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Using Emerging Technologies for Hybrid and Flipped Classroom Learning

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Abstract

I have been teaching the course, Engineering Economy, at the undergraduate level for engineering students as well as for engineering technology students for over three decades. During the past seven years, I have gradually implemented the use of various components of e-learning into the course. I have started teaching the course in a flipped classroom mode and, as such, I am now able to deliver this course either as an on-line offering or as a hybrid class. I have also incorporated various forms of technology into the classroom. My course offering is now completely paperless and can be considered to be at the cutting edge in the application of technology in course delivery. As a result of the hybrid course offering, I meet with the students for one-third of the time only. Although I have made the course more rigorous and have reduced the student contact hours, the class cumulative grade point average has gone up significantly in the last eight years. The failure rate in the class has also gone down.

Keywords

Engineering economy, elearning, hybrid, flipped classroom, video lectures.

The Need for Change

The method of delivering education has changed very significantly since the start of this millennium. This change has been precipitated partly by the availability of new technology and applications software, and partly to satisfy the needs of the generation of students who are now in college—better known as the millennial students. These students have some unique characteristics which make it difficult for them to derive maximum benefits from the traditional classroom lectures of 50 to 75 minutes duration. Research suggests Millennials prefer a variety of active learning methods. When they are not interested in something, their attention quickly shifts elsewhere. Interestingly, many of the components of their ideal learning environment—less lecture, use of multimedia, collaborating with peers—are some of the same techniques research has shown to be effective.[1] This indicates that the typical "chapter" format of lectures should be modified into smaller "learning units", each unit being a small topic related to the overall chapter and having specific learning outcomes.

Millennials have grown up be being able to Google anything they want to know, therefore they do not typically value information for information's sake. As a result, the professor's role is shifting from disseminating information to helping students apply the information. One of the greatest challenges for teachers is to connect course content to current culture and make learning outcomes and activities relevant.[1] This indicates the need for helping students apply the information learned in the course so that students can understand the value of that information. In the traditional education system where the information is delivered to the students in the

classroom through lectures, there is not enough classroom time available to help the students with the application of the material. This need has resulted in some educators "inverting" the classroom. Lage et al.[2] state that "Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa. The use of learning technologies, particularly multimedia, provides new opportunities for students to learn, opportunities that are not possible with other media. . . . The instructors focus on the desired outcome (for instance, having the student prepared for discussion) and allow the student to choose the best method to reach that outcome." Although the flipped classroom can be taught without online resources, the Internet allows the instructor to invert the classroom without sacrificing content coverage.[3]

Take the example of Khan Academy. Originally developed as a means of helping his cousins with math, Salman Khan's efforts have expanded into 1800+ videos on YouTube, with nearly 22 million views between them. In these brief 10-15 minute tutorials, Khan explains basic (and not so basic) math concepts in a concise manner that students can easily digest and reference later. . . . Khan Academy videos are viewed more than 70,000 times per day – that's more students than most major universities.[4] The popularity of Khan Academy . . . has even drawn raves from Bill Gates, among others—suggests that mini-lectures, delivered apart from the classroom, could pick up momentum in higher education.[5] The success of the Khan Academy is an excellent example of the acceptance of creating short educational videos of individual concepts, and posting them on the web for students to view and learn.

The Engineering Economy Course

For more than 30 years, I have been teaching two courses covering the subject of Engineering Economics at the undergraduate level for (1) all engineering majors and (2) for technology majors. In these courses, I teach several different mathematical concepts dealing with the time-value of money. These concepts are then used to compare multiple alternatives to select the best one. This course also covers the concepts of depreciation and its computation by several different methods. Additional topics such as impact of taxes on earnings (personal and corporate), the effects of inflation, and risk analysis are also covered. It is primarily a mathematical course. Over the last seven years, I have gradually incorporated various features of e-learning into the course. As such, today the entire course is handled through e-learning and it has become completely paperless such that not a single sheet of paper is exchanged between the students and me.

The balance of this paper describes the current structure of the Engineering Economy course as offered by me, and how it is delivered to students. The techniques described are fairly simple to use and can be easily adapted to most courses. All it requires is the availability of an e-learning platform in the educational institution, and a desire by the individual instructor to change his course delivery system. Hence these techniques can be adopted very easily.

Restructuring the Course for Flipped Classroom Delivery

Although the textbook is divided into chapters based on major topical content, I have divided the course material based on learning outcomes of the course. Hence, the entire course has been divided into about 40 learning units, each unit typically being a single topic. For each

learning unit, I have prepared four items: (i) PowerPoint notes, (ii) "video lecture" based on my notes, (iii) some solved examples which are presented in video format, and (iv) several assigned end-of-chapter problems along with answers for students to solve. Some of the introductory units only have the first two items. Students are advised to complete all the parts of a single learning unit before they move on to the next unit. They have found this "structure" to be valuable since they can now familiarize themselves with one unit before moving on to the next. Each of the above four components of a learning unit are described below:

PowerPoint Notes: I have spent a lot of time in preparing the PowerPoint slides for each learning unit and there is nothing unique about this. However, since this is a mathematical course, I have taken the effort of introducing animation and colors into each slide. The animation during the lecture allows equations to be viewed one part at a time. Thus, the students can participate in the formulation of the equation as it is being presented. Moreover, I have used different colors to depict the various cash flows in the graphics of the cash flow diagram. Each part of the equation has also been coded in the same color so that students can correlate a cash flow in the diagram with its corresponding part in the equation. Students have commented that this makes it easier for them to understand the material. All my PowerPoint notes are posted on e-learning as PDF files so students can download them and use them to follow the video lectures.

Video Lectures: With the use of a screen capture application, I have developed the ability to record my "video lectures" directly on my laptop without any assistance. I can record lectures in my office or at home and the only equipment required is a small microphone and the laptop computer. Applications such as "Camtasia Studio" and "My Screen Recorder Pro" record all screen movements and my voice as I move through my PowerPoint presentation. The recording (video and audio) is loaded on the University's server for streaming. The students can easily view the video on any computer and have the ability to fast forward and rewind the video without any significant delay. This allows them to view any segment of the video multiple times if necessary.

I try to limit the length of each video lecture typically to 15 minutes. I have found that the students like this length of the video lecture since they can easily complete it in one sitting. If any topic is longer, I divide it up into two or three units so that the "video lecture" remains within the length guidelines.

Videos of Solved Examples: For each learning unit, I have solved 2 to 4 problems and prepared a video of the solutions. Before creating the video, the questions are entered into the computer. Below each question, all the given data is summarized followed by a solution to the problem. When recording the video lecture, I first read the question, and then analyze the information that is given followed by a discussion of the analysis leading to the solution methodology. Once again, this video is loaded on the University's server and is streamed on demand. Just like the lectures, the student can view any part of it multiple times by rewinding or fast forwarding it as desired.

Assigned Problems: For each unit, I give a list of 4 to 8 problems from the end of the chapter in the text book related specifically to that unit. I also give the answers for each of the assigned questions. The student is asked to solve all the assigned problems before considering the unit

to be complete. No submissions are required and hence there is no grading involved.

Using *e-learning* for Delivering the Course

Until 2011 the e-learning system, *Blackboard Learning System Vista Enterprise (WebCT Vista*), was used at my university and was provided by *Blackboard Inc.* Three years ago the University switched over to a different system provided by a Canadian Company, *Desire2Learn*. As mentioned above, I started using e-learning about eight years ago and, currently, I am using several tools in the course. The purpose of each of these tools and how it is being used in my course is described in this section.

Contents: All the material needed for the course is placed under contents. This material can be in the form of files or can be linked directly to files. My PowerPoint notes and the list of assigned questions with answers are placed as PDF files. All the videos are linked to its URL so that when this link is clicked, the video file is opened in a box ready for playing. Each file can either be made available for the entire semester or it can be made available between any two dates. The Course Syllabus is also placed as a PDF file under contents. I have created modules equivalent to the chapters in the text book. Under each module, I have multiple units (items). Under each item I place links to the specific files needed for that unit including video files.

Quizzes: This module is used to administer tests of any kind. It is made available on the specified date and time and for the given duration only. The testing material questions can be in a variety of forms such as multiple-choice, true and false, etc. and can be computer graded with the grades being posted automatically to the grade book. I use this feature to administer weekly multiple-choice quizzes based on the learning units assigned for that week. Each quiz can be taken by the student at any time during the week once they have reviewed the posted materials for that week. The test score is released to the student immediately upon completion of the quiz. I am now allowing two attempts to the quiz (questions are administered in a random order for each attempt) and the higher of the two scores is posted for that quiz. This encourages students to review the materials again before the second attempt. Each quiz (10 in all) is worth one percent of the course grade.

Dropbox: If there is any evaluation material that needs to be hand-graded, it can be placed in the Dropbox. Each item to be submitted is placed as a unique item in the Dropbox and is released to the students on a pre-specified date and time. The completed file must be submitted by the student at another time on the same date or any other date. The testing/instruction file(s) to be released are posted in the Dropbox and, upon completion of the item, the students submit it back to the Dropbox. I use this feature for two different types of evaluations. During the semester, I give three one-question quizzes (20 minutes each) and three four-question exams (50 minutes each). Since my class meets in a room equipped with computer workstations, these quizzes and exams are taken during the class meeting. Upon completion, I upload all the student files to my laptop, grade them on the laptop, and return the graded file back to the student with my comments. I also post the student's grade for that item and the solution to the quiz/exam being graded. This helps the student understand how it should have been solved. I also use the Dropbox feature for two take home assignments. I place the assignment and a video detailing my instructions on how to work on the assignment (formatting and procedure). Once again,

upon completing the assignment, the student submits his work back to the Dropbox.

Calendar: This tool is used to compile a calendar for the course which indicates all the deadlines that have been established for the various items in the course. Since one of the hardest parts of self-study is to maintain self-discipline and have good time management skills, a calendar with all the due dates shown is found by the students to be extremely valuable. My students have found the calendar tool to be very beneficial as they have only one location to refer to periodically to keep track of the course requirements.

Reports: At any point in time, the instructor can look at this tool to know how many students have visited each component of the unit and how much time has been spent on it on an average basis. Similar information is also available on any specific student. This helps the instructor to see if a student is keeping up with the course materials or is falling behind. I regularly monitor the reports tool and send emails to students who I feel are behind. This 'forces' them to keep up with the material since they know that there is a 'pair of eyes' watching them.

Grades: This is a very valuable tool for the students—the better students always want to know their grade with reference to the class so they can try to improve it, whereas the weaker students always want to know their grade standing as the semester progresses to see if they will pass the class or obtain a certain minimum grade. As I finish grading and post the grade on each item on e-learning, the student knows his exact grade standing from the grade book. The students really love this immediate feedback on a real-time basis and many of them take corrective action to avoid a disastrous semester end.

Email: This feature stores each student's email address so that emails can be sent to him by the instructor. I constantly use this feature to send emails to one or more students or even to the entire class to make them aware of any upcoming requirements for the course, or for the need for them to take some corrective action. I have found that using this tool is much faster and simpler than using my regular email system.

In the course syllabus, I include a schedule of learning units to be covered during each week of the semester and the students are asked to follow this schedule. Since the typical student has difficulty in following a schedule (because he spends his time on what is interesting instead of what is required), I have instituted a weekly quiz which the student is required to take once he has viewed the video lecture sometime during the week. Since these quizzes have a grade component to it, it helps to keep most students on schedule. All the course materials remain on e-learning for the entire semester so that students can move along at their own pace, reviewing the components in specific units multiple times if necessary.

Using the Flipped Classroom Model

For the last three and a half years, I am offering the 3-credit course on Engineering Economy as a hybrid class. Instead of meeting the class for three hours a week, I now meet the class once a week for one hour only. As mentioned earlier, all my lectures are placed on e-learning in the form of video lectures which the students view at their convenience. I do not lecture during the class period and this time is used exclusively for answering questions, taking quizzes and exams,

and for solving additional problems. Earlier, my class time was primarily spent in lecturing on topics and, occasionally, solving a problem or two. With this new format of video lectures, I have flipped the classroom and have solved 70 end-of-chapter problems and placed on e-learning. Additional problems are solved in class when time permits. The students have found this format to be extremely valuable and are able to perform much better in their exams and quizzes, thus raising the overall class average.

Since I am using the flipped classroom model and various tools of e-learning, the course has become completely paperless. In its current form, all my notes and class materials are posted on e-learning. The student can look at the course materials and view the video lectures and solved problems any time at his convenience thus offering him more flexibility. If he wants to review his graded work or its solution, he can access it on e-learning. The class statistics for each quiz/exam are also available to the student so that he can compare his performance with that of the class.

Simply speaking, although the students submit eighteen quizzes, exams, and assignments during the semester, not a single sheet of paper is used in the solving, submitting, and grading process—hence it is truly a paperless class. I have made it a point to grade every single submission and return it to the student with his grade through e-learning within 24 hours. In one semester, students listed the following advantages of this paperless class:

- 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, and resources are all stored in one place and are easily accessible.
- The PowerPoint 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.

Effectiveness of Changing the Methodology

Figure 1 shows the grade frequencies (as percent of class) in selected semesters over a period of eight years in the engineering economy class. Six semesters were chosen over this time period; the first four were every third semester and the last two were every year. The following changes were made during each selected semester:

1. **Spring '04 (Sp 04)**: The class was taught in a traditional manner in a regular classroom using formulas and interest tables. PowerPoint slides were used for my lectures but were not given to the students.
2. **Fall '05 (F 05)**: The class was taught in a computer lab and the PowerPoint slides were made available to the students (in PDF format).
3. **Spring '07 (Sp 07)**: The class was changed over to a "paperless" class. Students took all quizzes and exams on the computer through e-learning. In each of exams 2 and 3, one question was included to be solved using Excel.

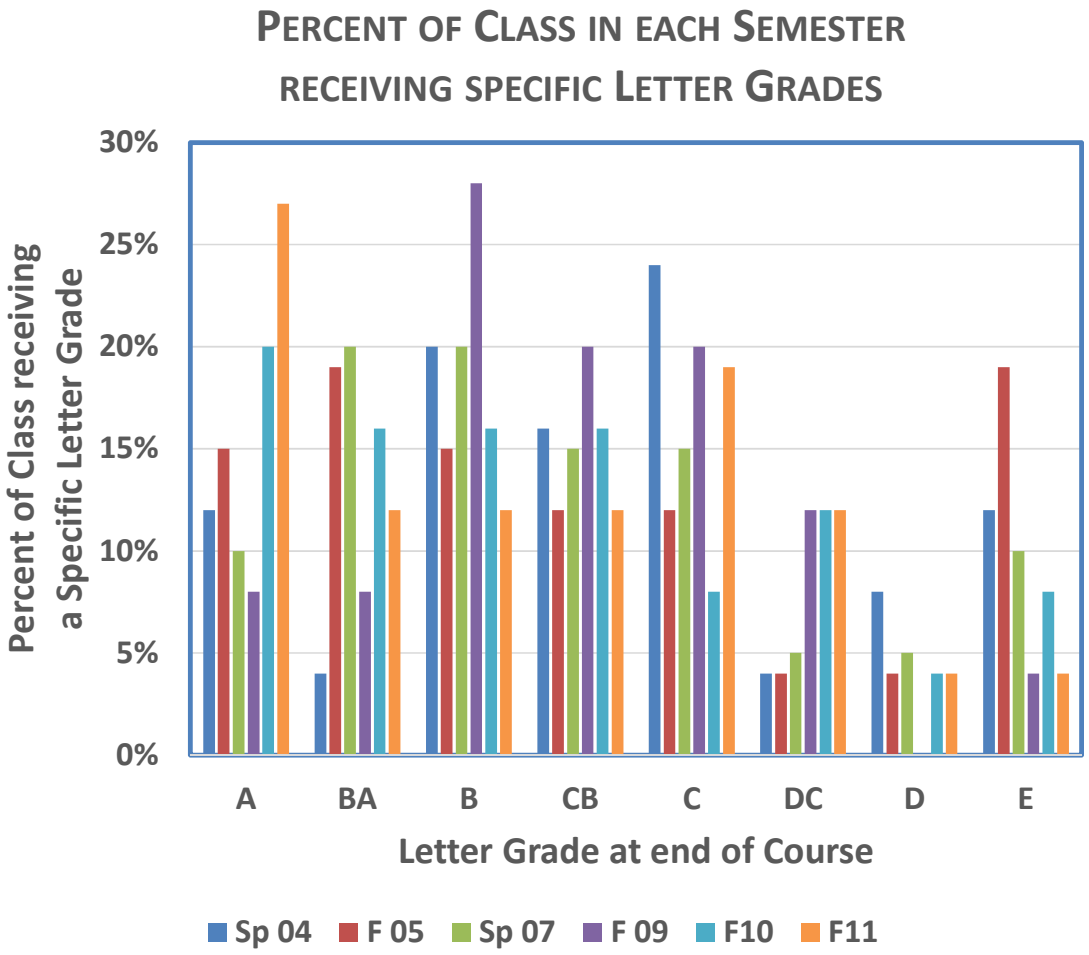

Figure 1. Grade Frequencies (as Percent of Class) in Selected Semesters

4. **Fall '09 (F 09)**: The format was changed so that time value of money was taught using formulas and interest tables and the rest of the course taught using Excel only.
5. **Fall '10 (F 10)**: During the class, "videos" of the lectures were recorded in class and posted on e-learning for students to review as and when they wanted. This was in addition to them attending the actual classroom lectures.
6. **Fall '11 (F11)**: The entire course was restructured into learning units each having PowerPoint notes, video lectures and videos on solved problems, and assigned problems with answers. All of these were posted on e-learning. After completing the time value of money topics, the rest of the course was taught using Excel only for solving all problems. The flipped classroom model was used and the course was offered as a hybrid class and the one-hour-a-week class meeting times was used for solving problems and taking quizzes and exams. The entire course was taught as a "paperless" class.

The Spring ’04 semester can be considered to be the base line when only traditional teaching methods were being used and Fall ’11 is the semester when I started teaching the course in the flipped classroom with hybrid format. A descriptive observation of the grade frequencies (as a percent) in Figure 1 shows a clear increase in the percent of class receiving an ‘A’ grade and a definite decrease in the percent of class receiving an ‘E’ grade. In addition, there also appears to be an increase in the percent of class receiving a grade of ‘BA’. This indicates a clear improvement as new resource materials were created and the teaching methodology changed over this eight year period. Moreover, the Class Cumulative GPA in Spring ’04 was 2.24 and in Fall ’11 was 2.71. This indicates an improvement of half a letter grade over this eight year period thus showing the benefits of the various techniques described in this paper.

Table 1. Grade Distribution by Semesters and Confidence Intervals for the Difference in Proportions.

		Course Grade at End of Semester							
		A	BA	B	CB	C	DC	D	E
Semester	Sp '04	12%	4%	20%	16%	24%	4%	8%	12%
	F '11	27%	12%	12%	12%	19%	12%	4%	4%
Confidence Interval	Lower	0.042	0.006	-0.181	-0.136	-0.164	0.006	-0.106	-0.154
	Upper	0.258	0.154	0.021	0.056	0.064	0.154	0.026	-0.006

To validate this observation, I performed a statistical analysis of the difference between the proportions of students in a grade range between Spring ‘04 and Fall ‘11. As shown in Table 1, the results demonstrate that the changed teaching methodologies yield statistical differences in the highest (A and BA) and the lowest (E) grade groups where the 95% confidence intervals for the differences of proportions are (0.042, 0.258), (0.006, 0.154), and (-0.154, -0.006) respectively. This validates the conclusion that, using the flipped classroom model and hybrid delivery of the class, more students are able to perform better and fewer students are falling behind and failing the class.

Conclusion

There is no doubt that my innovations in the design and presentation of the Engineering Economy course has brought the delivery of this course in particular, and learning in general, to a whole new level. I have moved away from the traditional methods of student note-taking and testing and made the course “paperless”. I have developed a procedure to record the lectures onto my laptop without the help of any other person or equipment. Instead of devoting all my lectures on the course material, I am using the “flipped” classroom model and streaming my “video lectures” on e-learning so that students can view them outside the classroom at their convenience. I now use the scheduled class meetings to administer quizzes and exams and for solving problems. I am taking learning to a whole new level by applying the learned materials to solve problems. An analysis of the grade distribution in the class over several years indicates that my new format in teaching the course is definitely better than the traditional methods.

In the “flipped classroom” model of education, routine activities such as knowledge and information dissemination are done at home and the testing and application of the materials such

as problem solving is moved to the classroom. In the "on-line" model both, the information dissemination and the application are done at home. However, in this model, due to minimal or no interactions between the student and the instructor, the level of applying the material is limited. I have developed a combination of both these models where the course is offered as a "hybrid" model. On-line testing has always been a concern to the "traditional" instructors because it encourages plagiarism, especially if the course is offered simultaneously to students in a limited geographical area such as on-campus. In my hybrid offering of the course, the information dissemination and its application is done at home and all the testing is done in a supervised environment in the classroom. My model also provides students an opportunity to discuss any problems in the application of the material with the instructor in the classroom. As a result, although the student contact hours have been reduced significantly, the students are being challenged at a higher level of learning and, on an overall basis, are performing significantly better.

By incorporating new and emerging technologies in my teaching, these changes have fostered critical thinking among the students and inspired them to apply the techniques learned in the course to real-life problems. The results presented clearly demonstrate the benefits achieved by implementing the various techniques described. Although these techniques were applied in teaching the Engineering Economics course, most of them can easily be adapted to other courses in Industrial Engineering in particular, and the engineering discipline in general. These techniques are so simple that they have a potential for widespread adoption, especially since most academic institutions today already have an e-learning platform available. All it will require is the desire to make the change and a time commitment by the faculty member.

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