Integrating Engineering Economic Analysis Across the Engineering Curriculum

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Abstract

A three-phased project is underway in the School of Engineering at the University of Pittsburgh that is aimed at integrating engineering economic analysis across the curriculum. In the first phase, an engineering economic analysis needs assessment was done. During the second phase of the project, the course content for the engineering economic analysis courses is being modified based on the needs assessment. The third phase will integrate the material into other courses in each of the school's engineering disciplines by developing and making available (via the web) an *Engineering Economic Analysis Template*. In this paper, we will report on the current results of this project and propose that a similar project can be extended to other engineering schools across the country.

Introduction

Engineering economic analysis is a core engineering competency that plays a vital role in decisions made by engineers. This body of knowledge is currently not well integrated into the engineering curriculum at many schools and is predominantly taught as a separate course in isolation from other courses in which the concepts can (and should) be applied.

In the School of Engineering at the University of Pittsburgh a three-phased project is underway that is aimed at integrating engineering economic analysis across the curriculum. This research does not propose to advance the body of knowledge in the field of engineering economic analysis, rather it proposes to advance the awareness of the topic in other engineering disciplines and to more carefully integrate the material into the engineering curriculum. In the first phase, an engineering economic analysis needs assessment in the eight engineering disciplines on the University's main campus (Oakland) and the engineering technology program at the Johnstown branch campus was done. The goals of this assessment were to identify the material in the current engineering economic analysis course content that was relevant to each discipline; identify any missing material in the current course content; identify courses in each discipline that would benefit from the integration of engineering economic analysis material; and identify example projects or decision situations in which a graduate of the discipline would be faced with an economic decision. During the second phase of the project, the course content for the engineering economic analysis courses is being modified based on the needs assessment. The third phase will integrate the material into other courses in each of the engineering disciplines by developing and making available (via the web) an *Engineering Economic Analysis Template*. The

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template will be a "how to" for engineering economic analysis that will allow a student to determine if a proposed engineering solution is economically attractive.

Goals and Rationale

Engineering economic analysis plays a vital role in nearly all decisions made by engineers. Ultimately the solutions to engineering problems must prove to be economically acceptable, (i.e., affordable), realizing positive benefits over the long-term. For example, no matter how attractive the design of a product is, if it cannot be produced and sold at a profit, then the design will not be practical. Despite this importance, engineering economic analysis is often overlooked by engineering students and novice engineers in the feasibility analysis of various project alternatives.

Because of this, students typically do not have the opportunity to apply the concepts learned in the classroom to a "real-world" engineering problem outside of the classroom. Although relevant "real-world" examples are used in class and new ones are frequently added, students are rarely faced with having to determine the economic feasibility of an actual engineering solution. Thus, the subject matter becomes isolated and is not automatically applied when a novice engineer attempts to solve an engineering problem. Students working on senior design projects do not always consider the need for an engineering economic analysis, despite the fact that often one clearly should be done. If the engineering economic analysis is considered, then the students may not know how to correctly carry it out.

Engineering economic analysis is a core engineering competency as demonstrated by its inclusion as one of the primary topics covered by the "Fundamentals in Engineering" Exam. This exam is a required element in the process of earning the Professional Engineering (PE) license. Furthermore, the current criteria of the Accreditation Board for Engineering and Technology (ABET, the national board that certifies engineering and engineering technology programs) require that engineering programs demonstrate that their graduates have the ability to "identify, formulate, and solve engineering problems" and "understand the impact of engineering solutions in a global and societal context." [1] The engineer must therefore consider the economic impact of proposed engineering solutions.

The integration of curriculum is a relatively new concept in engineering. Recently, there has been significant movement in engineering education towards integration of curriculum. In 1993, Bordogna, et. al. reviewed a number of studies and found a consistent theme suggesting that integration of curriculum was critical to improving undergraduate engineering education. They stated, "A common theme in the studies is that engineering is an integrative process and that curriculum innovation therefore should be toward this end." [2] In recent years, coalitions of engineering schools, sponsored by the National Science Foundation and including the University of Pittsburgh School of Engineering, have been introducing an integrative curriculum in the freshmen year. However, this has not yet extended to upperclassmen and subjects such as engineering economic analysis.

Engineering economic analysis is taught at both the Oakland and Johnstown campuses. IE 1040, Engineering Economic Analysis, (offered at the Oakland campus) is a required course for students

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pursuing a Bachelors degree in Industrial Engineering or Civil Engineering. It is also taken as a technical elective by many students from the other six engineering disciplines and thus is considered a "service course." Four sections of IE 1040 are offered each calendar year with enrollments of approximately 30 students in the Summer Term and anywhere from 40-70 students in the Fall and Spring Terms. A mixture of students from the various Engineering disciplines is enrolled in each section.

ET 1103, Engineering Economics, (offered at the Johnstown campus) is a required course for students pursuing a Bachelors degree in Engineering Technology for the Mechanical, Civil and Electrical disciplines. Three sections of ET 1103 are offered each calendar year with enrollments of approximately 30 students each.

These courses (IE 1040 and ET 1103) are for the most part taught in isolation of other courses in which the concepts can (and should) be applied (such as senior design "capstone" courses). The authors have made strides to more fully integrate engineering economic analysis into the Industrial Engineering curriculum in the senior design course. However, more can be done to integrate it further within the Industrial Engineering curriculum as well as within the other engineering disciplines.

Project Description

The project contains three major phases. In the **first phase** of the project, a complete survey in the eight engineering disciplines in Oakland (bio, computer, chemical, civil & environmental, electrical, industrial, mechanical, and material science) and the engineering technology program at Johnstown was performed. The main objectives were to:

1. Identify the material in the current engineering economic analysis course content that is relevant to each discipline.
2. Identify any missing material in the current course content.
3. Identify courses in each discipline that would benefit from the integration of engineering economic analysis material.
4. Identify example projects or decision situations in which a graduate of the discipline would be faced with an economic decision.

To facilitate the collection of this data, a structured interview guide was developed. This guide contained a summary of the entire project, and then discussed specific objectives for the first phase of the project. A series of questions were asked, broken down into six major categories:

1. Requirement – Is the engineering economic analysis course required?
2. Current coverage in your curriculum – Is there any engineering economic analysis material currently taught in any of your courses, and if so the details?
3. Relevance of the engineering economic analysis course – What material is relevant, what material should be added or subtracted?
4. Integration – Should the engineering economic analysis course material be integrated and if so, how?

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5. Template – Would you see value to building an *Engineering Economic Analysis Template*?
6. Miscellaneous – Other sources of data such as from alumni surveys, self-assessments and ABET assessments.

The results of these interviews showed that while most undergraduate coordinators felt that engineering economic analysis was an important topic for students, it is not necessarily covered in their particular curriculums unless a student takes IE 1040 or ET 1103. The exception was the Civil Engineering Department that includes economic analysis in several other courses such as Construction Management and requires IE 1040. Moreover, faculty outside of Industrial Engineering expressed somewhat of a discomfort with their knowledge of engineering economic analysis to be able to teach the material in their class and furthermore did not want to devote classroom time to covering the topic. They did state that if a resource could be built that they could direct their students to, they would be more likely to address the topic of engineering economic analysis. Two topics missing from the current course (on the Oakland campus) were mentioned: Replacement Analysis and the impact of social science issues such as environmental and safety. Most interviewees (but not all) agreed that the material should be integrated into the Senior Design Project course and that a template might be useful for their students. A number of interviewees suggested various projects on which their students have worked that might benefit from an economic analysis.

An unexpected outcome of the interview process was the increased visibility of IE 1040 as a technical elective. The Spring, 2003 enrollment for the one section of the course being offered jumped to 87 students!

In the **second phase** of the project the engineering economic analysis course content was modified based on the results of the survey completed in phase one. Its objectives were to:

1. Identify the respective disciplines of each of the students enrolled in the course.
2. Require students to identify current problems on which they are working (in a co-op, internship, research project, or in another class) to which they can apply the techniques of economic analysis.
3. Include the relevant material for those disciplines in the course content for that section of the class.
4. Include examples relevant to the respective disciplines.
5. Require that students apply the engineering economic analysis tools and techniques to an actual engineering project.

As a result of the interview process, Replacement Analysis has been added to the course content as of Fall 2002. The instructor has also attempted to begin identifying social science issues that may impact engineering decisions and the effect these may have on the economics of a decision.

An analysis of enrollments in IE 1040 over a 1½-year period showed the breakdown of disciplines enrolled in the class. Table 1 depicts these results.

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Discipline	% of students
Industrial	33.7%
Civil	29.4%
Electrical	11.1%
Computer	10.7%
Bio	2.8%
Chemical	2.4%
Material Science	1.2%
Mechanical	1.2%
Other	7.6%

Table 1. Enrollment in IE 1040 by Discipline

Each semester students complete a biographical form that includes identification of their specific major so that the instructor can determine the general make up of that particular section. This will allow the instructor to tailor examples specifically to particular disciplines. Some of this was done in the Fall of 2002. For example, in the section that was primarily Industrial Engineering students, more emphasis was placed on IE examples while in the evening section (that consisted of a broad array of disciplines) a variety of examples was used. More of this will be done in Spring 2003.

Beginning in Fall 2002, students completed a survey asking them to identify a project in which they were involved that benefited or could have benefited from an engineering economic analysis. The project might have come from an on-the-job experience (internship or co-op), a research project experience, or coursework. A number of interesting examples were identified. This survey will also be administered in Spring, 2003.

Beginning in Spring 2003, the IE 1040 course will require students to complete a project in the form of a case study. This project will comprise 15% of the final course grade. Teams of 2-3 students will select a real world problem that lends itself to engineering economic analysis and that can be written as an engineering economics case study. A requirement is that the situation or problem should be engineering and/or business related. The final write up will include a description of the situation and organization/business, the specific economic decision(s) involved, a description of available data, assumptions, a description of the economic analysis techniques that are applicable to the problem or situation and calculations associated with those techniques, and the final decision.

The **third phase** of the project (which is ongoing) will be to integrate the engineering economic analysis material into other courses in the various engineering and engineering technology disciplines. This phase will be the most extensive, lasting approximately six months. This will be done by developing and making available an *Engineering Economic Analysis Template*. The template could be made available to all engineering students via a course web page in Blackboard. Blackboard is a web-based application used at the University of Pittsburgh to provide online access to course materials and resources. The template will be somewhat of a "how to" for

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engineering economic analysis. Initially, the template will include a tutorial to guide a student on finding the discounted present worth for a project, computing a benefit/cost ratio, and basic cost estimation. It will be developed generically, so as not be discipline specific. Faculty requiring discipline specific content would need to supplement the template with their own material. The web page will also include both original and previously published case studies that will be indexed by engineering discipline. In addition, the web page will have a special section devoted to economic analysis for Senior Design Projects. References and Links will also be included. At the writing of this paper, the third phase is underway and there are minimal results. At the presentation, the project should be completed and the authors will be prepared to present the final results.

Summary and Conclusions

This project will impact a great number of engineering and engineering technology students at the University of Pittsburgh. Enrollment in IE 1040 (Oakland) includes approximately 150-200 students per year (and this enrollment number appears to be growing) and there are approximately 90 students per year enrolled in ET 1103 (Johnstown). In addition, students not enrolled in either IE 1040 or ET 1103 but enrolled in senior design and other courses will have the opportunity to gain engineering economic analysis skills through the use of the *Engineering Economic Analysis Template*. Thus all engineering disciplines will be impacted across the Oakland and Johnstown campuses.

An additional benefit of this project is that the proposed model that is developed for engineering economic analysis can be readily applied to other core engineering and science courses such as statics and dynamics, probability and statistics, thermodynamics, and circuits. This will allow for further integration of the School of Engineering curriculum.

Finally, results of this research can be easily extended to other engineering schools across the country. Similar benefits can be realized.

Acknowledgements

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