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# Course Strategy: Coupling Industry-centered Analyses and Engineering Design Principles to Develop Skills Relevant to Students' Careers

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# Course Strategy: Coupling Industry-centered Analyses and Engineering Design Principles to Develop Skills Relevant to Students' Careers

**Abstract**

Instructional Environment: The 300-level Engineering Economy course is offered by an Industrial Engineering department at a large, regional university. The course is a requirement for the Industrial, Electrical, Chemical, and Paper Engineering programs.

Delivery Method: The three credit-hour course is delivered in a traditional classroom format. Multiple sections are offered during the fall and spring semesters, with approximately 30 students per section. Instruction takes place during three one-hour sessions per week.

Approach to Instruction and Technology: The instruction underscores the role of financial analysis in industry. Traditional Engineering Economy topics are covered briefly during class, but the emphasis is on analysis and engineering design by way of using case studies and financial models constructed in Microsoft Excel and enhanced with a simulation software. TVM Skills are primarily developed through independent problem solving using a TVM calculator.

Topics Covered: Economic decision-making, accounting, cost estimation, interest and equivalence, PW/AW/ROR analysis, uncertainty, depreciation, taxes, replacement analysis, inflation.

Assessment: Exams and case studies comprise the major assessment elements. Rigorous, paper-based exams are used to assess a student's understanding of fundamental Engineering Economy skills. Case studies are assessed on the thoroughness of the analysis and on how well the methods and findings are communicated in a written report.

Rationale: The ultimate goal of this approach is to build skills that will be most useful to students in their careers. In practice, engineers need to perform analyses that combine many factors at both the strategic and operational levels of organizations, that incorporate elements of product and/or process design, and that consider various forms of risk and uncertainty. Analyses in industry will also likely involve after-tax cash-flows and debt capital more often than they will involve basic techniques such as simple payback or comparisons of equal cash flows. Therefore, it seems appropriate that the emphasis from the first day of class should be on performing analyses that are as sophisticated and complete as possible.

Lessons Learned: This approach demands that some traditional instruction practices such as the use of factor tables and formulas be abandoned so that class time can be spent discussing the case studies, which may require a leap outside of the instructor's comfort zone. This approach can also be challenging for students during the first few weeks of a course because they must absorb new concepts in addition to learning to use Excel in new ways and also learning to use a new type of calculator (the TVM calculator). However, it is our experience that this approach develops a high-level of competence and confidence in students, especially in the more fundamental aspects of Engineering Economy.

## Introduction

There are probably many engineering faculty who think of Engineering Economy mainly as a course that enhances students' marketability by equipping them to speak the language of business (i.e., money), that teaches the basic financial techniques needed to pass the FE Exam, and may touch on a few personal finance topics. It is probably not often thought of as an engineering design course where fundamental engineering skills are sharpened by performing sophisticated analyses. Certainly, an Engineering Economy course can be both of these things.

In this paper, we seek to illustrate to the Engineering Economy Education community a version of the course where the focus is on engineering design and analysis techniques that go beyond what is possible if too much emphasis is place on fundamentals for too long. Because the course strategy described here has been applied successfully in engineering curricula (and engineering technology curricula on a reduced scale), readers can have confidence that the approach works. The motivation behind the approach is a desire to treat Engineering Economy like a true engineering design course and to provide for students a truer picture of the complexity that financial analysis in industry will entail.

## Instructional Environment

The course offered through the Industrial Engineering department at a Western Michigan University and is a required course serving four of the university's programs. Table 1 provides an approximation of enrollments by major. As an upper division engineering course, enrollment is restricted to engineering majors, but the course can be taken by students still in their pre-engineering programs.

The course is typically offered in the fall and spring semesters and in an 8-week summer session. Multiple sections are offered during the fall and spring semesters, with approximately 30 students per section. Instruction takes place during three 1-hour sessions per week. The student population is comprised of primarily traditional students, so the course is generally scheduled during the day.

## Delivery Method

The course is delivered as a traditional lecture in a standard classroom (not a computer lab) and has the "feel" of a traditional engineering course. Many topics and techniques are introduced by hand using a white board (in contrast to topics and techniques being introduced using slides, course notebooks, etc.), although technology plays a critical role. Completed financial models using Excel software are frequently shown as the instruction transitions from introducing concepts to emphasizing the necessity of linking concepts together when analyzing more realistic problems and when performing design work.

## Approach to Instruction and Technology

Even though the whole of what is accomplished in an Engineering Economy classroom ought to be more than a summation of the various technologies and instructional approaches that can be applied to the subject, the approach to instruction and technology does drive much of the learning. Because the theme of the course is intended to be engineering design and industry-centered analysis, the approaches taken have been refined over time to best meet these goals. The basic instruction flow involves introducing engineering economy concepts using traditional (by hand) methods, then transitioning quickly to using technology to solve problems (calculator and computer), and then moving on to larger analyses using a computer. Of course, fundamental skills that ultimately enable a student to engage in the engineering design aspects of the class must be well-developed, so we will address instruction on the basic Engineering Economy topics first.

Introduction of textbook topics is primarily done by hand on a white board, which is a familiar method to most students. TVM factors are still prominent in the course text so they are used as a basis for introducing concepts, including the use of factor equations. Students are taught use factors and equations to solve problems (in a pretty rigorous manner), but the instruction quickly transitions to using technology to solve problems. Students are taught how to lay out problems on paper and then use a financial calculator rather than equations to solve for an answer (very quickly!). This highlights to students that the manipulation of mathematical expressions is not strictly necessary to solve problems, but that understanding the purpose behind the equations is. A dedicated financial calculator is demonstrated in class, but students are permitted to use graphing calculators (nearly all have TVM functions available) if they wish. Once the calculator methods are introduced, equations and factor tables are abandoned (although factor notation is still used).

The next phase of technology introduces computer spreadsheets (Microsoft Excel), which of course are neither new or novel in teaching Engineering Economy. However, instead of solving small problems that can just as easily be done by hand or a calculator, the emphasis is on using large problems with many analytical components and on incorporating risk and uncertainty using simulation. This portion of the instruction involves analyzing case studies where many fundamental curriculum elements (e.g., calculating a present value (PV), determining a simple breakeven point) must be combined in an analytical way. The instructional emphasis is not on how to use technology to address the fundamental aspects (e.g., using an Excel function to find a PV, linking cells to calculate a simple breakeven point), but on strategies for linking the elements together. For example, it is easy to calculate how much one should save on an annual basis in order to accumulate $1,000,000 by the time one retires using an assumed rate of return. However, it is not easy to calculate (by hand) the percentage of one's salary to begin saving today in order to have "enough" for retirement when the rate of return and inflation rate vary from year to year, the rate of your salary growth is uncertain, your lifestyle in the future is uncertain, and how long you will want to work is uncertain. Technology should be used to answer such questions in higher education because technology would be used to answer such questions in real life!

It is important to pause here in order to link this retirement planning example directly to our underlying notion of coupling industry-centered analysis and engineering design in EE. The real concepts at work in the retirement situation are identifying a problem (saving for retirement) and the variables generally within my control (how much I save, the career I choose), understanding the unknowns and uncertainties of the problem (salary growth, inflation, future needs, how long I intend to work), creating boundaries for a problem (i.e., bounds on the unknowns), and then generating realistic alternatives in order to select an approach. This is the essence of engineering design, and using Excel and simulation to build an employ an analytical model to address the basic problem allows students to demonstrate their capacity for design. This approach to analysis and design can then be extended to any number of Engineering Economy topics (e.g., replacement analysis, IRR analysis, after-tax cash flow analysis) where models can be developed to explore complex questions. We prefer to use case studies where the worlds of engineering and finance are linked through design parameters and uncertainty (e.g., the design features of a product and their impact on sales and profit).

**Topics Covered**

There is comprehensive coverage of Engineering Economy topics in the course, which is enabled in-part by the use of technology and the rigorous treatment of concepts in the case studies and exams (see next section). There are also subtleties of the course flow that make it possible to cover many topics, such as introducing inflation early in the course in an early case study so it is already familiar to students when the inflation chapter finally rolls around.

A listing of topics covered in the course in order they are presented in class is shown in Table 1.

Table 1: Topic Coverage

| Week | Topic | Week | Topic |
|---|---|---|---|
| 1 | Ethics, Accounting | 8 | FW, B/C Ratio, PB, Breakeven |
| 2 | Estimation, TVM | 9 | Decision Trees, Depreciation |
| 3 | TVM | 10 | After-Tax Analysis |
| 4 | TVM | 11 | After-Tax Analysis |
| 5 | PW & AW Analysis | 12 | After-Tax Analysis |
| 6 | ROR & Incremental Analysis | 13 | Replacement Analysis |
| 7 | Comparing Alternatives Cont. . . | 14 | Inflation |

**Assessment**

Assessment in the course is primarily done through exams and the case studies (of which there are usually 5). Case study assessments involve the development and use of an analytical simulation model in Excel and communication of the analysis in a written report.

There are three exams (two mid-term and one final) in the course. Exams are comprehensive and are done exclusively by hand with no reference materials allowed. The use of a financial calculator is therefore necessary (for TVM calculations). Analyses that would normally be performed using Excel are done by hand and the calculator and are therefore scaled down to be able to be done in the time allotted. Performing analyses by hand is no trouble for students who understand how to build models in Excel, because they recognize many analyses involve arithmetic until the final number (NPV, IRR) must be calculated. The exams are very rigorous and demanding, so students must understand concepts well and be able to perform calculations efficiently.

**Rationale**

In the opinion of the authors, Engineering Economy is too often thought of as a non-engineering course, when in fact many or most students will go on to careers where economic concerns go hand-in-hand with their core engineering work. As students matriculate up the ranks into management or executive positions, their financial responsibilities to a firm may come to dominate their time. It would be a shame for any young engineering professional or executive manager with an engineering pedigree to think that the financial and engineering aspects of professional life are not directly linked. We acknowledge that this notion is probably discussed in many high-quality MBA programs (where many of our students hopefully find themselves), but we still feel that giving undergraduate engineering students the opportunity to perform analyses where financial and engineering aspects are clearly linked is invaluable.

Another aspect of our rationale is that the subject of economics is worthy of serious rigor in an engineering program. This approach could present problems for those teaching very large sections, online courses, or perhaps in lower division courses where a student's engineering skills are not as well-developed. However, in traditional classrooms made up of upper-division engineering students, students often appreciate not spending their time in courses where there is no clear technical component imbedded within the work.

**Lessons Learned**

As with any course where the subject at hand is given comprehensive and rigorous treatment, it takes time to refine the delivery. One of the authors has applied this strategy for teaching Engineering Economy for many years and firmly believes that engineering students appreciate being challenged by the in-depth analysis and engineering design components. Over time, the course has garnered a reputation for being very challenging, so students are aware of the challenge from the outset. Another author applied a "watered-down" version of the strategy to an Engineering Economy course that did not have a reputation for being challenging, and the sudden change was a little shocking for students. The takeaway from this is that it may be appropriate to migrate the course toward an emphasis on engineering design over a few semesters to lessen the possibility of a one-and-done situation.