Current Practice and Teaching of Engineering Economics in Brazilian Universities

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Abstract

Engineering economics includes tools which permit to evaluate the economic feasibility of alternative solutions considered along with their major technical requirements. Realizing the changes that are being discussed about new approaches in engineering education, this work aims to analyze the practice and teaching of engineering economics in Brazilian universities, thereby contributing to the identification of opportunities for improvements in the teaching and learning process of such concepts and tools in Brazil. The methodology followed was essentially exploratory. Firstly, it was obtained relevant evidence from the general information offered by universities and production engineering departments. Secondly, a questionnaire was used to gather data from the responsible of each identified undergraduate and graduate program. The analysis of this evidence contributes to the understanding of the current practice and teaching of engineering economics in the Brazilian universities, namely which concepts and tools, teaching strategies, interdisciplinarity approaches, partnerships with firms and type of real problems are used.

Keywords: engineering economics; engineering education; Brazilian universities.

1 Introduction

Engineering teaching and practice in Brazil is living a significant moment in this 21st century, especially by investment possibilities in the area of infrastructures. Nevertheless, there is a lack of engineers in the country. According to Telles (2012), Brazil presents a number of six professionals for each thousand workers, while in the United States and Japan this number raises to 25. The author also points out that only 9% of the courses offered in the country are in the engineering domain. Furthermore, Frischtak (2007), based on a World Bank study, highlights that, in order to achieve the level of industrialization of countries such as South Korea or accompany the process of China's modernization, it would be required an investment in infrastructures in the order of 4 to 6% of the Gross Domestic Product (GDP). In Brazil, this rate has remained in the order of 2%.

Engineering Economics is mainly an application of concepts and tools to support decision-making mostly for problems with a strong and complex technological and engineering nature. Engineering economics techniques are used to clarify and quantify the advantages and disadvantages of each alternative investment. Indeed, it is also known that an investment project appraisal consists mainly in analyzing the implications of capital allocation (i.e. investment) decisions (Guimarães Neto, 2007).

In Brazil, undergraduate engineering programs have at least one course on engineering economics. The "Pedagogical Political Project" includes topics on engineering economics which complement other issues such as production costs reduction strategies, which require a specific knowledge on accounting, finance, production strategy, industrial facilities design and product design. Furthermore, at the graduate level (specialization and master) some education institutions provide courses named "Engineering Economics" particularly focused on a target audience (e.g. production and project managers, general managers) that need to improve their knowledge on investment and project analysis. For instance, in the real estate market, project cash flows are estimated in order to be used as a tool for designing and analyzing investment scenarios which can be used to predict the profitability and the risk of the project, as well as to analyze alternatives for fundraising, to decide between competing projects, the best tax scheme, etc.

In this context, teaching and practice of Engineering Economics, ask for effective and efficient methods and approaches. Furthermore, according to Costa (2009), engineering programs should seek to interact with the industry and the practitioners. These relationships can be achieved through technology parks and other spaces where the industry and the academy may easily establish contact, and through specific partnerships or projects where students, teachers and practitioners work together to solve real problems. Indeed, nowadays, effective teaching and practice in engineering schools is increasingly demanding and challenging.

Thus, the aim of this research project was mainly to analyze the practice and teaching of engineering economics in Brazilian universities, thereby contributing to the identification of opportunities for improvements in the teaching and learning process of such concepts and tools in Brazil. In this exploratory study it was obtained evidence on the teaching and practice of engineering economics in Brazilian universities from the general information offered by the universities and through a questionnaire sent to the responsible of a sample of 35 undergraduate and graduate engineering economics programs. The questionnaire required information on the designation of the course, which topics of engineering economics are covered, which teaching strategies are used in the practice and teaching of engineering economics, among other questions.

This paper is structured as follows. After a general conceptualization of engineering economics fundamentals, namely scope, concepts and tools, it is described the research methodology followed in this research. Subsequently, the results obtained, and the analysis and the discussion of the findings are presented in section 4. Finally, the last section summarizes the main conclusions and highlights opportunities for further research.

2 Engineering Economics

In this section the concepts and tools used by engineering economics will be identified, as a basis for the following discussion on the use of engineering economics in production engineering programs.

2.1 Scope

Engineering economics uses analysis tools that are applied to the cash flows of an investment project, which are obtained by means of a model simulating the project behavior. The result of the analysis drives the decision-making: decide to invest or not in a project, choose the best investment alternative or determine the value of a project or a company, for instance (Quiza, 2011).

Engineering and technology-based systems can be represented through models, with the goal of predicting their behavior. In the same way in Engineering Economics we can adopt the generic concept of **“**system**”**, by means of the following definitions: a) the systems may be seen as the projects or investment options; b) the operating range is measured in terms of time and its upper bound is the project horizon; c) the operations are represented as cash flows that occur during the project horizon; d) the models will have the objective to predict the system behavior over time, in terms of economic viability of the projects in evaluation (Nakao, 2005).

Engineering Economics uses a set of techniques that allow the monetary quantification and economic evaluation of investment alternatives, giving the necessary knowledge for decision-making to those who need it. The engineering economics techniques used for analyzing projects are intended to clarify and quantify the advantages and disadvantages of each alternative investment. It is also known that an investment project appraisal consists in identifying and analyzing the implications of certain decisions in applying capital resources. These consequences vary from one project to another, but generally include the ones of financial and economic order (Gonçalves, Neves, Calôba, Nakagawa, Motta & Costa, 2009).

2.2 Concepts and Tools

Engineering economics teaching and practice is explained through six main topics namely: Financial mathematics (i.e. types of interest, time value of money, present and future values, equivalence factors), Cost analysis and selection of economic alternatives (e.g. the computation of present values, investment costs, annual costs), Equipment replacement and retirement, Project evaluation (i.e. the computation of the different cash flows, net present values, internal rate of return, payback period, breakeven analysis, benefit-cost ratio), Project Risk and uncertainty analysis, Cost-benefit analysis (i.e. considering externalities, the computation of economic NPV and economic IRR) (Watts Jr & Chapman, 2012).

2.2.1 Financial mathematics

Engineering Economics is, generally speaking, an application of mathematical techniques in financial decision-making problems. It is a set of procedures and techniques used in investment analysis which are employed in choosing the best alternative among several possibilities or to assess the economic viability of a particular investment. In both cases, all technically feasible alternatives or possibilities must be analyzed (Frischatak, 2007). Financial mathematics is directly linked to the time value of money, which, in turn, is linked to the existence of interest profits. The values of an investment should be compared with net profits provided by the project which occur at different times, defined as cash flows (Dergamo, Sullivan & Bontadelli, 1993). Cash flows are compared through the interest rate.

2.2.2 Cost analysis, selection of alternatives and equipment investment

Replacement decisions are of critical importance for companies. Indeed, the replacement of equipment is a problem that occurs in all companies, especially in industries. The methods normally used are Net Present Value (NPV) and Equivalent Uniform Annual Value (EUAV). A replacement of equipment is cost-effective when the EUAV of the new equipment is lower than the annual costs of the existent one. Such analysis should be done when existent equipment appears to have excessive operating costs or increased maintenance costs (Nascimento, 2012).

2.2.3 Project evaluation

The primary tools or methods of analysis used by Engineering Economics are the Net Present Value (NPV), the Internal Rate of Return (IRR), the Payback Period, the Breakeven Point and the Benefit/Cost (BC) Ratio (Black, Seaton, Chackiath, Wagland, Pollardd & Longhurst, 2011). Furthermore, projects should be analyzed in terms of risk and uncertainty. Finally, a project with external impact (i.e. responsible for externalities) should be analyzed in terms of its economic contribution to all stakeholders and the society through a Cost-Benefit Analysis (CBA).

The Net Present Value (NPV) is defined as the algebraic sum of the discounted cash flow values associated with the project. In other words, it is the difference of the present value of income less the present value of costs. It should be highlighted that the project will be viable if NPV is positive.

On the other hand, the Internal Rate of Return (IRR) is calculated from the cash flows of the project, when the net present values of outflows (cost of investment) and cash inflows (net profits) is equal to zero. It is a demonstration of the profitability of the project, and the higher the IRR is, the more advantage the project has in financial terms. A project, to be acceptable, must have an IRR exceeding the opportunity cost of the capital or the basic rate of interest established by the monetary authorities (e.g. Central Bank of Brazil).

The Payback Period (PAYBACK) consists of determining how much uptime (the time unit generally considered is the year) is required for an investor agent to recover the invested capital. A rough estimative for the payback may be obtained by dividing the sum of investments, costs and expenses incurred by the sum of income/profit earned.

The Benefit/Cost Ratio (BC Ratio) is heavily used and its interpretation is relatively easy. It is calculated dividing the discounted benefits by the discounted costs of the project. The project would be rejected by this criterion if the BC Ratio is below the unit (i.e. $B/C < 1$). If the NPV is higher than zero and the IRR is higher than the Weighted Average Cost of Capital (WACC), the BC ratio is higher than one.

2.2.4 Project risk and uncertainty analysis

Uncertainty can be defined as the lack of knowledge about the future. When analyzing projects the uncertainty can represent a risk or a potential for loss. The decision making process should consider the uncertainty and risk issues.

When applied to project appraisal, risk may be measured as the variability in the project NPV or IRR. Risk Analysis may be done by assignment probabilities to the various outcomes of an investment project and study the behavior of the project using, for example, decision trees. It can also be done by sampling the parameter values and study the range of the results obtained.

Sensitivity analysis works in a slightly different way. The values of the relevant parameters are systematically changed. The projection of cash flows is examined again by changing the value of each one of its main variables. It allows knowing how the variation of the main factors influences the expected results of the project, particularly in terms of NPV and IRR (Blank & Turquin, 2007).

2.2.5 Cost-benefit analysis

In a Cost-Benefit Analysis (CBA), the present value of all costs and benefits for all stakeholders should be combined to produce an economic Net Present Value (NPV). Externalities which result from the project should be considered. These consist of social costs or benefits that manifest themselves beyond the realm of the project and influence the welfare of third parties without any monetary compensation. Where the project needs or deserves an evaluation by a public entity, the externalities generated should be taken into consideration. The evaluation of the project from the private perspective does not consider the effects on third parties arising from associated externalities. Nevertheless, the externalities generated by a project are in many cases difficult to quantify. Thus, besides the perspective of the firm, external factors should also be considered (Valentin, Ioan, Andrei & Delia, 2012).

3 Materials and Methods

The methodological approach was essentially exploratory. Firstly, general information was taken from the program plans available in the respective universities websites. This data was collected during February 2012. Secondly, it was also carried out a web questionnaire during March 2012. The invitation to participate in this questionnaire was sent by email to the responsible of undergraduate and graduate courses in engineering economics or related topics in production engineering programs of 35 universities selected as being the ones showing better performance in the year 2011, in the country. This evaluation is made by the Ministry of Education and Culture that generates a ranking of the programs (Indice Geral de Cursos – IGC) in the country, based on teaching quality parameters, including grades of a national exam (Exame Nacional de Desempenho de Estudantes – ENADE) among other criteria (MEC, 2012). The major part of these universities are Federal Universities; complemented with the state universities of Rio de Janeiro and São Paulo and the Catholic Pontific Universities. From the information obtained in ABEPRO (2012), only 46 (forty-six) of the 67 (sixty-seven) Federal Universities in Brazil offer programs in production engineering. And considering the 27 (twenty seven) States of the country, the program is offered by federal institutions in 20 States. The production engineering program is one of the engineering programs that has excelled in the last 10 (ten) years in Brazil.

In the questionnaire sent it was required information about the designation of the course, the program in which it is inserted, the typology of the program, which topics of engineering economics are covered, if the topics identified are supplemented with other topics, which strategies (present and planned for the future) are used in the practice and teaching of engineering economics (like project led education, serious games, interdisciplinary, partnerships with companies, real case analysis) and examples of the previous strategies or approaches.

As described in Table 1, the questionnaire has 10 different questions. Five of them ask for general information and are characterized by open answers. Question 4 allows understanding which topics of engineering economics integrate the course program and their extent. Questions 6 and 7 asked, respectively, the relevance of several teaching strategies nowadays and in the future (next 3 to 5 years). Finally, question 8 asked for examples of project-based teaching strategies.

Table 5: Questions sent to the responsible of the engineering economics course

Questions	Type of question	Type of answer	Topics
Questions 1, 2, 3, 9 and 10	General information	Open	
Question 4	Topics covered (6 topics)	Ten points scale from 0% to 100%	Financial math, Cost analysis, Substitution problems, Project appraisal, Risk and sensitivity analysis, Cost-benefit analysis
Question 5	Other topics?	Open	
Questions 6 and 7	Teaching strategies (actual practice and planned for the future)	Ten points scale from totally disagree to completely agree	Project approaches, Serious games, Interdisciplinarity, Partnerships with firms, The use of real problems
Question 8	Examples of teaching strategies based on projects approaches	Open	

From the 35 contacts established, only 10 complete questionnaires were obtained in time to be analyzed. A total of 14 questionnaires were received, 4 of them incomplete. It is noteworthy that 3 remainders were made with 3 to 4 days interval. In this study, 80% of the results obtained were from undergraduate programs in production engineering, 10% from other undergraduate programs in engineering, and 10% from graduate programs (MBA). From these programs, 80% name the course "Engineering Economics", 10% "Financial Mathematics" and 10% "Decision Support Systems".

Therefore the data collected presents information on goals, strategies, teaching practices and contents related to engineering economics and similar courses in production engineering programs of the Brazil best universities (Appendix 1).

4 Results and Analysis

This section presents the results obtained from the questionnaire. The analysis is essentially about the topics covered by engineering economics courses, teaching approaches currently in use and teaching strategies for the next 3 to 5 years. Differences between undergraduate and graduate courses are analysed and discussed.

The basic engineering economics concepts and other related issues are important in engineering programs in general and in production engineering programs in particular, e.g. cost control and analysis, investment appraisal, among others. Nevertheless, the teaching of engineering economics has changed substantially over time, with a decrease in repetitive calculations and the corresponding increase in the attention given to project activities and/or decision-making problems. On one hand, these changes have been facilitated, as happens in other disciplines, by the generalization of the use of electronic calculators and computer programs (e.g. spreadsheets). On the other hand, new teaching approaches and strategies have been assuming increasing relevance (Costa, 2009).

Based on additional information from the coordinators of production engineering programs in the northern region of the country, it has been observed that in relation to the content taught in engineering economics, they seek to reconcile with the other universities in the country through the "Pedagogical Political Project" (PPP). Generally speaking, engineering economics has a basic course content that involves financial mathematics, cost analysis, project evaluation, sensitivity analysis and cost/benefit analysis. Nevertheless, our results show that undergraduate and graduate courses cover differently these topics. This is particularly interesting. As shown in Figure 1, risk analysis but also cost-benefit analysis and cost analysis are relatively more important in graduate courses. Undergraduate programs have a focus on financial mathematics, equipment replacement and project evaluation. Results are presented in terms of the median. The median gives a better idea of the general tendency in the data when the data is not symmetrically distributed. The median represents the middle value, i.e. 50% of values are below it and the other 50% are above it.

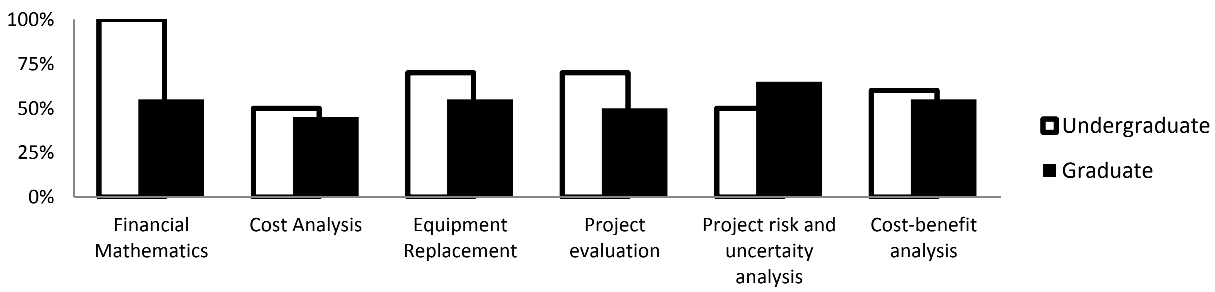

Figure 9: Topics of Engineering Economics

Secondly, engineering economics is interlinked with other subjects in the general field of "economics management". Responses to our questionnaire indicate that engineering economics courses may include topics such as "cost management" and "production costs", on one hand. On the other hand, they can include "investment appraisal computation models" (using spreadsheets for example), the computation of the WACC through the use of a capital asset pricing model (CAPM), or the use of real options. Finally, also Analytic Hierarchy Process (AHP) for multi-criteria project analysis and Monte Carlo simulation for risk analysis can be taught in engineering economics courses.

Thirdly, in terms of current teaching strategies, they were found differences between undergraduate and graduate courses. In undergraduate programs, engineering economics is characterized by a higher interdisciplinarity (through links with other courses) than in graduate programs. Interdisciplinarity, the use of project approaches and real problems are the teaching strategies more important in undergraduate courses (see Figure 2). On the other hand, graduate programs use much more approaches in terms of teaching strategies but the use of real problems and project approaches remain very significant. These results represent the median of the responses – for instance 7 and 10 means, respectively, "agree" and "completely agree". Furthermore, serious games are not relevant for both undergraduate and graduate courses and partnerships are not significant in undergraduate courses. These findings can be taken into consideration for the correct design of teaching strategies in each type of engineering economics courses. Indeed, there are differences which should be considered.

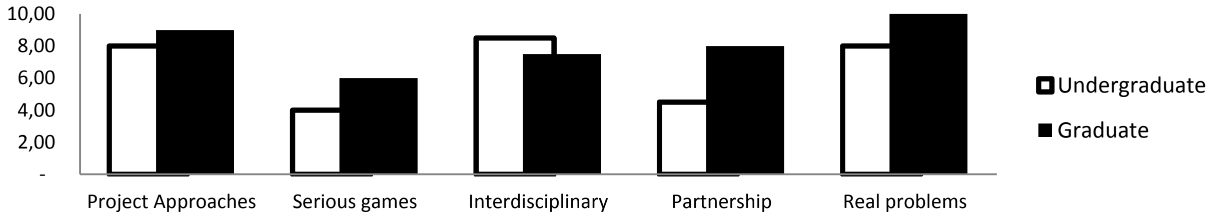

Figure 10: Current Teaching Strategies in Engineering Economics Courses

Fourthly, responses highlighted that there is, in general, an intention to increase the use of the different teaching approaches presented in our questionnaire – but remaining each one with the same relative importance. However, there are differences between teaching strategies for the next years in undergraduate and graduate courses. Figure 3 explain these differences. Positive differences mean that such specific teaching approach is expected to be more important in graduate courses than in undergraduate ones and vice-versa.

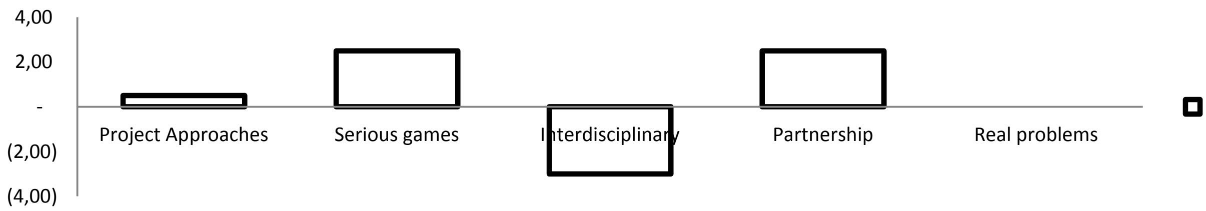

Figure 11: Teaching Strategies for the Next 3-5 Years in Engineering Economics Courses: Graduate vs Undergraduate

These results show that Interdisciplinarity appears to be much more relevant in undergraduate courses than in graduate courses during the next 3 to 5 years. On the other hand, graduate courses appear to will invest much more in “serious games” and “partnerships” in the next years to support their teaching strategies. Indeed, the audience and the goals of undergraduate and graduate programs are different and these results suggest that they are pushed to follow different teaching strategies.

5 Conclusions

The aim of this paper was to present and discuss current and future practice and teaching of engineering economics in Brazilian universities at the undergraduate and graduate level. At the graduate level, *lato sensu* system, there is a limited number of institutions offering engineering economics courses.

Findings showed that in addition to classroom lectures, the use of real-world problem-solving methods, project-based approaches and the integration with other courses of the production engineering program allow a much more practical and effective teaching and application of engineering economics contents. Teaching approaches based on project approaches are more stimulating and promote creativity and the consolidation of students’ theoretical knowledge.

The economic and social responsibility of the engineer in Brazil is very high nowadays. The engineer becomes a protagonist of the technological development and an actor of social transformation in a fast-growth economy. Thus, engineers in general and production or industrial engineers in particular must have a solid academic knowledge, tested practical skills and be effective in terms of decision-making and real problem-solving. Appropriate teaching strategies, methods and tools play a crucial role here.

This research was essentially exploratory and a few hypotheses were derived from the findings. Thus, further research through a large scale survey or using in-depth case studies can validate, complement and extend these conclusions.

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Appendix 1 – Questionnaire.

1. Name of the discipline in the field of engineering economic.

2. Program name in which it is inserted the discipline/University.

3. Typology of the program.

4. Engineering economic topics on the identified program plans:

4.1 Financial mathematics (interest, time value of money, present and future values, equivalence factors, etc.)

4.2 Cost analysis and selection of economic alternatives (present value, investment cost, annual costs, etc.)

4.3 Equipment replacement problems

4.4 Projects evaluation (e.g. cash flows, net present value, internal rate of return, payback, benefit-cost ratio, etc.)

4.5 Sensitivity analysis, project risk and uncertainty

4.6 Cost-benefit analysis (i.e. externalities, economic VAL and TIR)

4.7 *Comment (optional)*

5. In discipline, the topics identified in the previous question are complemented with other themes? If yes, indicate which.

6. How has been held engineering economic teaching in the identified discipline?

7. In the next 5 years, how may the engineering economic teaching be?

(10-point Likert scale from 1- Totally disagree t 10- Totally agree)

6.1 / 7.1 Teaching strategies: use of approaches based on project

6.2 / 7.2 Teaching strategies: use of "serious games"

6.3 / 7.3 Interdisciplinary with other disciplines, programs or projects

6.4 / 7.4 By partnerships with companies and business

6.5 / 7.5 With analysis and real troubleshooting

6.6 / 7.6 *Comments*

8. May indicate examples of approaches teaching based on project used in the discipline, of games and simulations, of interdisciplinary connections, of partnerships with companies, of using real problems?

9. Your name / post / university (optional).

10. email (optional).