



## **Engineering Economics and Its Role in The Engineering Curricula**

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## Abstract

Engineering economics is a field that addresses the dynamic environment of economic calculations and principles through the prism of engineering. It is a fundamental skill that all successful engineering firms employ in order to retain competitive advantage and market share. Many schools across the country have integrated courses in engineering economics for their students, thereby providing them with the tools to optimize profits, minimize costs, analyze various scenarios, forecast fluctuations in business cycles, and more. Despite the importance of this field, many universities are unable to effectively teach economic concepts to engineering students in ways they are able to understand. A survey by Lavelle, et al.<sup>1</sup> displayed that fewer than half of participants used effective educational practices (i.e. collaborative grouping) when teaching engineering economics. By promoting a more engaging and holistic learning approach, students can have the opportunity to become better problem solvers.

Accordingly, ABET (Accreditation Board for Engineering and Technology) has published strict course outcome requirements for accredited programs. It is the intent of this paper to highlight various methods of teaching engineering economics to students in ways that maximize learning, as well as emphasize its importance for the modern engineer. Through the vigilant implementation of various teaching styles, experiential learning techniques, and integrated curricula, engineering students can successfully bridge the gap between the real world and the classroom. These can be achieved through a variety of mediums, one of which includes collaborative learning. An article by *Prism*<sup>2</sup> succinctly highlights the benefits: (1) Higher levels of achievement; (2) Greater academic self-esteem; (3) Solving more complex problems; (4) Positive relationships.

## Introduction

Engineering economics studies various financial and economic problems pervasive to engineers in a variety of industries. Like all engineering courses, economics-based engineering courses have a strong quantitative component; however, unlike the more traditional courses, studying engineering economics requires extreme elasticity in learning style that is conducive towards understanding interdisciplinary material. As a result, students who have taken courses in the aforementioned field have adopted a variety of techniques that have been shown, both experientially and empirically, to permit higher order learning and critical thinking.

Following the fundamental principles put forth by Benjamin Bloom promotes a well-rounded learning strategy that emphasizes a concrete approach towards evaluation, synthesis, analysis, and more. Along with several psychologists in the mid 20<sup>th</sup> century, Bloom amalgamated the underlying mechanisms of several domains (cognitive, affective, and psychomotor) into what's

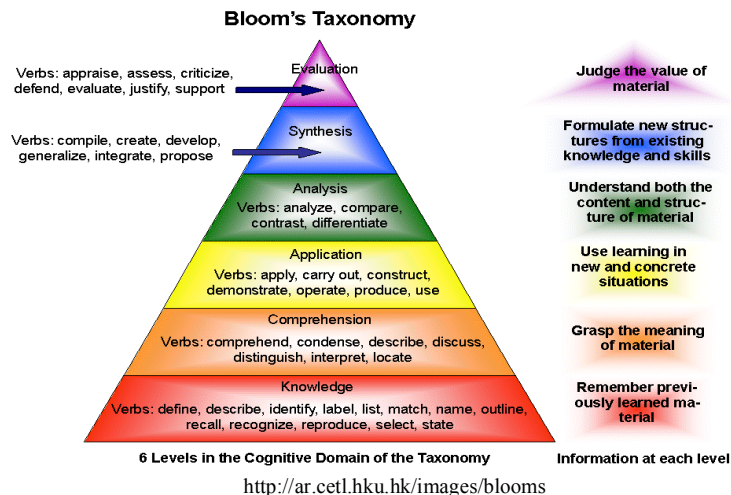
called Bloom's Taxonomy. By understanding the hierarchical structure of this taxonomy, students have successfully supplemented these ideologies into their learning patterns. This paper explores some of the many methods for teaching engineering economics in a way that enables engagement and long-term retention.

It is also the intent of this paper to address the importance of integrating economics into the engineering curricula. Due to globalization and economic complexity, engineers are now required to have an in-depth understanding of the markets and how changes in these markets affect their bottom line. These can include a variety of things, such as understanding interest rates required to increase or sustain levels of capital stock, opportunity cost, net present value for calculating the value of investments, basic cost and revenue analysis, and more. Once we understand the mechanisms for learning engineering economics and its importance to 21<sup>st</sup> century engineers, it becomes apparent that this field will play a growing role in shaping successful engineers.

### Teaching Engineering Economics

The field of engineering economics aims to create value in two domains: real world application and academic theory. As such, there are some key prescriptive recommendations for fostering learning in this field.

*Educational Practices.* Professors have the distinct responsibility of increasing student achievement. After all, research shows that the classroom environment has the biggest impact on how well students learn. In response, O'Connor<sup>3</sup> proclaims that there are simple steps educators can take to improve pedagogy and provide **GREAT** instruction: (1) **G**uided by the curriculum; (2) **R**igorous with research-based strategies; (3) **E**ngaging and exciting; (4) **A**ssessed continuously to guide instruction; (5) **T**ailored through flexible groups. On the other hand, students are also expected to understand the hierarchical structure of learning and be able to solve problems with critical thinking. This taxonomy, established by Benjamin Bloom, promotes these invaluable learning skills to students in a clear method<sup>4</sup>. As the figure below shows, learning begins with memorization and ends with evaluation. By understanding the basic mechanisms for effective learning, we can now delve into various educational practices and their purpose in engineering economics.



*Collaborative Learning.* Educators agree that the grouping of students during learning helps to promote critical thinking; actively exchanging ideas among groups increases interest, stimulates participation, and supports evaluating ones' ideas. Based on empirical data, psychologists posit that individual cognitive skills are developed in a social context<sup>5</sup>. Collaborative learning can be hosted through a variety of mediums, including, but not limited to, big discussions, teamwork-intensive activities, and group projects. Numerous studies show the positive influence collaborative learning had on promoting higher levels of understanding and stronger retention of material<sup>6</sup>. As such, practices have been successfully established in engineering economics courses. One such course is the University of Pennsylvania's *ESE 400/540 – Engineering Economics* course. In conjunction with the aforementioned studies and ABET requirements, *ESE 400/540* mandates that the expected outcome is to “be able to work effectively in teams of 4 or 5 to perform case study analyses and to present findings in written reports and verbal presentations” [ABET Program Outcome D]. The professor integrated this by assigning team case study projects, whereby students would work in groups to research topics that apply to real world problems. The teams would then present their findings, where a heavy emphasis would be placed on the “written and verbal communication skills.” This approach by Professor Cassel, an industry veteran, is imperative for training future engineers.

*Computer Supported Learning.* The incorporation of technology in modern education has revolutionized learning. Students are now able to use software to suit a plethora of needs that were unavailable to them a decade ago. MIT's OpenCourseWare initiative and Khan Academy are some of the many online tools available to students. They provide lectures on thousands of different topics, including engineering economics, organic chemistry, advanced thermodynamics, differential calculus, and everything in between. Rather than dwell on memorizing information from the books independently, students can now supplement these strategic lectures with their own resources to create a personalized understanding. Computer supported learning further promotes active learning by engaging students in experiential exercises. A recent technique that has been successfully integrated into the classroom is the use of Microsoft Excel. Students have the availability of downloading accurate data from online databases (such as the Federal Reserve's data on infrastructure spending or inflation) and working together to analyze and project trends for the future. One such course offering this is Fresno State's *Economics 103 – Introduction to Business Cycles*, which has successfully integrated Excel data analysis into a supplementary bi-weekly lab. This provides students the opportunity to get into groups, download the data, build graphs, run statistical tests, analyze external shocks, see various patterns, and more. These innovative methods are imperative for students studying engineering economics, since the techniques and strategies of collaborative quantitative and qualitative analysis are key to fostering interdisciplinary engineers who can observe the markets and streamline their output for producing maximum results.

*Clicker Technology.* The growing use of student response systems, such as iClickers, in classrooms also provides a suitable medium for engaging all students. Students sometimes shy away from classroom discussions and activities for fear of providing the wrong answer. Supplementing these unique technologies allows them to process the information (either alone or with partners) and anonymously provide a response. Numerous studies confirm the above assertions, particularly in quantitative courses like engineering economics. One historically beneficial method for integrating iClickers in these courses is to begin with big-picture questions

and end with detailed questions: start by asking about the definition of the time value of money, and finish with calculating the time value of money given certain parameters.

The goal as an educator of engineering economics should not be to simply convey the material to the students; rather, it should be to enhance and develop students' abilities to learn things at a higher level. By having an understanding of the various learning mechanisms, educators can help facilitate self-learning and thereby create value in the two domains. The recommendations above provide some insight into solutions that have been observed by researchers, scientists, and educators for decades.

## **The Value of Engineering Economics**

Engineering economics is a topic that all industry-bound students should learn because of its real-world applications. In response, Northwestern University has made engineering economics an integral component of senior design courses in all Chemical Engineering curricula<sup>7</sup>. Their faculty covers a variety of topics that are relevant to practicing engineers, some of which will be discussed in this section. Engineering economics poses numerous benefits because it allows those in industry to make strategic decisions for their companies.

While macroeconomic and financial competencies are key for business operations, engineering economics further provides a mechanism for decision-making. It forces engineers to think twice before making many choices in everyday operations, such as process configurations, materials, production size, and other economic factors<sup>8</sup>. During a mass-production manufacturing process for example, it may make sense to use an additive manufacturing convention if the production size is relatively small. However, after a certain point, it will become more economical to use injection molding. If the engineer decides to use injection molding, they will then have to decide what type of materials they should use: metals, plastics, glass, etc. The detail and accuracy with which these processes are carried out are another economic calculation based on margins of error, tolerance, reproducibility, and affect on performance. Daily decisions by the engineering firms (based on an economic framework) will decide how successful and profitable that company is.

In most undergraduate engineering programs with courses in engineering economics, there are a number of key topics, among many others, that are generally covered: time value of money, cost analysis, interest rates, economic fluctuations, and depreciation. These subjects are essential for engineering economics because they provide the foundation for engineers to make good decisions in the business environment.

*Time value of money* is the idea that money has a different value now than it will in the future. This is due to a number of dynamic variables, such as inflation and interest rates. These values are standardized through present and future value calculations, thereby equalizing the time-dependent variables. This is very important for engineers because these calculations provide an intuition as to how money should be spent and saved, how cash flow should be negotiated in contracts, and how interest rates can affect the present and future values.

*Cost analysis* is a key tenant for balancing a business's budget, as well as for calculating the viability of a project. Engineers can compare the costs and benefits of a project, and determine whether the benefits outweigh the costs enough to entertain the project. Each are then further broken down into subcategories. There are fixed costs (initial infrastructure), variable costs (each additional input), total variable costs (aggregate of all inputs), and total costs (fixed costs plus total variable costs). Meanwhile, the benefits can comprise of total revenues (final sales), marginal revenues (each additional sale), and profits (final sales minus total costs).

*Interest* is another concept that is important to economical engineers. Many times, engineering firms take out significant loans to finance construction of major projects. Having a clear understanding of the cost of borrowing money is crucial to making appropriate business decisions. For instance, if the costs of a five-year long project (after accounting for the annually compounded interest rate) exceed the revenues collected, then it would be unwise to pursue the project. Many construction companies are highly cognizant of interest rates (mortgage rates in particular), because if mortgage rates are too high, many people can't afford to finance buying new houses. Thus, once the demand for homes dries up, construction companies must pursue other avenues to make money.

*Economic fluctuations* characterize the changes in the market economy as peaks, recessions, troughs, or expansions. Each of these four stages has a direct impact on the choices made by businesses, particularly construction companies. During a recession, decisions made by the Federal Reserve and U.S. Government provides a signal for the direction of the economy. For example, if the Federal Reserve decides to engage in expansionary monetary policy, they will lower interest rates in order to make it cheaper to borrow money for business operations. In response, many firms can take advantage of the temporary stimulus and invest heavily.

*Depreciation* is the loss of value in an asset over time. During the 2008 housing market collapse, many homeowners saw the value of their homes depreciate tremendously, leading them to go underwater on their mortgages – many to a point where their loans exceeded the values of their homes. Depreciation plays a major influence on engineering firms; it is important for engineers to calculate the “wear and tear” that activities have on their expensive equipment. This allows them to calculate how much it costs their firm to operate a piece of equipment for a period of time, and how much they should recoup annually to compensate for these costs. Furthermore, since capital depreciation is tax-deductible, savvy engineers can save their firms tremendous amounts of money.

## **Conclusions**

The marriage between economics and engineering is one that is crucial to the success of engineers in the 21<sup>st</sup> century; the interdisciplinary nature of the topic offers key insight into the underlying mechanisms that drive daily business operations. Engineering economics is an integral component to many engineering curricula across the country, covering a wide variety of topics including the time value of money, cost analysis, interest rates, economic fluctuations, depreciation, and everything in-between. Furthermore, it has been noted by renowned engineer John Hayford<sup>9</sup> that engineering and economics “help to develop the very valuable habit of thinking in terms of groups rather than of individuals.” By understanding and implementing the

outcomes, framework, and tools for actively teaching engineering economics, future engineers can continue evolving as problem solvers and innovators.

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