



Engineering Economics as a General Education Course to Expand Quantitative and Financial Literacy

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Abstract

This paper presents the case for why engineering economics should be a commonly accepted general education course. Currently, most engineering courses are not considered appropriate for the general education of a college or university student. In the past an engineering economics course focused primarily on financial mathematics; however, the modern engineering economics course centers on financial decision making in addition to financial mathematics. These topics are applicable, if not mandatory, for students pursuing interests in engineering, law, product development, public service, entrepreneurship, marketing, business, finance, political science, sociology, government, and ethics. This issue is timely because schools at various levels (e.g., K-12, community colleges, and universities) are including the concepts of quantitative and financial literacy into their required curricula, with some being required by state law.

Motivation and Introduction

There is enormous pressure on curricula at public universities from legislatures to reduce the number of credits for graduation, while increasing graduation and retention rates and maintaining a substantial level of general education (or similarly named programs, such as: core curriculum, foundation curriculum, etc.) for the graduate. A reduction in credit hours is particularly difficult for engineering due to ABET accreditation requirements and employer expectations for engineering competency. Typically, the general education of a baccalaureate graduate includes a number of credits in composition, humanities, social sciences, physical sciences, mathematics, and physical education. Engineering courses are not considered appropriate due to the advanced mathematics and science requirements for the courses. However, the argument of this paper is that the current topical coverage of an engineering economics course satisfies the requirements for social and/or behavioral sciences recognition because it provides necessary skills in quantitative and financial literacy with respect to decision making. This argument follows the patterns and urgencies for increasing K-12 standards in mathematics in support of a thriving future science, technology, engineering, and mathematics (STEM) workforce.

Other key arguments of note:

- Economic and social progress is an outcome of engineering change and application. It is estimated that 75-88% of all wealth creation is attributed to the application of technical and engineering change¹⁻³. This was originally shown by the Nobel Prize winning, macroeconomist, Dr. Robert Solow¹ and has been verified recently by others^{2,3}.
- Engineers apply and develop science and technology in designing products and systems. Via innovation, engineering design, research and development new technologies will become available to society over time. Understanding the economic characteristics of a technology and its costs is what distinguishes engineering economics from other branches of economics and finance.

- Engineering economics provides the foundation for making economic choices between competing technologies. Correct application of engineering economics principles to these choices will create new wealth for a society.
- Engineering economics can deal with the impact of new technology on environmental factors, public policy, and social sustainability.
- If students want to know the economic logic that has led to better ways of doing things, lower cost, and higher aggregate standards of living, it befits them to know the fundamental principles of engineering economics.

This paper also argues that including more engineering courses as general education courses could aid in the recruitment and retention of students who would not have considered engineering as incoming university freshmen. Thus, engineering economics as a general education course could aid in the recruitment and diversity of the engineering student body, and eventually the engineering workforce. This paper is organized as follows. It begins with an overview of the curriculum for social science and engineering education, followed by a literature review involving engineering related to these topics. Based on this foundation, it examines high school initiatives and future workforce initiatives. It concludes with student survey results from an undergraduate engineering economics course (with all students being engineering majors), and then summary remarks.

Curriculum Introduction

Social Science, as a General Education requirement, is described as⁴: “The goal of the social sciences is to help us understand the way that we live, especially the relation between the individual and the group, sometimes from an historical but often from a contemporary perspective. Vital to the continued health and success of our society is an understanding of the complex individual, political, and social dynamics that make up the modern world. Students should not only have knowledge of the principal concerns of the social sciences, but they should also understand the methods by which social scientists collect and evaluate knowledge.”

Engineering, as a discipline, seeks to find solutions that will benefit humanity and the society. The key curriculum attributes of the engineering economics course, as outlined in the following sections, are the application of the decision-making process to a variety of contemporary problems where technology and/or money are objectives or constraints. Consequently, based on these attributes, the course would be suitable for students interested in a wide range of fields including engineering, law, product development, marketing, business, finance, political science, sociology, government, and ethics.

Engineering Economics Curriculum

One goal of engineering economics is to teach students how to include the time value of money and the time value of technology within the decision making process. The course covers technology issues related to making decisions in today's society. A non-engineering student could be successful in this course and find value in its topics. The knowledge in the course is broad-based to a variety of non engineering disciplines, while it also meets the academic requirements of all engineering majors. For example, the financial mathematics topics are directly aligned with the Fundamentals of Engineering exam, which is necessary for engineers to become licensed within the state and nation. The point critical to broad application is that the

core topics of engineering economics can be presented in a way which does not require mathematics above the typical university level.

Note, depending on the engineering course objectives and topical coverage of the engineering economy course at a particular university, the current course could be modified to meet general education requirements and still maintain the current engineering course objectives. However, it may be the case that a different version of the course would be offered to satisfy the general education requirements of non-engineering students, and the current course be modified to satisfy the general education requirements and the engineering course objectives. This paper leaves that application to the specific program and individual reader.

The key is that the course provides an overview for analyzing decisions from the time value of money and time value of technology perspective for both individuals and organizations. Examples generally draw from a contemporary perspective rather than a historical perspective but touch on topics such as inflation in terms of consumer price indices, product price indices, and the federal minimum wage, which have historical significance.

The course covers a wide set of Social Sciences applications: Benefit/Cost ratios, Public Policy Projects, Taxes, Inflation, Bonds, Credit Reports, Investment Pyramid (Return versus Risk), and Ranking Methods. Each of these topics cover issues associated with making a decision. For example, within many public policy projects there are difficulties in quantifying the benefits and costs (which can be more subjective than quantitative), they often have long life horizons (e.g., parks, bridges, roads) which make it difficult to estimate usage, maintenance, etc., disagreements amongst stakeholders (e.g., "Not In My Backyard"), ethical issues (e.g., eminent domain), and financing issues (e.g., taxes versus bonds). After a discussion of the issues and assumptions, methods for collecting and evaluating the required data can be discussed in order to make an informed decision. For assignments and class discussions, students must make a definitive argument explaining the conclusion of the decision (both from the subjective and quantitative perspectives) using the decision making process outlined in class.

The examples covered by this course can include important contemporary issues; such as: a discussion as to why Kodak declared bankruptcy in January 2012, and why the United States Postal Service continues to raise the rates for first-class mail. The topics are not restricted to management, accounting, or economics. The overarching topic is decision-making within a broad-based context.

Engineering Entrepreneurship Curriculum

One of the traditional topics of engineering economics is the time value of money and this integrates well with one of the fundamental topics of entrepreneurship, the time value of technology. Understanding the fundamental concepts of engineering economics and then applying them to the technology innovation field is of great importance for graduates who pursue careers with start-up companies or technology development companies. Many engineering programs have created entrepreneurship curricula, and the implied knowledge of engineering economics is required in order to be successful within those curricula. Linking engineering economics with courses in engineering entrepreneurship is already occurring nationwide in

engineering programs. This is in addition to linking engineering economics (as a decision-making analysis course) to the engineering design process.

Flexibility of the Engineering Economics Curriculum

Course management systems and the corresponding course management styles of the professors have allowed the engineering economics course to be flexible in its delivery. It can be taught in large or small sections, synchronous or asynchronous, face to face or online (or hybrid), mixed methods, etc. The style differs greatly from one university to the next, but the content is overarching. There are a variety of textbook choices and innovations in the use of spreadsheets within the curriculum.

In summary, engineering economics contains critical topics that should be common not only to all undergraduate engineering majors within the USA, and is included on the Fundamentals of Engineering Exam, but also has broad application in many fields, can be delivered flexibly, and can be taught at various levels of math complexity. It is an area that has an opportunity to flourish as engineering programs and general education programs better understand the importance of decision making, entrepreneurship, and technology innovation within engineering economics.

Literature Review

Engineering education research has received continuous and growing support over the recent decades, and the engineering education literature indicates an improvement of engineering teaching and learning. A recent article⁵ summarizes the historical developments and presents goals for future research by specifically addressing these goals by developing “Strategies for Bridging Research and Practice.” Studies have been published that analyzed why students choose engineering and the primary conclusion was that students choose engineering based on their individual values⁶⁻⁸. Thus, there is a need to link student identities to engineering identities. A recent study has been conducted evaluating engineering students using identity theory⁹. There has also been a study focused on underrepresented students (i.e., females, minorities) with regards to their graduation rates, grade point averages, and changes in major across multiple universities¹⁰. There have also been studies on specific courses or content (e.g., engineering design)¹¹⁻¹².

Within the K-16 realm, there has been a push to increase the mathematical competency of students. Within the book, Mathematics and Democracy: The Case for Quantitative Literacy¹³, the findings and suggestions are aligned with National Academy of Engineering (NAE) recommendations¹⁴; that an individual will need to have a basic understanding of decision making to make competent financial decisions in order to survive in the 21st century society. Additional newspaper reports, nationally funded studies, and books have been published on the importance of quantitative literacy¹⁵⁻¹⁹. The proposed concept of having engineering economics taught as a social science general education course continues on the prior work in engineering education, with a focus being on engineering economics.

Recent Engineering Economics Education Literature

There are many recent and ongoing studies of engineering economics education within the published literature. A futuristic look at engineering economics education was completed by

Eschenbach²⁰ in 2002. He makes a number of observations about the future of the course given past trends. He also provides insight into topical coverage of the traditional versus modern textbooks. In 1999, there were two papers with suggestions and comments for undergraduate engineering economics education by Hartman²¹ and Eschenbach²², and a follow-up discussion²³ in 2005. These papers discuss the (perhaps unwanted) move towards financial mathematics from decision making analysis, and also discuss spreadsheets and online educational tools (e.g., CD and online material in addition to the textbook material). It should be noted that recent engineering economics textbooks, published in 2011, have reemphasized decision making analysis²⁴⁻²⁵. Basically, engineering design includes the evaluation of multiple alternatives (including their economic impact, etc.); thus, engineers need to be skilled decision-makers and evaluators and the evaluation of economic impact of those decisions is taught in engineering economics. Many recent (since 2000) articles have been published that provide either structure or experiences in teaching engineering economics at both the undergraduate and graduate levels²⁶⁻³⁰, and the inclusion of risk and uncertainty in engineering economics³¹⁻³².

Linking to High School Initiatives and Future Workforce

Introduction

The topics and content of engineering economics are closely related to a number of regional and national initiatives. This section links engineering economics to high school initiatives throughout the country and to the growing technical demand of the country's workforce.

High School Initiatives and Inadequacy of the Common Core

Many states are looking closely at the specific learning outcomes of high school courses and an engineering economics course in college general education integrates well with these efforts. For example, Virginia has a policy for all public high school students to pass a Financial Literacy course prior to high school graduation³³. The topical coverage of this course links directly to a college course in engineering economics due to an emphasis on decision making with the time value of money concept for individual decisions (e.g., obtaining a loan, developing a personal budget, implications of a simple contract). The engineering economics course advances these topics at the individual level and also incorporates an understanding of decision making at the organizational level. The need for such a course at the high school level is to ensure success in the future workplace, and also preparing students for success in college. Engineering is being touted as a field that is not producing enough graduates for the jobs that are currently available in the USA³⁴.

The National Council of Teachers of Mathematics (NCTM) has published a series of reform documents over the past 25 years³⁵⁻³⁸. New national standards for math instruction promote inquiry rather than memorizing and following procedures indicated by the teacher. More recently, NCTM published the Common Core Standards to provide consistent state standards. With these higher national, state, and local standards, increased pressure has been placed on students to increase their mathematical and science competencies. However, as suggested by a former Common Core Validation Committee member³⁹, the common core is not preparing students for STEM degrees, rather it is preparing the high school students for nonselective colleges and nonselective majors. *In other words, the Common Core does not prepare high school students to take calculus in the freshman year of college.*

The Engineer of 2020

The outputs of engineering programs over the next few years will make up a portion of the engineering workforce in 2020. The Engineer of 2020⁴⁰ includes members of the graduating class of 2020; *those students, assuming four years of high school and four years of college, entered their freshman year of high school in Fall 2012.* Many of these students will participate in AP courses and take AP exams while in high school. Furthermore, these engineers must be competitive in an increasingly dynamic and globally competitive technical environment and economy^{14, 41-42}. Basically, as engineering educators, one must prepare students to be modern and innovative without knowing what will be modern and innovative in the future.

The Demands of Industry

Technological development and industrial growth are increasing exponentially with expanding global applications, requiring a workforce that is adaptive to learning new technologies and developing innovations. A strong knowledge and understanding of STEM content and positive attitudes toward quantitative thinking are necessary to seek out opportunities in a constantly changing work environment⁴³⁻⁴⁴. In addition, the NAE publication, *Technically Speaking*¹⁴, emphasized the need for all people to obtain technological literacy to function in the modern world. Mathematical literacy has also been recognized for influencing students' education, professional, and life opportunities and their ability to engage in public policy debates that most often involve data-based arguments⁴⁵.

Conclusion

The topics and content of engineering economics are closely related to a number of regional and national initiatives. High school initiatives include financial literacy and personal finance; however, the common core is still not adequate for a high school graduate to go directly into an undergraduate engineering curriculum. The NAE has identified outcomes and traits of the future engineer and future workforce, these traits stress the need to understand engineering economic principles and their application to technology and society.

Survey Results of Engineering Students

Students are a critical stakeholder in this question of allowing engineering economics to be classified as a general education course in the social sciences (or behavioral sciences). We explored this by surveying 85 students (51 male, 30 female, and 4 unspecified) enrolled in an undergraduate engineering economics course, near the end of the semester at the Pennsylvania State University's University Park campus in the Fall 2013 semester [IRB approval on 2/8/2013; human subjects assurance number 42153]. The questions involving engineering economics as a general education course are provided in **Table 1**.

All of the students surveyed were either juniors or seniors in an engineering degree program, and all of the students had completed either microeconomics or macroeconomics at the undergraduate level (24 of the students had taken both microeconomics and macroeconomics).

Table 1: *Student Survey Questions for Engineering Economics Course.*

Relevant Survey Questions
1. Which of the following economics courses did you take or are you currently taking? - Microeconomics - Macroeconomics
2. If you took one or both of the courses listed in the prior question, which of the following courses do you feel was more valuable for you? (Circle Only One) - Economics Course(s) - Engineering Economics Course
3. Do you feel as though every student (non-engineering and engineering) should take a course like engineering economics? (Circle Only One) - Yes - No
4. Do you feel as though a course like engineering economics would be a good course to offer as a General Education course available to all students (as either social and/or behavioral science)? (Circle Only One) - Yes - No

The following bullets summarize the survey results:

- All 85 students indicated that the engineering economics course was “more valuable” than the microeconomics course and/or macroeconomics course.
- All 85 students indicated that the engineering economics course should be taken by both engineering and non-engineering students.
- The students also overwhelmingly indicated, 97.6% (83 of the 85), that engineering economics would be a useful general education course as a social science (or behavioral science) option.

It should be noted that the microeconomics course and macroeconomics course were included in this survey because they are allowable general education electives, and one (of the two) is required by Pennsylvania State University’s Industrial Engineering B.S. program. These courses are usually taken in the freshman or sophomore year. The second economics course can be taken to further achieve the general education requirements at the university of this particular engineering program.

Discussion and Conclusions

The concept of incorporating engineering economics as a general education course within an undergraduate education for all students (engineering and non-engineering) will contribute significantly to the understanding and interpretation of quantitative and financial literacy in general education. Preliminary research has shown that engineering students feel that engineering economics is more valuable than traditional economics courses and should be taken by both engineering and non-engineering students, and those same students overwhelmingly believe engineering economics should be included as a general education course. Further work would include surveying non-engineering students. It was also shown that this concept follows

the initiatives and thrusts for K-12 education in the USA to promote a thriving future STEM workforce.

The unique research component of this concept is to provide evidence of student learning and student success for engineering economics as a designated social science course to meet university general education requirements. This evidence will be used to produce published literature and reports that other engineering programs can use to request engineering economics as a general education course for their respective students and non-engineering students at their university.

Fundamentally, the concept will improve engineering education and add an additional pathway into engineering. The impact and significance of this project will provide evidence for universities across the USA to use engineering economics as a general education course to meet their social sciences education requirements. The engineering student will have the ability to take additional engineering content, engineering programs will have the flexibility to add more engineering content to their curricula (since a prior social science course can be eliminated), and most importantly this will open a pathway into engineering. The engineering economics course will become more diverse and multidisciplinary, with a possibility of encouraging non-engineering students to transfer into engineering, add an engineering minor, and/or pursue an engineering career. At minimum, the non-engineering student will get an overview of the engineering decision making process, financial mathematics, and engineering entrepreneurship while contributing to a more diverse engineering course. If engineering economics is to be implemented as a full scale general education course (and perhaps as a portion of course), then there is an opportunity for education materials (e.g., textbooks, online learning materials) that include more social and behavioral science initiatives and less financial mathematics.

Once successful, it is expected that additional engineering courses may be considered for general education courses; including topics and courses devoted to introductory engineering design, engineering entrepreneurship, and engineering ethics.

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