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Course Strategy: A Little Bit of Everything is Probably Too Much

Dr. Karen M. Bursic, University of Pittsburgh

Associate Professor and Undergraduate Program Director for Industrial Engineering at the University of Pittsburgh. She received her B.S., M.S., and Ph.D. degrees in Industrial Engineering from the University of Pittsburgh. Prior to joining the department she worked as a Senior Consultant for Ernst and Young and as an Industrial Engineer for General Motors Corporation. She teaches undergraduate courses in engineering economics, engineering management, and probability and statistics in Industrial Engineering as well as engineering computing in the freshman engineering program. Dr. Bursic's recent research has focused on improving Engineering Education and she has 20 years' experience and over 20 publications in this area. She has also done research and published work in the areas of Engineering and Project Management. She is a senior member of the Institute of Industrial Engineers and the American Society for Engineering Education (where she has served as the Chair of the Engineering Economy Division) and a registered Professional Engineer in the state of Pennsylvania.

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Instructional Environment

The course described in this paper is offered by an Industrial Engineering department at a large public university. It is required for all Industrial (IE) as well as Civil Engineering (CE) students and is generally taken in the sophomore year, though not always. It is also taken as an elective by the other engineering disciplines in the school in either the sophomore, junior, or senior year. Three sections are offered per academic year and each has between 50 and 80 students enrolled. The author of this paper is the primary instructor for this course and will be referred to as "the author" throughout this paper.

Delivery Method

Pre-COVID, the course was delivered in a traditional manner in a computer equipped classroom. During COVID most students attended via Zoom meetings that were recorded. The class meets for two 1 hour and 15 minute sessions per week. A Learning Management System (LMS) is used (Blackboard up until fall 2020 when the University switched to Canvas) to provide lecture notes, assignments, track grades, and so forth. Pre-COVID the LMS was not used to deliver course content and no online teaching had been done except in the rare instances that the instructor was unable to be present and a video lecture might have been given. During COVID class recordings were posted to the Canvas page although synchronous attendance to the live presentations was expected. Thus, the course is a traditionally delivered course, not an online course and the expectation is that it will return to that format in fall 2021.

Approach to Instruction and Technology

A variety of active learning pedagogies have been experimented with in the course over the years. The instructor gives short lectures with "clicker" (student response system) participation questions throughout to keep students engaged. We are currently using Top Hat as our student response system. Lectures are broken up with in-class group problems or mini case studies so students practice with real world style questions (that go beyond the typical back of the chapter problems). Weekly quizzes are given via Top Hat (with immediate feedback) so students can assess their understanding. Students can view course announcements, assignments and due dates (as well as submit those assignments), download lecture notes, track their grades, and so forth via the LMS. In one recent semester, the author also incorporated the book publisher's online resources in order to include online algorithmic problems in the assignments. This added a third "system" that students needed to have an account with and use during the course. More recently, the author has incorporated Gradescope to submit and grade the midterm and final exams (a fourth "system"). The Canvas site has direct links to both Top Hat and Gradescope.

Students are taught 3 methods for solving problems – hand/formula calculations, hand/table calculations, and using the Excel functions. Because the course is taught in a computer equipped classroom and many students bring their own laptops to class, the instructor is able to easily incorporate Excel spreadsheet usage into the course. More advanced problem solving is done on

Excel. Students are told that they must be able to solve basic equivalency problems by hand using given formulas, this is what is typically expected on the quizzes and the midterm exam. No formula memorization is ever required. Tables are presented as simply a "shortcut" to doing the number crunching (i.e. "the number found under (F/P, 5%, 7) is simply $(1 + .05)^7$ …these just save you from doing the computations yourself"). Excel is presented as "how you'd actually do this in the real world." Thus Excel problem solving has been heavily incorporated into the course and is now included on the final exam.

Topics Covered

This is an introductory level course and covers the most commonly covered topics in this type of course, including:

- Making Economic Decisions (Present Economy Studies)
- Basics of Accounting
- Cost Estimating
- The Time Value of Money and Equivalency
- Evaluating & Comparing Projects using Equivalent Worth
- Evaluating & Comparing Projects using Rate of Return
- Benefit Cost Ratio Method & Analysis of Public Projects
- Dealing with Uncertainty (Breakeven, Sensitivity Analysis)
- Depreciation & Income Taxes
- Replacement Analysis

Assessment

Assessment is done via weekly assignments and in-class group problems (20% of the course grade), weekly quizzes (15%) and two exams, a midterm (30%) and a final (35%).

Pre-COVID, the midterm exam was paper and pencil only with formulas and the discrete compounding tables provided. About 70% of the final exam was also paper and pencil while the remaining 30% consisted of two cash flow analyses (one before-tax, one after) done using Excel. Since COVID, the exams are given remotely and are open book and notes. For the midterm exam, students can choose to solve problems using formulas, tables, or Excel but must show their work when submitting answers to questions. Students complete the Final entirely in Excel and an Excel file is submitted to the LMS.

The quizzes are given live in the classroom via Top Hat and are typically open book and notes. This format allows for immediate feedback to students.

Weekly assignments consist of problems solved either by hand with formula or tables or completed in Excel. In-class group problems are also included as part of the assignments grade, some are done with formulas/tables and some using Excel. During the fall 2019 semester only, the homework assignments also included algorithmic problems provided by the book publisher with their electronic resources and students submitted these online to be automatically graded. About 1/3 of the problems were assigned and graded in this manner.

Rationale for the approach

The course has always been taught with the goal of providing students with practical applications (as opposed to a theoretical background) of economic analysis concepts and enabling them to answer business and management driven questions regarding their engineering projects. That is, which alternative is the least costly? Which alternative is the most profitable? Does the investment have a high ROI? …and so forth. Given the bulk of the students that take this course are hoping for jobs in industry upon graduation, a more practical non-theoretical approach with plenty of focus on "real world" problem solving is imperative. The introduction to problems and case studies that are more comprehensive than the typical back of the chapter problems reinforces this focus. Since IEs generally do not take the FE exam, FE style questions are not emphasized although the types of problems students might encounter on the exam are briefly discussed for the benefit of the CE students. The textbook used also has FE style practice questions for students to review if desired.

This is not to say that teaching the theory behind concepts such as equivalency or return on investment is not essential or done in the course. Engineers must be taught to go beyond the "calculations" and they must be able to draw conclusions that help business owners make good economic decisions. This requires that they can answer such questions as, "What does that IRR mean to my business?" We place a strong emphasis on drawing conclusions and making a decision…not just providing a number for NPV or IRR or a B/C ratio. This is what engineers do…solve problems and make decisions… so a solid understanding of what the results mean is critical.

In addition, our students need to understand that decisions cannot always be made based purely on least cost or highest profit, so an emphasis on considering additional criteria that may not immediately seem quantifiable is also very important. What about quality and reliability in a make vs. buy decision for example? How about the impacts of an engineering project on the environment? Is my solution sustainable? Is a proposed solution to a public project the most equitable way to use public funds? Is the least costly design also the safest design? Questions like these and so many more should be considered. Remember, ABET accreditation Criterion 3 regarding student outcomes include outcomes 2 ("an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors") and 4 ("an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts"). These are also strongly emphasized in this course.

With respect to technology and modern teaching pedagogies, success in undergraduate teaching requires an understanding of what works and applying those methods in the classroom. Engineering education research has demonstrated that active learning (which is focused on increasing student engagement in the classroom) does, in fact, work. As a result, the author has implemented such pedagogies as Problem Based Learning (PBL), case studies, Model-Eliciting

Activities (MEAs), student response systems, cooperative and team based learning, and even the occasional "flipped" class.

In addition, not one of the students taking the course, when eventually faced with the need to complete an economic analysis, will sit down and do that by hand…they are going to use an electronic spreadsheet, most likely Excel. Thus while we must naturally teach fundamental knowledge and provide students an understanding of concepts such as equivalency and return on investment, we also need to teach the practical skill of using a spreadsheet.

The use of all these different pedagogies and technologies has led the author to ponder the question, "How much technology is too much?"

Lessons Learned

With over 25 years of experience in teaching, the author is able to draw a few basic conclusions and make some recommendations for teaching an introductory engineering economic analysis course and these are provided below. Note that since this paper is part of a panel session on course strategies, the author will provide further descriptions of pedagogies used in the course during that session. We will also discuss what works well and what can be improved in both pre-Covid and Covid modes.

1. It's much more effective to teach the *fundamental concepts well and with a degree of theoretical depth* rather than surface cover too many concepts in the course.
2. In the "real world" students will use spreadsheets for the bulk of the economic analyses that they do. So while a clear understanding of the mathematics behind an economic analysis is critical, *teaching spreadsheets is necessary* and a computer classroom aids in this. Thus in a traditionally delivered course, computers in the classroom are a must.
3. Teach students to never ignore the actual conclusion or decision from an economic analysis and always *draw that conclusion or make the decision in context*. Students will of course get the math and the calculation correct eventually but they must be able to state what conclusion should be drawn or decision should be made and do that by considering multiple criteria.
4. With respect to *technology,* the use of lectures, computers in the classroom for Excel, active learning, Top Hat, Blackboard/Canvas, algorithmic problems solving with the textbook, Gradescope, the occasional video lesson, case studies and more is too much! A simpler approach should be adopted. That approach can be at the preference of the instructor but with the goal of keeping the student engaged in the teaching/learning process and this cannot be done by pure lecture alone. Each instructor should choose their preferred LMS (typically determined at the college or university level) and then apply only those tools that are integrated with that platform. This way, students have a single location in which to sign on and access all course materials.