AC 2008-267: DOES CLASS SIZE MATTER? REFLECTIONS ON TEACHING ENGINEERING ECONOMY TO SMALL AND LARGE CLASSES

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Abstract

Having recently transitioned from a small, private university to a large, public university, I was immediately faced with 172 students in my engineering economy course. The course is required by nearly all engineering majors, with variants taught in industrial, chemical, civil, and environmental engineering departments. The student count was in stark contrast to my previous average of 48 students per year, varying from 12 to 73 students. While many control variables were held constant (same lecturer, same textbook, same assignments), some varied (different student population, different lecture schedule, different number and length of exams). We report on differences in the courses, including the quantitative performance of students and qualitative differences in delivery as observed by the instructor.

Introduction

As noted by Felder[3], Dr. Phillip Wankat, a noted writer of teaching in engineering, said “that anything you can do in a large class you can do better in a small one.” Having experienced both sides of this situation, I would have to agree.

In my first semester at a large, public institution, I taught engineering economy. This course is required by all engineering majors and the Department of Industrial and Systems Engineering teaches a version taken routinely by industrial, mechanical, electrical, computer, and computer science engineers. The class was populated with 172 engineers, split evenly between juniors and seniors. Having recently moved from a small private university with enrollments generally near 40 per class, this was quite a shock!

Teaching large classes is not new, but it was to me. As a graduate student, also at a large public institution, I had the pleasure of teaching engineering economy to roughly 70 industrial and systems engineering majors numerous times. This number seemed to pale in comparison to my assigned 172 for the Fall of 2007 semester.

As a researcher, I sought the literature to help in this endeavor. There are a number of resources available at various institutions to help deal with large classes. For example, a simple search on the Web located resources at a number of universities, often through a Center for Teaching. One example of this is Ives[2], which includes practical steps on dealing with large classes, including educator testimonials. The educational research literature also provides this type of information, as in Felder[3]. Lewis[9] provides a detailed bibliography of the literature on teaching large classes.

In this paper, I highlight the “tips” that I found most useful and how they were implemented. Many of these are general in nature. I also highlight which concerns noted in the literature that did not seem to be relevant in my case. This discussion is followed by situations I believed to be specifically germane to engineering economy.

Large Class Size Issues Regardless of Material Taught

Following the advice of Ives[2], Felder[3], Felder et al.[4], Lewis[10], and Wankat[13], among others, I tried a variety of tactics in order to be efficient with my large class, as well as trying to promote a learning environment. From that information, I found the following to be most useful when teaching the large class:

- *Detailed syllabus*: The entire course was laid out on the syllabus, including daily lectures, dates of exams, and project due dates. This is clearly the benefit of having taught the course numerous times. It helped alleviate problems with absences before they were to occur (i.e., student travel for job interviews).
- *Homework*: Homework was assigned weekly. From this set of problems, a subset was collected and a further subset (often only one problem) was graded (and the others were merely checked to see if attempted, for credit). The students were told the subset for collection, but not which were to be graded. This kept them honest, motivated them to do the homework, provided some reward, and greatly reduced the grading load. Solutions to all assigned problems were posted on the due date, eliminating the acceptability of late homework.
- *Returning homework*: After returning the first homework in a pile, I realized that this would not work, as only one third of the class saw it. So, I made 10 folders labeled with letters of the alphabet (A-D, E-H, etc.) and placed material according to the last name. The folders made it around the room much more quickly than before. Quizzes were returned this way, as were exams, with the final grade on the back so it could not be seen.
- *Posting notes*: "Incomplete" notes were posted on the Web for all lectures. Students merely had to fill in the blanks (solutions to examples, completion of derivations, etc.). This promoted attendance (as I would not release completed notes) and allowed me to get through all of the required material.
- *Additional exams*: To ease the stress on students (more grading opportunities) and break up lectures, four exams were given during the semester with a final, as opposed to only two exams when taught previously.
- *Short quizzes*: A number of short, multiple-choice quizzes were given in class to break up lectures and keep the students focused. The quizzes were relatively easy *if* the students paid attention in class. Half of the quizzes were announced while the others were not.
- *Preventing cheating*: Up to three graduate students generally helped me "patrol" the exams. Hats and cellphones were forbidden. I was fairly sure that cheating did not occur as I routinely handed out eight versions of each exam. The problems differed according to wording and data.
- *Exam grading*: I fortunately had two teaching assistants (TAs). Each of us would grade one problem and I also graded the short answer problems. I reviewed all TA-graded problems as they tended to grade harsher as they had trouble assigning partial credit. I graded the final exam myself as it followed an open-ended format (see _______[7]).

There were a few issues from the literature that were to not be terribly important in my case. That is, nothing changed from my previous policies with vastly smaller classes for the following:

- *Make-up policies*: Maybe it is because I provided all of the dates at the beginning of the semester, but I did not have too many make-up requests. (I did not have a formal policy.)

Over the course of the semester, I accepted a dozen late homeworks and gave five make-up exams. Quizzes were not eligible for make-up as a valid excuse merely removed the score from the average.

- *Required attendance*: I do not (and have never) require attendance. My philosophy is that students are adults and they are paying for their education. I was pleased that about 80% generally attended, with the exception of the day before Thanksgiving.
- *Class participation*: I routinely like to wander while I lecture and thus continuously paced across the front of class and up the aisles. This, I believe, helped keep their attention. Furthermore, I routinely asked for their input through questions and generally got good participation. Note that the examples used in class were different than the textbook and nearly all were derived from real investment problems in the media (see _______[6,8]). It is believed that the use of real problems helped motivate participation.
- *Student names*: I wanted to learn the students' names, so I had them make placards on the first day. Roughly 70% "lost" the tag before the next lecture. They did not seem to care that I knew very few names.

Again, these issues may be critical in other large classes, but they did not seem to impact the delivery of this class.

Large Class Size Issues Central to Engineering Economics

This section highlights issues concerning large classes that were pertinent to teaching engineering economy, as opposed to any large class. I teach engineering economy in the context of decision-making: a problem or opportunity is identified, possible solutions are developed, costs are estimated, the solutions are analyzed under risk and uncertainty, leading to a final decision where the investment is tracked after implementation (_______[5]). Given my tendencies, I found the following topics of concern, but as engineering economy can clearly be taught in a number of ways, this may not be true for all educators.

Incorporating Active Learning into Classes

A significant amount of the teaching literature is concerned with infusing active learning ideas into large classes (see, for example, Benjamin[1]), as these techniques are shown to produce results with respect to student learning. Previously, I would have the class perform a number of different tasks that would promote these ideas while also breaking up the monotony of lectures. For example, when teaching the concepts of problem definition and solution generation, the class would be broken into groups and each would be presented with an investment opportunity. As opposed to lecturing on the Delphi Method or nominal group technique for generating ideas, the groups would merely perform the steps and report on their results. Unfortunately, this type of activity is not conducive to large classes when space is limited (172 students were assigned to a room with 172 seats). That is, merely getting students into groups was a laborious task that took excessive time – valuable time during a 50-minute lecture.

Given this administrative issue, group tasks during lectures were abandoned. While this may not be considered a loss in a traditional engineering economy course that does not focus on decision-making, it was considered a loss in this context as the group dynamics of decision-making are hard to capture in a lecture format. It was hoped that this loss would be minimized through group-assigned project work (outside of the classroom).

With this loss of group activities in lecture, short multiple choice quizzes (as noted earlier) were used intermittently to break up lectures and see if students were following the material. In hindsight, other techniques (as in Ives[2]) such as having students write down a lingering question at the end of class and submitting it upon exit or working out a problem in the middle of class with a neighbor might have been viable. These will be examined in future course offerings.

Using Projects and Open-Ended Exams

Teaching engineering economy in a decision-making context lends itself to the study of a number of real, open-ended problems. To this end, I assign four projects (the first is minor compared to the other three) throughout the semester:

1. Find and evaluate two loans (from a newspaper or the Web) for the car of your choice and illustrate which is better. (Performed with two randomly selected partners.)
2. Develop an automated spreadsheet that takes user inputs about a project (investment, horizon, interest rate, depreciation method, etc.), calculates various measures of worth and generates graphical analyses to aid in the decision-making process. (Teams of up to five students, self-selected.)
3. Complete an assigned case study motivated by a real investment described in the media. (Teams of up to five students chosen by the instructor according to semester grade distributions with each team having a different case assigned by the instructor.)
4. Complete a replacement analysis study of your personal automobile. (Performed alone.)

Note that in each of the above projects, the teams are working on slightly different problem sets. This prevents "help" from group to group. Also, the groups were assigned differently for each project. Additionally, as reported in _______[7], I assign a final exam that is similar to the third project, but completed alone within the allowable time of 2.5 hours.

As the projects and final exam were open-ended (no specifics were given with regards to required output and the inputs were often highly uncertain and had to be estimated), I graded them myself – as it is often difficult for a graduate student (and even a professor!) to properly assign credit in these cases. It is estimated that the group projects took on the order of 15-20 minutes to grade (each) for a total of about 12 hours while a similar (total) amount of time was taken on the individual project and the final exam (roughly 5 minutes each).

This may seem like a short amount of time to grade the final project and exam, but one must realize that these are open-ended problems and one can quickly determine the "path" of analysis. Specifically, an investment option is provided with some data – enough to construct an initial cash flow diagram with information about what portion of the data is uncertain. From here, the student should conduct (at a minimum) a sensitivity analysis to identify the risk. From there, the risk can be investigated (through a variety of methods, including breakeven analysis, scenario analysis, probabilistic analysis, etc.) and a decision can be made. Although time is limited on the final, a good write-up that clearly spells out assumptions and a discussion about important non-economic impacts is appreciated. Due to the time limits and lack of a computer to aid in computation, I did not "worry" about calculation details such as whether the proper project length was inserted into the present worth calculation. These details were tested throughout the semester in quizzes and exams. The objective of the exam was to "assess a student's ability to make an economic decision" with real information (_______[7]).

Note that many instructors may shy away from assigning projects due to the grading burden (roughly 60 "evening" hours were lost to grading during the semester). However, a study of large classes at the University of Texas-Austin by Lewis[10] concluded that "students enjoy large classes more if they are tested at higher cognitive levels as in essay tests." While the students were tested in "routine" fashions with multiple choice quizzes and computational questions on the four exams, the final exam and projects allowed for testing at these higher cognitive levels.

In this setting, the students did not suffer the loss of a learning opportunity because (much personal) time was sacrificed to grade the assignments rather than eliminate them altogether. It is truly believed that if the projects had been abandoned due to the grading burden, then the students would have suffered by not having an opportunity to apply skills learned in class to real-world investment examples.

While the projects were completed in this class, it should be noted that the increased class size may have impacted student learning through two other means: (1) Grading may not have been as detailed due to the increased workload; and (2) Group sizes in the larger class were bigger for two of the projects. This was also designed to decrease the grading load. A larger group does not necessarily mean diminished learning opportunities, but it is conceivable that the students would spread the workload over the larger group, thus placing less responsibility on each individual student.

Covering Advanced Material in Risk Analysis

Teaching engineering economy in a decision-making context requires that one goes well beyond the concepts of cash flows, discounted cash flow analysis and measures of worth. Significant time must be spent on estimation, risk analysis (sensitivity analysis, breakeven analysis, project balance, scenario analysis, simulation analysis, etc.) and dealing with other complications, such as taxes, multiple options and dynamic options over time. These topics are not always covered in engineering economy courses, as evidenced by the recent publication of textbooks that only cover "essentials" or "fundamentals" (see, for example, Newnan et al.[11] or Park[12]).

As a method of comparison, the final exam solutions from the Spring 2007 small class offering (34 final exams) were compared to the latest, large class offering (149 final exams). Specifically, the desire was to compare the methods used to identify and evaluate the risk of the proposed investment opportunity. We previously reported (_______[7]) that the use of sensitivity analysis and other tools used in risk analysis were on the rise when compared to previous years in this final exam format.

Table 1 presents the findings from these two exams. The table shows that a higher proportion of students utilized sensitivity, payback period, and project balance analysis in the smaller class. However, the long term average (previous six semesters of smaller classes) shows that the average number of students using sensitivity analysis is 40.2%, which is similar to the large class average.

Table 1. Summary of analyses utilized by students on the final exam.

Analysis	S2007 (34)		F2007 (149)	
Sensitivity Analysis	26	76%	62	42%
Non-Economic Discussion	26	76%	99	66%
After-Tax Cash Flow Analysis	11	32%	40	27%
Payback Period Analysis	27	79%	92	62%
Project Balance Analysis	21	62%	30	20%
Scenario Analysis	2	6%	15	10%
Breakeven Analysis	4	12%	14	9%
Benefit-Cost Analysis	0	0%	0	0%
Expected Value Analysis	2	6%	0	0%
Decision Tree Analysis	0	0%	1	1%
Economic Life	0	0%	0	0%
Variance Analysis	2	6%	0	0%

Note that this is not a completely fair comparison. The spring exam was taken over a three hour time period while the fall's lasted only 2.5 hours. Furthermore, students could use Excel software in the spring offering. This could not be accommodated in the large class. The exams were different too, as the spring offering dealt with the development of an aircraft while the fall's topic was the expansion of a mine. Further, note that this is merely a comparison of the number of students attempting an analysis – it does not make any distinction between a "good" or "bad" analysis.

As an instructor, it was disappointing to see that less than half of the students employed sensitivity analysis in the latest semester. However, it was encouraging to see that more than half employed some measure of risk, although payback period is a rudimentary calculation. We can only speculate, but the time constraint and lack of a computer for use during the exam may have had drastic implications in these results. Also, as noted in the previous section, the increased size of groups for project work and decrease in grading input may have contributed to diminished learning and performance.

Conclusions

We have reported on different experiences when teaching engineering economy with small and large class sizes. Many techniques readily available in the literature for teaching large classes effectively, regardless of discipline, are pertinent – especially with regards to administrative tasks as seemingly trivial as returning homework and exams.

Additionally, we reported on a number of issues that appear strictly pertinent to teaching engineering economy. For example, we found it difficult to incorporate "non-lecture" activities into class, even though some of these may be suited for engineering economy. However, engineering economy problems related to the use of interest factors (straightforward computations) were utilized in short multiple-choice quizzes to break up lectures, retain students' attention, and provide easy to grade assignments.

We were able to utilize our previous project assignments in order to provide active learning experiences outside of the classroom, although with larger project groups. The burden in the large class is with grading, especially open-ended case-study type problems, as it is not easily allocated to TAs. It was estimated that a total of 60 hours was allocated to grading the four projects and open-ended final exam. It is not clear how this load can be alleviated while still retaining the essence of the assignments and final.

Most of this paper describes the instructor experience. However, a rudimentary analysis compared the methods utilized in similar final exams between previously taught (smaller) classes to those in this larger class. The goal was to ascertain whether there was a difference in the use of advanced methods, generally associated with risk analysis. The analysis showed that students from the smaller class utilized advanced risk analysis methods more readily when attacking an open-ended final exam when compared to the student solutions from a large class. However, the long-term average of smaller classes was similar to the large class. Clearly, more data is needed to verify this finding, but it does appear that students in large classes can learn to deal with complex problems and use advanced techniques similarly to small classes.

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