

Developing an Introductory Engineering Management Course – a Case Study

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Abstract

Today's business world demands engineers to be prepared to compete in a global market. Therefore, it is of great importance for engineering students to have exposure to management topics for them to be ready for the workforce once they graduate. By examining the curriculum of the Engineering College at the University of Puerto Rico, an opportunity to develop a new course related to engineering management was identified. Taking this into consideration, a benchmarking analysis was done among different well-established engineering management programs to create an introductory course of engineering management. This new course was successfully offered for the first-time during Spring 2019. This last semester, Spring 2020, the course was improved and taught for a second time with almost 94% increase in registered students. As part of the final project of the course, several students thoroughly evaluated the temporary course and presented their recommendations related to relevant topics for engineers, assessment tools, etc. The process of establishing the course as permanent within the industrial engineering department and as a professional elective for both undergraduates and graduate students is undergoing. The final syllabus is the expected deliverable of this effort.

Keywords

Engineering Management, Engineering Professional Electives

1. Introduction

The addition of a new course to an engineering curriculum is a significant achievement when an opportunity to obtain relevant knowledge is identified. This was the case with the elective course created during the academic years from 2017 to 2019. The experience started identifying management skills needed for engineers based on the results obtained through the surveys done to the industry advisory board as part of ABET (Accreditation Board for Engineering and Technology) (APPM 2019) accreditation requirements. Taking these soft skills into consideration, a benchmark (Definition of benchmark 2020) was done comparing universities with well-established and recognized engineering management programs in the United States. Using the results obtained from the benchmarking study, an initial version of the proposed syllabus was created for an introductory course in engineering management with multidisciplinary focus. This article presents how that initial syllabus was developed and later used and improved by customizing it to the specific needs of the engineering students at the University of Puerto Rico.

This elective course was created with senior undergraduates and graduate students from different engineering disciplines in mind. For the students to take this course, they need to have had some exposure to engineering economic analysis or at least understand basic concepts about evaluating capital investment projects; this was used to determine the prerequisites of the course. Because it is an elective or a professional elective course, it was designed as a three credits course with forty-five contact hours. While the course was being developed, the emphasis was put into a course for multiple engineering disciplines to help on the creation of real-life scenarios where engineers must work with professionals from different disciplines.

During Spring 2019, a total of sixteen (16) students; six (6) graduates representing 37.5% and ten (10) undergraduates (or 62.5%) took the course and only one was from a different engineering discipline. For the second time the course was offered, Spring 2020, the number of students who took the course increase in total by almost 94% having thirty-one (31) students, all of them from the industrial engineering department. The distribution of the students was six (6)

graduate students or a 19% and twenty-five (25) undergraduate students which represents 81%. These numbers show that the increase in students' participation is on the undergraduate students. Because we are a campus with a small graduate program in comparison to the bachelor level program, the initial impact this new course is having may be considered as positive sign because it is impacting our largest group of students. There is an opportunity of looking for ways to increase the participation of students from the other engineering disciplines to allow the students to have the multidisciplinary experience.

The following sections of this paper include the review of relevant literature, the methodology used, the analysis of the data obtained and of the initial results and conclusions with recommended next steps.

2. Literature review

The review of relevant literature for this project considering the planned benchmarking analysis was divided into three major areas: (1) the syllabuses used for the introductory courses of engineering management by well-established and recognized engineering management programs in the United States, (2) the textbooks used by the studied programs and additional available books that include the topics identified as needed for the new course at the University of Puerto Rico, and (3) the methods of evaluation used for the identified universities and their grading systems.

The five universities considered for the study in alphabetical order are: Colorado University (Colorado University 2018), Northwestern University (Northwestern University 2018), Texas A&M University (Texas A&M University 2018), University of Tennessee (University of Tennessee 2018), and University of Utah (University of Utah 2018). For these five universities, it was found that they have solid programs of engineering management and as expected, they offer multiples engineering management courses as part of their curriculums. Relevant topics were identified from the introductory level courses found at the mentioned universities. Because for these programs, more than one course introducing the concepts of engineering management was found, general topics were pinpointed from each entry-level course from every program. These topics were analyzed considering the management skills set needed for our engineering students that are not currently covered in any other required course for the different engineering disciplines that we have in our engineering college.

For the revision of textbooks related to management and engineering management topics, the books used by the universities studied were the first ones that were evaluated. Furthermore, similar textbooks were identified from online academic libraries. The textbooks were evaluated based on two important aspects: content (identified topics are included in the book) and product rating (based on evaluations by academicians and students available online). Refer to Table 1 for this part of the literature reviewed. There are four (4) books rated 4 to 5 (on a Likert scale with a maximum of 5) (Likert scale 2020). The book with the maximum rating was eliminated from further consideration because it is related to a simulation software for strategic business and that will not be part of the suggested syllabus for the new course. The other three books with rating 4 or higher, will be considered (or similar books) if currently available for the course under development. The chosen textbook and references for the course will be included in the following sections.

Table 1: Textbook used by the universities selected and average product rating/feedback

University	Textbook	Product Rating	Source	Additional Product Rating	Source
McCormick School of Engineering	StratSim: A Strategy Business Simulation, Interpretive Software.	5 ★★★★★	Interpretive.com	-	
University of Tennessee	Guide to the Engineering Management Body of Knowledge 3ed	1 ★	Amazon.com	3.75 ★★★	goodreads.com
Colorado University	Understanding Business 10ed	4.3 ★★★★	Amazon.com	3.6 ★★★	Abebooks.com
Texas A&M	Project Management, The Managerial Process 6ed	3.7 ★★★	goodreads.com	-	
University of Utah	A Management 11ed				
	B Developing the Leader Within You	4 ★★★★	goodreads.com	3 ★★★	getabstract.com
	C The Elements of Style 4ed	4 ★★★★★	goodreads.com	-	
	D The Elements of Style				

The evaluation and grading systems used by the five studied universities were reviewed and analyzed to decide the system to be used for the course being developed. Table 2 presents a summary and comparison of the evaluation and grading systems of the five engineering management programs studied. As can be seen on the comparison, there are various similarities and significant differences among the programs that were reviewed and the most relevant are the following:

were evaluated until a preferred one was identified. Also, textbooks that are currently used in other industrial engineering courses were identified and included as references in the syllabus.

- *Step 4* - Recommended the desired methods of evaluation and grading based on being innovative due to the multidisciplinary emphasis of the course. In addition, the prerequisites of the course were selected.
- *Step 5* - Developing the course syllabus based on previous steps and complying with the university requirements including the following:
 - Course description and course goals.
 - Textbook(s) and references.
 - Course topics with contact hours.
 - Course resources.
 - Grading and evaluation methods.
- *Step 6* - Improvement of the developed syllabus was done after the first time the new course was offered

4. Data analysis and results

The analysis of the data obtained from the engineering management programs studied was done to make the final selection of the topics to be included on the entry-level new course, to choose the textbook and references, and to decide on the appropriate evaluation and grading system for the course. Additional important details are discussed on this section and the relevant results will be presented as the different parts of the developed syllabus.

Table 3: Modules and topics for the syllabus

<p><i>Module 1: Introduction to Management; Book: Management 14th ed.</i></p> <ul style="list-style-type: none"> A. Management and Organizations B. Understanding Management Context: Constraints and challenges
<p><i>Module 2: Management Principles; Books: Management 14th ed., Understanding Business 11th ed.</i></p> <ul style="list-style-type: none"> A. Managerial Issues <ul style="list-style-type: none"> 1. Global Environment and Change and Innovation 2. Diversity and Ethics and Social Responsibility B. Planning <ul style="list-style-type: none"> 1. Managers as Decision Makers 2. Foundations of Planning 3. Strategic Management - Tools and Techniques C. Organizing <ul style="list-style-type: none"> 1. Basic and Adaptive Organizational Design 2. Managing Human Resources and Managing Teams D. Leading <ul style="list-style-type: none"> 1. Understanding Individual Behavior and Motivating Employees 2. Managers and Communications and Managers as Leaders E. Controlling <ul style="list-style-type: none"> 1. Introduction to Controlling 2. Managing Operations 3. Managing Human Resources
<p><i>Module 3: Accounting and Financial Information; Books: Accounting Principles 12th ed., Cornerstones of Cost Management 4th ed., Engineering Economic Analysis 13th ed., Understanding Business 11th ed.</i></p> <ul style="list-style-type: none"> A. Cost Management <ul style="list-style-type: none"> 1. Managerial Accounting and Cost Accounting 2. Corporate Finance B. Managing Financial Resources <ul style="list-style-type: none"> 1. Understanding Accounting and Financial Information 2. Financial Management C. Time Value of Money <ul style="list-style-type: none"> 1. Cash Flow Diagram and Interests 2. Present Value and Future Value 3. Minimum Attractive Rate of Return and Internal Rate of Return

The selected topics were grouped into three modules identified as: *introduction to management, management principles, and accounting and financial information*. Under each module, the recommended textbook or reference and the chosen topics related to the main subject were included (refer to Table 3 above). The analysis to decide on the recommended textbooks and references is presented on section 2 while relevant literature was reviewed. Results presented in Table 3 relate to Steps 1, 2, 3, and 5 of the methodology.

The information presented on Table 2 (section 2) was used as a base of comparison to select the grading and evaluation system to be included in the syllabus of the developed course. Additionally, due to the multidisciplinary focus of the course, teamwork evaluations have a significant weight on the final grade of the course for each student. The assessment of the course will include multiple evaluation tools consisting of individual grades (quizzes, mid-term exam, and final exam) and group grades (project, presentation, and case studies). Furthermore, a standard grading curve was adopted. Refer to Table 4 for the evaluation of the course. Results presented in Table 4 relate to Steps 4 and 5 of the methodology used.

Table 4: Evaluation and grading

<i>Assessment Tool</i>	<i>Quantity</i>	<i>Percentage (%)</i>
Quizzes	1	5%
Mid-term Exam	1	15%
Final Exam	1	15%
Case Studies	3	45%
Project	1	10%
Presentation	1	10%

Following the last step of the methodology, when the Spring 2019 semester was about to start the syllabus was updated and improved to reflect current needs of our students in relationship to the topics to be discussed as well as the grading system. Additionally, updated editions of the references were included and an engineering management textbook (Chang 2016) was added. Table 5 presents the revised syllabus showing that the course was planned in five different modules using the selected textbook and six references that combine new books for the industrial engineering students and textbooks used in other departmental courses. Another significant improvement for the first time that the course was offered, is that external collaborators were included throughout the semester to share their experiences in engineering management with the students. Four knowledgeable engineering or technical managers were invited as a complement to offer interactive talks for the students in diverse topics such as: change management, project management, and global setting challenges.

Table 6 illustrates the revised evaluation/assessment and grading system that was chosen to evaluate the students both for their individual performance as well as in group assignments and projects. A significant change from the original syllabus is that exams were eliminated to enhance the students' experience working and presenting in teams and this is shown by the increase on the weight given to group work.

Following the improvement step of the methodology once again, for the Spring 2020 semester, the syllabus was updated to reflect newer editions of two of the references used in the course. Table 7 presents the syllabus used for Spring 2020 where the shaded areas show the changes made versus the Spring 2019 semester.

Table 5: Revised syllabus for Spring 2019

Topics	Readings
<i>Module 1: Introduction to Management</i> <ul style="list-style-type: none"> • Management and organizations • Management constraints and challenges 	Chapter 1 – textbook (Chang 2016)
<i>Module 2: Management and leadership in engineering</i> <ul style="list-style-type: none"> • Managerial issues • Planning, organizing, leading, controlling • Communication and teamwork • Change management 	Chapters 2-5 – textbook References 1 and 4 (Robbins and Coulter 2018) (Nickels et al. 2016)
<i>Module 3: Accounting and Financial Information</i> <ul style="list-style-type: none"> • Cost management • Managing financial resources 	Chapters 6 and 7 – textbook References 2, 3, and 5 (Newman et al. 2017) (Hansen and Mowen 2018) (Kimmel et al. 2015)
<i>Module 4: Project Management Principles</i> <ul style="list-style-type: none"> • Project plan and scheduling • Human resources management, development & motivation 	Reference 6 (Kerzner 2013)
<i>Module 5: Other Relevant Topics</i> <ul style="list-style-type: none"> • Ethical and socially responsible engineering managers • Global setting challenges 	Chapters 11 and 13 – textbook

Table 6: Revised evaluation system for Spring 2019

<i>Assessment Tool</i>	<i>Quantity</i>	<i>Percentage (%)</i>
Quizzes	3	30%
Case Studies	2	40%
Project	1	10%
Presentation	1	20%

Table 7: Revised syllabus for Spring 2020

Topics	Readings
<i>Module 1: Introduction to Management</i> <ul style="list-style-type: none"> • Management and organizations • Management constraints and challenges 	Chapter 1 – textbook (Chang 2016)
<i>Module 2: Management and leadership in engineering</i> <ul style="list-style-type: none"> • Managerial issues • Planning, organizing, leading, controlling • Communication and teamwork • Change management 	Chapters 2-5 – textbook References 1 and 4 (Robbins and Coulter 2018) (Nickels et al. 2018)
<i>Module 3: Accounting and Financial Information</i> <ul style="list-style-type: none"> • Cost management • Managing financial resources 	Chapters 6 and 7 – textbook References 2, 3, and 5 (Newman et al. 2020) (Hansen and Mowen 2018) (Kimmel et al. 2015)
<i>Module 4: Project Management Principles</i> <ul style="list-style-type: none"> • Project plan and scheduling • Human resources management, development & motivation 	Reference 6 (Kerzner 2013)
<i>Module 5: Other Relevant Topics</i> <ul style="list-style-type: none"> • Ethical and socially responsible engineering managers • Global setting challenges 	Chapters 11 and 13 – textbook

The use of external collaborators was included again with even more success than the previous year because six knowledgeable engineering or technical managers offered interactive talks for the students in diverse topics such as: change management, accounting and finance, project management, people management and human resources, engineers as consultants, and enterprise architecture. Having this kind of opportunity of sharing the teaching aspects with experienced engineering managers as collaborators is not a common practice within the department. It makes a direct impact on the students by enriching their whole experience as senior undergraduate or graduate students who are close to embark in the professional environment. To promote active involvement of the students during the talks given by the collaborators, participation was evaluated as part of their grades where the students had to be present during the talks and fill out a short questionnaire of each talk. This helped the professor to receive immediate feedback from the students to continue with further improvement of the course in the immediate future. Refer to Table 8 for the changes in the evaluation where the highlighted cells are identified.

Table 8: Revised evaluation system for Spring 2020

<i>Assessment Tool</i>	<i>Quantity</i>	<i>Percentage (%)</i>
Quizzes	3	30%
Case Studies	2	40%
Project	1	10%
Presentation	1	10%
Participation	Various	10%

6. Conclusions and Next Steps

The inclusion of this elective course to the Industrial Engineering curriculum as a multidisciplinary experience presents an excellent opportunity for the senior undergraduate students and graduate students of our campus that want to be prepared to engage in managerial responsibilities in the future. This course does not only aim to the managerial process in general, but it also gives students the preparation, vision, and practice of managing other fellow engineers or technical related professionals in their future jobs. The skills that the students learn in this kind of course will help them to improve important skills such as leadership, teamwork, and communication among many others that may not be included as part of the objectives of core courses of their curriculums.

The significant increase in undergraduate students' participation the second time the course was offered shows the need to offer a larger variety of elective courses that emphasizes on preparing students for their future as professional engineers. There is an opportunity of identifying how to increase participation of undergraduate students from the other engineering disciplines offered at the University of Puerto Rico. The participation of more graduate students represents another important opportunity. Because the industrial engineering graduate program is small in size when compared to other graduate programs in our campus, the focus must be on attracting graduate students from different engineering disciplines.

As part of the next steps, the analysis presented will be expanded to include recommendations received from the evaluation and analyses done by eleven (11) students that took the course during Spring 2020 semester. There were three out of eight groups of students (38%) that chose the topic of redesigning the course as their final project of the semester. This additional effort will be done to integrate the students' recommendations into the current syllabus to prepare the official syllabus to be presented for the approval of the course as a permanent professional elective for industrial engineering undergraduate and graduate students. Additionally, the plan is to offer the course once year including students (both undergraduate and graduate) from the different engineering disciplines that we have in our campus for which the course would represent an elective course.

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Biography

Mayra I. Méndez-Piñero, PhD, is Professor of the Department of Industrial Engineering at the University of Puerto Rico-Mayagüez Campus. Before joining academia, she worked for over twelve (12) years in a textile manufacturing environment. Her research focuses on using industrial engineering tools to optimize costs, for cost analysis and control, for cost modeling, and engineering economics in multiple applications such as manufacturing of electronics products, renewable energies, health services, higher education, and pharmaceutical industries among others.