

Enriching the Engineering Economics Class

Prof. Robert P. Leland, Oral Roberts University

Robert Leland has taught engineering at Oral Roberts University since 2005. Prior to that he served on the faculty at the University of Alabama from 1990 - 2005. His interests are in control systems, engineering education and stochastic processes. He has participated in engineering education research through the NSF Foundation Coalition, NSF CCLI and NSF Department Level Reform programs.

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Abstract

This paper describes an effort to enrich the Engineering Economics course by adding readings, class discussion topics and a research paper. The goal is to help students understand the non-quantitative side of engineering economics. In particular, students are exposed to examples of using engineering or business techniques to benefit people in need, and to introduce notions of risk and the quality movement.

Introduction

The majority of Engineering Economics textbooks cover the numerical basis for estimating costs, evaluating and comparing projects based on cash flows and computing taxes. This reflects the material needed for the FE exam very directly. The focus is on quantitative analysis based on a fairly narrow set of objectives. The typical text is lacking in giving students perspective on the broader impact of engineering and economic activity or the value added by the engineering profession, economic or otherwise. Important topics such as risk and the quality movement are also typically not included. In addition, current engineering students have a strong interest in seeing how their professional activities can benefit society. This paper describes attempts to enrich the class through short reading assignments, in class topics and a research paper. The goal is to give students a broader education that includes both the quantitative material in the textbook and non-quantitative perspectives.

The need for change in the teaching of Engineering Economics is well documented. In 1998, Hartman¹ described the curriculum as stagnant and unchanging, failing to include advances in the field. A literature survey by Evans, Nachtman and Needy² describes a consensus for a need to update the course, and a variety of innovations in teaching methods. Less innovation in course content has occurred.

Merino³ surveyed industrial stakeholders and had them rate the importance of various topics for economic literacy for engineers. The top four were Cost Estimation, Risk Analysis, Basic Engineering Economics (before tax analysis) and Cost Accounting. Risk Analysis, which is not generally taught, ranked high on the list. Both macro and micro economics still had significant support to be kept as important topics.

Rogers and Sattler⁴ describe the need to include environmental sustainability in Engineering Economics, and have produced a module to do so. They indicate that optimization of an individual firm's or project's outcome may lead to negative results in the long run. They

specifically introduce a concept called Tragedy of the Commons, in which individual agents, maximizing their own outcomes, may deplete a shared resource, such as clean water or energy, that is needed by all to function productively. They also address externalities, in which the activities of a firm create costs not borne by the firm itself, as in medical costs due to air pollution.

This paper⁴ raises the significant point that engineering and business are practiced in a more complex and interconnected world than we typically address in engineering economics, with significant non-quantitative factors.

Some examples of the importance of these non-quantitative factors include:

- When Mercedes Benz opened its plant in Alabama, they were given substantial tax reductions. They were offered additional tax reductions which they turned down because those taxes were needed to pay for the education of their employees' children. This decision would not be supported by typical quantitative analysis.
- A continuous improvement process may or may not yield an acceptable rate of return, but a failure to have one may make a firm uncompetitive and lead to loss of market share and eventually bankruptcy.
- In evaluating projected cash flows against a Minimum Attractive Rate of Return (MARR), we bring up the issue of whether profitable plants should be closed if their rate of return is not sufficient. Closing the plant would put hundreds of people out of work, and decimate the local economy.
- A decision on whether to outsource a labor intensive activity to an overseas plant may need to account for qualitative factors such as local labor practices and how they might reflect on the company reputation, as occurred with Nike

These kinds of issues, that are quite real, require students to have an awareness of the bigger picture, and a well developed value system.

A number of approaches to improve the engineering economics course have been reported.

Hartman¹ advocated teaching the subject in the context of a full design process rather than in isolation, including non-numerical factors in decision making, and accounting for risk and uncertainty. Decisions on when to outsource could also be added. Hartman⁵ also describes testing practices for the objectives of a problem based learning approach to the subject.

Walter⁶ proposed a systems approach for a graduate level class teaching finance, economics, cost accounting and cost management for engineers. The topics in this course are aligned with earned

value management system (EVMS) guidelines and are directly related to the wide range of business decisions made by engineers.

Bursic⁷ describes an undergraduate course involving an extended research project in which teams of students solve realistic problems related to contemporary issues involving complex, open-ended problems. The projects involve course concepts, but are assigned before the concepts are taught to promote independent learning. The students performed well, but had difficulty relating qualitative factors such as good will (outsourcing jobs to China) or privacy (RFID) to quantitative analysis.

Brach, Zeytinci and Behera⁸ describe an approach using public policy decisions as a means to teach engineering economy. They specifically propose home mortgage policies related to the depression of 2008. Students would be asked to analyze these policies using the concepts of engineering economics.

Fragoso-Diaz, Gray and Jones⁹ describe the use of a case study involving a disaster simulation to teach decision trees and decision analysis. The goal was to close the theory-practice gap, and give students confidence in applying class concepts to real problems. Tong and Nachtman¹⁰ describe a case study analyzing disruptions on the Mississippi River and their economic impact. Students were asked to do linear regression analysis, assess ability to bring a lock and dam back online, and evaluate a potential investment in maintenance of locks and dams.

Enriching the Engineering Economics Class

In this paper we consider steps to enrich the Engineering Economics course by introducing additional content, not always directly related to traditional Engineering Economics topics. At Oral Roberts University, this is a two credit class, taught at the 400 level, and taken primarily by seniors at the same time as senior design. For their senior projects, students are required to estimate costs, and plan and track progress, so there are some connections. It has been very helpful to enrich the course through short assigned readings, in class topics and a research paper. The goal is to give students a broader perspective on economic activity and the business side of engineering. These assignments and lectures address the non-quantitative side of practicing engineering and business that is quite real, and can easily overshadow the quantitative variables treated in most textbooks.

Readings

The readings are taken from business and investing publications, Technology Review, and various web based venues. They are assigned and due the next lecture. Students must read a short article, and write a ½ - 1 page summary. All students turning in a reasonable paper receive full credit. The focus is on content and exposure, rather than on composition and in-depth analysis.

Some of the readings I have used include:

*Woman Who Couldn't Be Intimidated by Citigroup Wins \$31 Million*¹¹, A manager in Citigroup's Mortgage division becomes a whistleblower exposing improper mortgage practices at Citigroup. This reading reinforces the importance of integrity, and addresses a principal cause of the recession of 2008.

*Professor on quest for India's hidden Inventors*¹². Management professor Anil Gupta travels through rural India to find inventors and inventions. He may share the ideas with other villages, or bring the ideas to market, so the inventor gets credit and makes a profit. Gupta and his aides have found over 25,000 inventions. This article encourages creativity, thinking outside the box, and being intentional about making a difference.

*From Tax CEO to Math Teacher: A Class Move: Tom Bloch sees plenty of addition with his Charter School*¹³. Tom Bloch, CEO of H&R Bloch, gave it up to teach 8th grade algebra at an inner city school. He then used his business skills and connections to found a tuition free charter school in Kansas City. This article encourages students to invest themselves in something larger than their own professions.

*ABB brings power to the poor in eastern India*¹⁴. A related film is available. ABB implements a solar power facility to recharge batteries in a community located far from the power grid, providing both economic and social benefits to the community. Students see a concrete example of engineering benefiting a community through intentional action.

*Domino's Founder Tom Monaghan Keeps the Faith*¹⁵, This article describes a successful business run on faith derived values that support quality, respect and opportunity for employees.

*Tata Nano*¹⁶. The Tata Nano is an extreme example of design to cost, seeking to be competitive to motor bikes. Although its designers were very creative in reducing costs, in the end, the vehicle proved to be unsafe. This was a topic that changed since I started assigning it.

*The Miracle of Pittron Steel*¹⁷. Wayne Alderson becomes a VP at Pittron Steel amid a violent strike, \$6M annual losses, and extremely low morale. Through biblical values, respect for workers, and intentionally creating a positive environment for employees, he turns the business around to \$6M in annual profits, a tripled workforce, and a five-fold increase in sales. This reading underlines the relational practices that can make a large difference in outcomes.

In Class Topics

Several topics are covered in class, and in general will involve class discussions. The Cost of Mars and Ned and Larry's topics reinforce cost estimation/control and comparing alternatives. Other topics are not directly related to traditional Engineering Economy topics.

*Aliou Conteh: Building a mobile digital network in Congo*¹⁸. This article describes a single individual envisioning and financing a digital cell network in Congo during a civil war. This article addresses the issue of risk, and that risk and return are proportional. The article is discussed in class, focusing on the risks taken and rewards received, as well as the ups and downs along the way. The students also hear an NPR interview with Conteh¹⁹.

*Upwardly Mobile*²⁰. Addresses the positive economic impact of wireless communication in rural India through the promotion of microenterprise. The article and discussion focus on the benefits of technology when used intentionally. Some students choose to do a more involved research paper in this area.

*Banking on Change*²¹, (He made beggars open bank accounts) Indian bank manager J. S. Parthiban encourages the poor to open savings accounts, helping them get free from predatory lenders. He makes microenterprise loans, and the film shows those who have benefited. This video is very moving and shows how expertise and intentionality can make a difference. It is available on several websites.

Cost of Mars^{23,24,25}, Powerpoint presentation on the cost of travel to Mars, cost drivers, and approaches to reduce costs such as Mars For Less, and Mars One.

*Ned and Larry's Ice Cream*²², Case study of a 'fictitious' ice cream company making a decision on how to package its ice cream, taking into account the environmental impacts as a cost.

Quality Movement. An introduction to the basic principles of the quality movement and corresponding approaches to engineering design of new products, and improvement of existing products. Continuous improvement is emphasized. Students are introduced to Six Sigma, DMAIC, DMADV, lean manufacturing and Kanban. Some students have done internships at companies using these principles.

Research Papers

Students complete a 7-10 page research paper. They can choose from a set of allowable topics proposed by the instructor, or they can propose their own topics subject to instructor approval.

Some of the instructor proposed topics are:

- Value of the Person program, started by Wayne Alderson at Pittron Steel. Alderson made Pittron Steel profitable again by applying biblical principles of respect and care.
- The Grameen Bank. The Grameen bank makes micro-enterprise loans to start small businesses in the Third World.

- John Perkins, the Christian Community Development Association and Voice of Calvary. Perkins pioneered a form of Christian Community Development to bring economic and spiritual recovery and racial reconciliation in Mississippi.
- One Laptop Per Child. A project spearheaded by Nicholas Negraponte of MIT to put computing resources in the hands of children in developing countries. Also a good example of design to cost.
- Impact of wireless communication in developing countries.
- The economic impact of Global Warming and the Kyoto Accord.
- Six Sigma and the quality movement.
- Extended report on the book Bringing Life: Seven Years Building Afghanistan²⁶ by Joshua Atkinson, an engineer who worked in Afghanistan rebuilding the country after war.
- Economic viability, impact and factors in the Hyperloop. This includes Elon Musk's original white paper, as well as published analysis of the topic and current commercial firms involved. Potential impact on society.

Some of these topics are more engineering oriented than others, but all give important perspectives on the big picture of practicing engineering in a global economic environment.

Student Survey Results

Students completed an anonymous survey concerning which reading assignments they liked best and least, which in class topic they liked best, and the reasons behind their choices. They were also asked to indicate the topic for their research paper, and the most important thing they learned from it. The survey is included at the end of this paper. The survey was taken in Fall 2016 for the readings and topics used that semester, and completed by 19 students. The results are in Tables 1 - 2. In general, the students preferred the material that was more technical, or more aligned with engineering. In their explanations they also expressed a strong interest in actions that benefitted others.

Table 1: Best and Worst Readings

	Tata Nano	Woman not Intimidated	India Inventors	Pittron Steel	Tom Bloch	None
Most Favorite Reading	7	1	9	2		
Least Favorite Reading	7	4	3		3	2

The most liked reading was on the hidden inventors in India, which combines both technology and benefit to society. Student comments indicated a variety of reasons for this choice, such as combining outreach and innovation, helping inventors and getting nothing in return, demonstrating the level of hidden talent in India, and impacting a rural area. One student indicated they would like to do this.

The Tato Nano was the most liked and disliked reading, indicating it should definitely be kept. Students who liked this liked the design to cost, and making transportation affordable. This topic also had significant technical content.

Students who liked Pittron Steel indicated they liked seeing the positive consequences of practicing good values in the workplace. Two students chose this for the topic of their research paper, even though it had little technical content.

Students were asked which in-class topic they liked best. The Cost of Mars and Congolese Wireless Network were chosen by the most students. These were also the most technical subjects.

Table 2: Best In Class Topic

	Cost of Mars	Congolese Wireless Network	Ned and Larry's Ice Cream	Banking on Change: Beggars open accounts	Quality Movement
Best Class	7	6	2	2	2

Students who chose the Cost of Mars gave reasons such as: an interest in space related work, futuristic stuff, applicable to current space exploration. One student liked it because it was furthest from normal.

Students who chose the Congolese Wireless Network said Conteh (who financed it) overcame adversity, risked everything for his dream and had it fulfilled, and said they had an interest in wireless communication.

Students choosing Banking on Change noted the banker shared his expertise and empowered people with love and humility. This was a non-technical topic, but one that showed significant human impact. One student felt the class on the Quality Movement was something they would use in their career, which may be an understatement.

From the survey results for the readings, the largest responses from the students were on the Tata Nano and India Inventors. Both of these had strong connections to engineering. The strong positive rating for the India Inventors appears to be due to the positive impact on people in India.

For the in class topics, most students chose the more technical topics on the Cost of Mars and Congolese Wireless Network (which is also a very dramatic story). As a general rule, the favorite topics seem to be ones that involve the positive impact of technology on human need, that bring together the students' expertise and career goals with their desire to help people and make a difference.

Students selected most of the possible research paper topics, with two students selecting a topic of their own. They reported learning a wide range of things from their papers, including:

- Considering the target market before building and finalizing a new product (OLPC),
- The positive impact of wireless technology on the economy, health and social life,
- The great ideas being generated by people at the 'bottom of the pyramid' (Grameen Bank),
- The importance of valuing the people around us (Value of the Person),
- To understand how the things I do will impact the world around me (Hyperloop),
- The need to look at both positive and negative impacts (Hyperloop),
- The diligence and hard work of Joshua Atkinson in Afghanistan,
- How to practically help a community by creating a more sustainable economy (John Perkins).

These comments indicate students learned some important lessons from their research papers that hopefully will stick with them and translate into practice.

The survey primarily addressed student preferences, which are important, but not a direct indicator of the effect of the readings and topics. The explanations of their choices of best assignments, and lessons from their research papers were more indicative of what they had gained from these assignments. The survey will be modified to better assess the impact on the students.

Preliminary Conclusions

There is a recognized need to enrich the Engineering Economics class to address qualitative issues, as well as the practice of engineering in a complex, interconnected world. This paper describes an effort using short readings, which require minimal effort on the part of the students or instructor, in class topics that require some effort, and research papers that require considerable effort to complete and grade. The goals of these readings and topics are diverse and include building character, encouraging creativity and compassion, and gaining a better understanding of the modern business environment. Appropriate topics can also encourage student interest in the subject.

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EGR 461 Engineering Management and Economy

Questionnaire

1. Of the short reading assignments, which one did you like best and why?
(Tata Nano, Woman who couldn't be intimidated-Citibank, India Inventors, Value of a person, Tom Bloch)
2. Of the short reading assignments, which one did you like least and why?
3. Of the classes on Cost of Mars, Congolese Wireless network (risk) and Ned and Larry's Ice Cream, bank accounts for the poor, or the quality movement, which did you like best and why?
4. What topic did you choose for your Economics Paper?
5. What is the most important thing you learned from researching and writing the paper.