Including Engineering Economics in the Engineer's Education

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***Abstract* – Engineers entering the workforce with some knowledge of business terminology and a working understanding of the time-value-of-money may be productive sooner than the inexperienced new graduate. The author has been involved in the establishment of specialized courses intended to prepare the undergraduate engineer to enter the business world. He has also structured course modules that add selected financial analysis tools, such as Engineering Economics methods, to existing courses. The keys to understanding Engineering Economics are the time-value-of-money and net-present value calculations, tools a new engineer should find worthwhile in both engineering and business situations. This paper is intended to assist those wishing to include financial analysis in the engineer's education by providing models of how this has been done.**

Index Terms – Business Concepts Engineering Economics, Net-Present-Value, Time-Value-of-Money

INTRODUCTION

This paper describes how certain business topics have been included in the education of graduating engineers at two universities. The business topics include financial terminology and analysis, engineering economics and related time-value-of-money concepts.

Graduating engineers usually have little knowledge of basic business terminology or of the time-value-of-money and how that knowledge can be used to evaluate engineering project alternatives through net-present-value calculations.

The current interest in sustainability and life cycle costing increases the need for students to understand the methods of environmental impact analysis that use net-present-value calculations.

Entrepreneurship, an area growing in importance for the economy and engineers, relies heavily on financing methods based on time-value-of-money calculations. Engineers bound for entrepreneurship need to be familiar with concepts like discounted-cash-flow and venture capital return-on-investment so including this material fits well in Entrepreneurship courses.

Some universities have filled this gap with business oriented courses. Universities now offer courses on Entrepreneurship while courses on Accounting and Economics have always been available in business schools or departments. Some schools of engineering and even some engineering departments are now integrating business content directly into their engineering curriculum and this paper describes how this has been done at two universities.

This paper also describes how a selection of business topics for undergraduate engineers was developed and how this list has evolved into a comprehensive group of financial topics that have been successfully included in a variety of courses. These courses range from specific courses on entrepreneurship and business to senior capstone design courses.

It is possible to teach the concept of the time-value-of-money as a distinct skill set. It is also possible to build a knowledge base that includes a spectrum of financial terminology and methods while developing a sense of what economic value and the time-value-of-money means. In the author's experience, a course that examines the financial affairs of a firm with classic balance sheet and income statement analysis and then transitions to "valuation" is an excellent method of introducing the student to time-value-of-money analysis. Students quickly see the value of being able to do interest-rate calculations for loan amortization and debt calculations for their own personal uses and they learn how to relate these skills to the business world.

Finally, this paper attempts to identify and organize the most basic list of business and financial concepts that the author believes graduating engineers should be acquainted with before they enter the workforce. Readers are encouraged to select concepts from these lists that may fit well into existing courses or to configure new courses that combine some of the listed topics.

SELECTING BUSINESS TOPICS

In the mid-1990's, the author, who had retired from full-time business involvement through the process of a business merger, was teaching a course on Entrepreneurship at Carnegie Mellon's Don Jones Center for Entrepreneurship. He was also participating on an advisory council for the

Dean of the School of Engineering, Dr. John Anderson, who is now the President of Illinois Institute of Technology.

Dean Anderson posed this question to the committee: What else should graduating engineers have studied? Dean Anderson had two advisory committees, one composed of fairly recent graduates and another, the author's committee, which was mostly comprised of engineering school alumni who had been out of the institution for much longer. In most cases this meant that the members or this committee had careers with some business responsibilities.

The committee explored ideas for both technical and non-technical subject matter that might be considered for inclusion into the already packed undergraduate course list. Recognizing that most of the members of the sub-committee doing this work had careers that spanned both engineering and business, it is perhaps not surprising that the final recommendation to the Dean was that all graduating engineers might be more productive as new engineers if they had the a basic understanding of basic business concepts.

The sub-committee assigned with making a recommendation suggested that existing courses could have business content added or a new course could be offered to attempt to include all or most of the topics the committee felt should be taught. The sub-committee called this proposed new course "Business for Engineers" and it developed a list of about fourteen topics for inclusion. In addition to financial topics, the final list included non-quantitative topics such as written and verbal presentation skill development, sales training and intellectual property concepts.

Dean Anderson suggested that the sub-committee make this course recommendation to the engineering school's course proposal review committee for their consideration. In due course, a comprehensive list of twelve business topics for inclusion in a new one-semester course was presented along with a recommendation that where possible, instructors with real world experience in the selected topic be recruited from industry to teach the "modules". The course committee approved the proposal and a new course was established in 1997, "Business for Engineers".

This new course of twelve modules included three "financial" titles, Financial Accounting, Cost Accounting and Valuation, along with others that relied heavily on the finance modules, such as Entrepreneurship. The course did not formally include Engineering Economics, which usually covers Present Value, Future Value and Net Present Value but it did introduce time-value-of-money concepts for dealing with topics such as discounted-cash-flow valuation methods.

Engineering Economics is one of the listed skills tested by the Fundamentals of Engineering exam and it is a key element of doing sustainability analysis, which takes life cycle costs and environmental costs into account. Most committee members thought that while the specific topic may well be an area that engineers should study, it would be better accomplished as part of engineering courses instead of including it in a business course.

After this new course was taught for a couple of semesters, one department, Mechanical Engineering decided to add financial content, including Engineering Economics, to both of two alternative courses intended for seniors. Since many of the students in the department had not taken the basic business course, the Department contacted the author and requested a concentrated financial module starting with the most basic business concepts of finance and finishing with engineering economics. This customization allowed the assembly of a sequence of class sessions that were termed Financial Accounting, Valuation and Engineering Economics, usually requiring about six hours of class time and involving two homework assignments.

The incorporation of this material into a required senior design course insured that every graduating engineer in a department has seen the material as an undergraduate. Attempting to fill these gaps in engineering education using only special elective courses means that some students will not see the material.

In 2009, the University of Pittsburgh initiated a new entrepreneurship course with a sustainability emphasis for its Industrial Engineering Department and the instructor of that course, Howard Kuhn, asked the author to lecture on financial matters. The available time allowed the inclusion of the time-value-of-money content in addition to the more basic financial accounting theory and this course is now in its second year.

COURSE CONTENT

One complication in assembling financial content for course use is that the range of knowledge of students varies widely. Both Carnegie Mellon and The University of Pittsburgh permit students from freshman year through graduate school to take the business course or entrepreneurship courses and since the courses are sometimes done in the evening, there have been students enrolled who have had years of work experience. At both schools, many students have working knowledge of the stock market, so valuation is not a new concept and essentially all of the students have some employment experience. Additionally, most have student loans, so they have an idea of what return-on-investment and loan amortization mean. Surprisingly few, however, know what gross margin is and very few students have heard of net-present-value analysis, so class sessions present topics familiar to some students and other sessions introduce very new concepts and techniques.

Finding a suitable textbook for such a diverse course is difficult. A related difficulty is that the economy is always evolving and students usually have some knowledge of what is happening, especially as it relates to the job market. It was decided that immediacy was an objective of outside readings so the Wall Street Journal was adopted as the required text for Business-for-Engineers. Rather than expecting students to read the entire Journal before each class, we assigned sections to be read for particular dates and then class discussions at the beginning of the next day's class focused

on those sections. We started with the printed Journal student subscriptions, which are available for one semester and even shorter periods, but the main course instructors have moved to using the On-line Journal [1] to simplify access. Students are interested in today's events and many have come to be regular Wall Street Journal readers long after taking the course.

The main assignment for the Business-for-Engineers course is a report on a student-selected public company. This report must include suitable financial analysis of the firm's financial statements and a defended argument for or against potential investors acquiring the company's common stock, an exercise that reinforces the financial accounting material presented in class.

The engineering school business course at Carnegie Mellon has now been presented for over 25 semesters (to about 1000 students in total) so there is a distilled standard set of topics included. However, the course material has continued to be refined and filtered and it is always influenced by current economic events. Recent additions include added emphasis on Sustainability. Below is a summary of each major financial topic (or "module") usually included along with the terminology covered in the class.

TEACHING ENTREPRENEURSHIP

Many universities now offer courses in entrepreneurship and these courses offer the opportunity to introduce students to many business concepts. This usually happens in the process of exposing the student to business plans, which normally include both projected financial statements and startup finance strategies. A course offered at Carnegie Mellon uses a text by Timmons [2] that introduces the reader to the time-value-of-money by describing the methods used by potential investors to project their expected return-on-investment.

The inclusion of financial statements in the course permits the easy inclusion of "valuation". This presents additional opportunities to cover the time-value-of-money through the description of discounted-cash-flow analysis.

While the students of these courses acquire some important financial analysis skills, they normally do not study net-present-value ideas and a fairly small percentage of the entire school of engineering take these courses.

The new entrepreneurship course offered at the University of Pittsburgh, as will be described in more detail below, adds "sustainability" to the course title and this shift in course emphasis to include this concept allows the introduction of life-cycle-calculations and net-present-value ideas. Obviously, the instructor presenting this extended material can relate the methods to the general engineering decision making process so entrepreneurship courses with this content are useful techniques of including engineering economics in an engineer's education.

FINANCIAL ACCOUNTING MODULE

This module covers Income Statements, Balance Sheets and the analysis of those documents and it is usually done in about 3 hours of class time. When done as part of an entrepreneurship course, more emphasis is placed on constructing projected statements and on analyzing small company statements but in every case, both large publicly help and small privately held company statements are reviewed. The homework requires the analysis of a small company's set of statements and the calculation of all of the required ratios or parameters.

Financial Terminology Covered

- Generally Accepted Accounting Principals
- Income Statements including:
  - Revenue
  - Expenses
  - Gross Profit and Gross Margin
  - Earnings
  - Operating Expenses
  - Earnings-per-share and Price-to-Earnings
  - Dividends and Yield
- Balance Sheets
  - Assets
  - Liabilities and Debt
  - Shareholder Equity and Net Worth
  - Share Types, Options and Full Dilution
  - Depreciation and Amortization
- Ratio Analysis
  - Comparisons over time
  - EBITDA
  - Debt-to-equity
  - Return-on-investment
  - All of the classic standard ratios with examples for public and private firms

The homework problems are easily adapted for exam use. The module has been done without a homework assignment but with added classroom examples. It was found that students performed better on exams when they had actually done some ratio calculations on their own for homework so this module currently supplies the class with a simplified set of financial statements for a small company and students are asked to perform a thorough set of ratio analysis calculations as a homework assignment.

The homework problems require the student to do several valuation calculations including market capitalization and net worth and when Valuation is included as a follow-on module, these homework financial statements become the basis for various value calculations to be done later.

VALUATION

The value of a company is first introduced in Financial Accounting with the concepts of Return-on-Investment, Market Capitalization and Net Worth but this more concentrated look at valuation introduces the important idea of the time-value-of-money and how this concept can be used to determine the Present Value of a potential investment, an idea that will be revisited in the Engineering Economics sessions.

As in the Financial Accounting Module, real-world examples of small company appraisals are distributed and analyzed along with some of the standard methods of public company market valuations including examples of how mergers and acquisitions are accomplished financially.

Valuation Techniques Explored

- Market capitalization and P:E
- Book Value and Net Worth
- Comparables
- Multiples of Sales
- Discounted-cash-flow
- Venture-capital-methods
- Liquidation

MANAGERIAL ACCOUNTING

The material presented in these sessions was selected to give the student a better understanding of the internal costs of a process or company. A term introduced in Financial Accounting, such as Cost-of-goods-sold, is easier to grasp and use if one knows how costs are actually accumulated.

Since the focus for the module is manufacturing of one type or another, students are exposed to several standard approaches such as process job costing and shop-order costing. This necessarily includes some material on the transferring of amounts from one account to another, which leads into at least a cursory explanation of standard double entry accounting, including debits and credits. Breakeven analysis has been added to this module so that students have been exposed to the topic. The material remains worthwhile, in the author's opinion but it is usually treated as unrelated to the time-value-of-money ideas included in other sessions unless time allows for the introduction of doing Breakeven Analysis by using Net-Present-Value methods. One or two class sessions are normally devoted to this topic and it is not usually included in the engineering economics modules added to other courses.

THE TIME VALUE OF MONEY

The core concepts of this topic, present value, future value and net present value, are useful in many applications. These concepts are also easy to make interesting in class since every student has real world loans or financial concerns that he or she will better understand after doing examples in class of loan amortization or investment interest accrual. It is also possible to assemble engineering alternative problems, such as building storage tanks from stainless steel or other materials that easily demonstrate how net present value calculations can facilitate the best choices for product design.

This module also allows the assignment of simple but complete homework problems, some of which can be engineering related while others are finance problems. A single class session coupled with a later problem review session has shown to bring most students up to a functional level of understanding. Problems from this module and the other financial modules also lend themselves to mid-term and final exams.

ENGINEERING ECONOMICS

This module is an extension of the time-value-of-money session and it can be done as an integral part of module or later. This module can also be done independently and as a stand-alone topic, but that approach misses the opportunity to demonstrate how the time-value-of-money concepts apply to numerous business situations. Students completing this module will be well prepared to take the Fundamentals of Engineering exam [3] engineering economics section if they are so inclined.

The main focus of this module is on net-present-value (NPV) and the methods of considering all of the financial benefits and costs of any project including decommissioning costs and salvage costs from a present value point of view. When used for engineering project alternative selections, this raises the question of the ability of those doing the analysis to accurately estimate long-range benefits and costs, a worthwhile topic for the student to contemplate. Class work involves doing several NPV examples and the homework reinforces this learning while preparing a student to do new problems.

While no formal texts have been employed, there are numerous on-line references to NPV calculations [4] and students are encouraged to either purchase a business calculator with PV, FV and NPV functions [5] or to program those into a scientific calculator. In the author's opinion, NPV thinking is an important part of most engineering activity and every engineer should begin to think about technical work in these terms. Excellent example problems can be found in the Fundamentals of Engineering: FE Exam Preparation manual. [6]

This module was first developed for use in a senior design capstone course in the Department of Mechanical Engineering at Carnegie Mellon University. After several semesters of having the author present the concepts and techniques, the department fully integrated the material into the course by having the course main instructor present the topic. This is a model of how other institutions might begin with a financial module taught by others added to a course. Later the main instructor may absorb the topic into the course. This may also improve the presentations over time

by relating the ideas more directly to other material in the course.

Homework problems that describe the comparison of engineering design alternatives from a life-cycle perspective are easy to construct and simple for the student to grasp. Variations on these problems can be included in exams.

SUMMARY

In the author's view, including some of these concepts in courses for the undergraduate engineer works well in preparing the student to participate in the process of making business decisions. The author suggests including a combination of business terminology and time-value-of-money concepts. While this can be done in stand-alone elective courses, it can also be accomplished by adding the desired material to advanced engineering courses. Done that way, a department could ensure that every graduate has certain basic skills for making engineering decisions that take into account life cycle costs of selecting a design or manufacturing alternative.

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