, Lavelle, and Eschenbach) [8]. Jumping ahead to 2002, Eschenbach [9] noted that a new focus on design and decision-making in engineering economy is facilitated by widespread use of spreadsheets, and that the field is developing pedagogically sound teaching of spreadsheet modeling.

Concurrent with discussion and curricular change, engineering economy text books have gradually introduced the use of Excel in solving these problems. (See changes from Park, 1993 [10] to Park, 2007 [11] as an example of this transition.) However, even though textbooks cover spreadsheets, tables of engineering economy factors still form the basis for most engineering economy courses. And in many cases, most solved examples shown in these books still use formulas or factors and interest tables.

Incorporation of Excel to Solve All Problems

The current class builds on this history of pedagogical development. In the class, every problem that is solved using the traditional methods is also solved using Excel. This is greatly facilitated by being able to easily switch back and forth from PowerPoint to Excel and vice versa on the laptop computer. To save time in the classroom, the data needed for solving some of the questions are included on the PowerPoint slides as an embedded Excel spreadsheet. When demonstrating the use of Excel to solve the problem, the spreadsheet on the slide is double-clicked, thus opening up the spreadsheet in Excel with all the data already in it. Appropriate built-in functions can then be used to complete the problem. The commonly used functions to compute the time-value-of-money are PV, NPV, FV, PMT, NPER, RATE, IRR, and EFFECT. Although there are no built-in functions in Excel to handle arithmetic and geometric gradient series, a cash-flow table can easily be developed with Excel to include these gradients in the numerical values. The above functions can then be used to find the single cash equivalent or a uniform series equivalent of the cash flow.

In addition to solving simpler problems with Excel, students are also taught how to program and solve complex problems using Excel spreadsheets. They are tested in these concepts through three elaborate assignments which they solve at home over a few days and then submit for grading. The students are asked to list all the "given" information in a group. As they prepare the spreadsheet template with appropriate formulas, functions, etc., they are required to use cell references whenever they need to use the "given" information. Once the template is ready, the students can change values of the "given" information and observe the impact on the solution. This flexibility allows the students to evaluate their design and make appropriate decisions as to the optimal values.

During the fall 2006 semester, the class was taught as a "paperless" course (more details of this procedure are described later). Exam #1 was given during the fifth week of the semester, followed by exam #2 four weeks later. One week after exam #2, the students took an hour-long exam in the computer lab and solved several problems using Excel only (where no calculators, textbooks, interest tables, or notes are allowed). These problems were similar to those given in earlier exams and quizzes and those found at the end of the chapters in the text book. The time allowed for each of these three exams was 58 minutes. Table 1 shows the statistics for all three exams in terms of (i) time used for submission and (ii) raw grades received. As one examines these statistics, there does not appear to be any significant difference in the statistics for exam #1 and #2. However, there is a definite difference in the values between the two exams (1 and 2) and the Excel exam. The students use less time to solve similar problems in Excel (Excel exam) as compared to solving by traditional methods (exam #1 and exam #2), and their overall performance is also better. One may be inclined to think that students using Excel could be quicker or perform better because it is used towards the end of the semester when the students have mastered time-value concepts. However, this conclusion would not be valid considering the fact that exam #2 is held in the ninth week and the Excel exam just a week later.

Table 1. Time Needed and Grades Received: Traditional Methods vs. Excel

Statistics	Time Used for Submission (in minutes)			Raw Grades Received (out of 100)		
	Exam #1	Exam#2	Excel Exam	Exam #1	Exam #2	Excel Exam
Mean	54.1	53.3	48.6	70.7	70	82.3
Median	54.0	54.0	49.0	74	72	92.5
Maximum	59	56	58	98	97	100*
Minimum	47	46	35	33	38	10
Std. Deviation	2.1	2.2	5.3	15.5	14.4	24.5
No. of Students	28	27	26	28	27	26

*8 out of 26 students scored a perfect 100 in the Excel exam.

Because of the positive experiences to date with students' solving problems using Excel, as a next step in innovation, an additional experiment is underway in the current semester. In teaching the initial chapters dealing with time-value-of money concepts, the traditional formulas, factors, and interest tables are being used to solve the problems. Excel is also being used to solve these same problems. This dual approach should allow the students to develop an intuitive and strong background in the time-value-of-money concepts while also learning how to solve problems with Excel. Starting with the various methods of comparison of alternatives and all subsequent topics, each student will be given a choice to either (i) solve the entire exam using formulas and factors or (ii) solve the same exam using Excel only. Hence, in the first exam, all the students in the class will solve problems using the traditional formulas and factors method. In the three subsequent exams, each student will be asked to voluntarily choose whether they would like to solve the questions (i) using formulas and factors, or (ii) using Excel. It is anticipated that this combined approach will prove to be extremely valuable to students when they enter the working world, where finding textbooks and business calculators are an exception for the engineer but having computers with Excel or any other spreadsheet software is commonplace. Moreover, if any of the students wish to take the Fundamentals of Engineering (FE) Exam, they would not be at a disadvantage since they would also know how to solve the problems using the traditional methods. The authors plan to report the results of this experiment at the conference in June.

Making the Course Completely "Paperless"

Another major change in the incorporation of technology in teaching the engineering economy course is to make it completely "paperless," an endeavor that has been quite successful. For the last two years, the class meets in a computer lab where each student has access to a PC. The author uses WebCT for everything in this course. For openers, all PowerPoint notes are posted on the website. During the lecture, the students can access these notes by logging into WebCT and following along with the lecture.

The course has four 20-minute quizzes (one question each), three hour-long exams (four questions each), one final exam for one and a half hours, and three in-depth Excel assignments which the students work on at home and then submit. All of these exams, quizzes, etc. are put in the "assignment dropbox" of WebCT and made available to students beginning at the class start time and ending after the allowed time has elapsed. The students download the appropriate assignment onto their PC in the lab, work on it, and then save it to their WebCT file space. Then they submit the file electronically through the assignment dropbox. The author downloads all the student files to his laptop computer, grades them on the laptop, and returns the graded file (with appropriate markings, comments, and grades in red) along with the overall grade to the student's WebCT area. A complete solution is also posted on the website. The students can then download their graded file and see where they made mistakes and compare their submission with the posted solution.

At the beginning of the semester, the students sometimes feel overwhelmed by the idea of having to take quantitative exams on the computer. However, with passing of time and with actual involvement in the process of going "paperless," they gradually get used to it. In a survey given to the class mid-way through the semester, some of the students' responses to the question "What have been the positive outcomes of making IME 3100 a 'paperless' course?" were:

- More convenient to go through notes. Teacher makes everything very organized and easy to study.
- It makes students use new skills and it forces us to adapt to change.
- Grades, notes, resources are all in one place and easily accessible.
- The notes, solutions, extra examples and Excel are all very valuable
- Don't have papers to keep organized. Everything is always available in one spot—online.
- I have access to course materials anywhere on campus, and at home. I like receiving instructions online and having assignments graded and posted on line.
- I don't have to carry a binder around and I can just put everything on my flash drive.

At the start of each semester when the students were told that the course would be paperless, many of them were worried about how they would take an exam directly on the computer. Initially many of them would write down the complete solution on paper and then transfer this information onto the computer. As a result, some of them would run out of time and not be able to solve all the problems. Moreover, some made mistakes in transferring the information from paper to the computer. Very quickly they realized that it was best for them to work directly on the computer.

At the start of the course, students' anxiety about its paperless nature varied from "no" anxiety (45%) to "quite a lot" of anxiety (21%). However, by the end of the course, students expressed substantially greater comfort. Work continues to alleviate anxiety or discomfort students may have about paperless aspects of the course.

During the summer 2006 semester, the author conducted an experiment to evaluate if going "paperless" was creating a disadvantage to the students in his class. Since he was teaching two sections of the same course during the semester, he taught one of the sections in the traditional manner where all exams and quizzes were done on paper. The second section was completely paperless. Without the prior knowledge of the students, two of the examinations (exam #1 and the final exam) had identical questions. Exam #2 had different but similar types of questions. The statistics of the scores on each of the three exams by the two different methods are given in the table below.

Table 2. Comparison of Scores Between Traditional Course (on paper) and "Paperless" Course

Statistics	On Paper			Paperless		
	Exam #1	Exam #2	Final Exam	Exam #1	Exam #2	Final Exam
Mean	71.3	74.6	72.6	71.1	80.2	71.3
Median	69.0	72.0	72.0	72.0	81.5	73.0
Maximum	94	97	99	100	100	92
Minimum	51	51	55	35	60	44
Std. Deviation	15.2	12.4	11.9	15.8	12.8	12.5
No. of Students	20	20	20	22	22	21

The raw scores of each of the three exams were analyzed using MINITAB. When comparing exam #1 (on paper) with exam #1 (paperless), at first the F-test was done to see if the variances were equal. From the results, it was concluded that the null hypothesis of equality could not be rejected. Having concluded equal variances, the means of exam #1 by the two methods were compared using the t-test. From the results, it could not be concluded that there is a difference in performance between the two methods. Similar comparisons were done for exam #2 and the final exam using the scores obtained by each of the methods. In both cases, results similar to those of exam #1 were obtained. The normal plot was also done for all the grades in all three exams by each of the methods. In each case, a normal distribution seemed a reasonable assumption. As such, we can safely conclude that there is no disadvantage for the students in taking the "paperless" exams.

Problems with Going "Paperless"

As easy as going "paperless" appears now, the author had to go through growing pains which he gradually overcame one at a time. Some of the obstacles that had to be resolved and the procedures that were used for resolving them are described below.

- What format should be used for writing the exams so that it becomes easy for students to write their equations and for the instructor to grade the answers in "red"?

  Considering that almost all PC's with a Windows environment have M.S. Word loaded on them, this was the obvious choice. The factors are written as (P/A, I, 8) and formulas are written as (1+I)^5. The values of each factor are obtained from the appropriate interest tables and written on the line below each factor. The equation is then solved using a calculator and the answer written down below the equation. When the student file is downloaded into the instructor's laptop computer, the reviewing toolbar is activated and "track changes" used before the question is graded. This ensures that all comments, grades, etc. are posted in red so that the students can easily see the comments and see where they lost points.

- How can the questions be laid out to make it easier to grade the exam?

  With paper exams, most instructors grade the same question for all the students and then move to the next question. However, when grading the exams on an electronic file on the computer, the only efficient way to grade the exam would be to grade all the questions for one student, save the file, and then open the file for another student.

- Once all the questions for a student are graded, how can we use a spreadsheet to automatically perform the calculations to compute the student's overall grade?

  An Excel spreadsheet giving a cell for each question number on the exam and the total of all points is embedded at the bottom of the page of the last question. As a question is graded, the points obtained on the question are entered into the worksheet. When all questions are graded, the total gives the points obtained on the exam by the student.

- Since the computer lab has a wired and a wireless environment, how to prevent students from passing solutions through email to one another?

  Each page has a textbox on it covering all but about ½" of space outside the boundaries to the edge of the page. The inside of the textbox is filled in with some light pastel color which is changed from one exam to the next. The question is written in this text box in black and the students are asked to write the answers in this text box also. The instructor stands at the back of the lab room from where he can see each student's monitor. The students are told about the purpose of the page color and that they should not switch to anything else until their exam is complete and submitted to the WebCT assignment box. The students are, therefore, mindful that they are being observed. Hence they do not risk sending their file to another student in the classroom.

- Since the exam is available through WebCT on-line, what prevents a student from taking the exam at home (where someone else can help him) and submitting it during the assigned time?

  This actually happened once. To alleviate this problem, during each exam the author asks the students present to enter a numbered code (randomly selected) alongside their name on the first page of the exam.

- Since going "paperless" is entirely dependent on various types of technologies, what can be done to minimize problems that may occasionally occur with any one of the technologies—PC, downloading, uploading, saving file, etc?

  Experience has shown that there should be at least two unused workstations available in the class room. Occasionally a computer locks up and the student has to move to another computer. If this happens, the student is allowed about five additional minutes to submit the exam. In order to ensure accessibility of their work from another computer, they are encouraged to save their file in either their workspace on the server (on the appropriate drive), or on a USB flash drive which they can bring with them. They are warned never to save their work on the desktop.

Two additional points should be made. First, the students are allowed five additional minutes to download the file from WebCT, rename the file and save on the computer, periodic saving on the computer, and then uploading and submitting the completed file to the assignment dropbox in WebCT. Second, the students are given a two minute warning so that they can submit their work in a timely manner.

Proposed Enhancements in the Future

Having converted all lecture notes to PowerPoint, having adopted Excel in solving engineering economic problems, and having made the entire course "paperless," what additional technologies can one adopt to enhance the learning by students? The answer to this question will vary depending upon individual experiences. What does this author plan to do in the future? He has already been able to record his complete classroom lectures in digital mode (audio and video) directly onto his laptop. No external assistance is required in this process and the quality of the output is excellent. As the lecture is being delivered, the notebook "screen movements" are recorded along with the audio of the lecture. At the end, the audio and video are merged into a single AVI format file. This file can then be converted (within a few minutes) into a WMV file which is substantially smaller in size (without much loss in quality) and can then be viewed with the Windows Media Player available with all Windows operating systems. The AVI file can also be easily compressed to MPEG4 format for video streaming.

As soon as the university has the capability of streaming audio-video files (hopefully during the Spring 2007 semester), the author plans to stream these prerecorded lectures to students registered for his class. The initial plans are to make these "electronic webcast lectures" available to students to review on their computers, multiple times if necessary. Students unable to attend the lecture because of illness or other emergencies would have the "lecture" delivered electronically to them. A student who could not understand parts of the lecture because of the complexity of the material could review the corresponding part of the lecture over and over again until it was clear. And a full-time working student who had to take the class for a degree program could register for it and, if necessary, download the lectures on a PC and sit through each lecture at a more convenient time. Some time in the future, the author plans to stop delivering lectures during class time and require students to “attend” these “electronic lectures” before coming to class. He will then use the class time to answer students’ questions and solve problems (something for which sufficient time is not available at present).

Conclusion

The authors have applied various forms of technology to enhance the teaching and the learning of engineering economy. They have plans to further innovate their delivery of material by using the latest forms of technology such as pre-recording of lectures on their computer and streaming these to registered students to view at home. The class room time can then be used much more efficiently to enhance learning by the students. Although all of the innovations presented earlier have been in the teaching and delivery of a course in engineering economy, all of the presented techniques can also be used for teaching most quantitative courses.

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