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Professional Skill Development in Engineering Economics and Project Management

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Employers require many skills in their employees in addition to technical proficiency. Many of the professional skills often articulated from college recruiters and discipline specific advisory boards include project management, organization, communication, teamwork, and leadership. Requiring extra coursework or experiences in very structured engineering curricula is often difficult. However, introducing some of these skills early in the students' curricula can provide the basis for reinforcement at concurrent and subsequent levels of coursework. Preparing engineering students with the professional skills they need in the workforce is crucial to their continuing success.

Introduction and Motivation

> *"I feel that I should be allowed to graduate with the amount of knowledge I amassed in this class."* Anonymous student comment

This paper presents a brief overview of a new engineering economics course, where students apply the concepts and skills in basic project management. The College of Engineering at one institution recently took the initiative to develop a first-year course to lay the foundation for professional skill development, while emphasizing engineering economics and project management through team-driven Project-Based Learning (PBL). Half the lessons are general economics from a real-world perspective so students can relate to the material and see how it impacts their lives and their engineering careers. The other half of the lessons focus on applying economics learnings to engineering and project management using examples and problems at both a personal level such as budgets and return on investment and at a more complex level involving project management related to product design. Students stay engaged through in-class discussions and activities, out of class reading and video assignments, and quizzes. The instructors also developed incentives through competition: Best Product Proposal and the Investor of the Semester. Instructors have found opportunities to complement other courses in the curricula, introducing the entrepreneurial mindset. This paper discusses the course's content and uses student feedback to assess the course learning objectives for continuous improvement of the course. The summative teaching evaluations show students gained new insight and perspectives to the engineering profession and the course integrated topics from various disciplines. Students also recognized the course's value in the larger context of their particular engineering major. The short-term benefits continue and evolve to shape student choices concerning additional upper-level offerings of engineering economics, project management, entrepreneurship, and leadership. Overall, the evaluation and assessment of the course invites an exploration of how to improve student learning, future course directions, and best practices in the field of engineering economics for students.

The National Society of Professional Engineers (NSPE) highlights Key Attributes of the Professional Engineer in its 2013 publication, Professional Engineering Body of Knowledge. This initiative was in support of the Society's vision, mission, and values and in acknowledgement of the need to prepare for and participate in continuous changes in technological, social, cultural, political, and economic conditions. Some of the listed attributes include: Knowledgeable about and skillful in business and management; and Able to provide leadership with the ability to effect change in strategies, tactics, policies, and procedures in projects and other roles [1]. Many other discipline specific organizations have produced vision documents [2] – [3].

The NSPE also defines 30 capabilities for engineers to know and be able to do by the time of entry into professional practice. Engineering Economics is one of the capabilities and is essential in comparing alternatives. Engineers are expected to be able to prepare detailed cost estimates of initial capital and annual operation, maintenance, repair, and replacement costs for a project. Additionally, Project Management is another one of the capabilities specified by the NSPE. Project management is the process by which an engineering organization meets delivery, schedule, and budget requirements and manages human resources [1].

ABET, the accreditation board for engineering programs in the US and abroad, identifies key student learning outcomes: "(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors"; and "(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [4]. The outcomes prepare graduates to enter the professional practice of engineering.

Technological development and industrial growth are increasing rapidly along with expanding global applications and social implications, requiring engineering graduates who are developing these innovations to have a deeper understanding of decision making and management. Input from department and college industry advisory boards at Penn State University revealed the desire and need for a new introductory engineering economics course for lower-level engineering undergraduates. Although one program initially requested a new course, there was interest from multiple programs. Feedback from the industry partners and employers revealed new graduates had technical knowledge in their disciplines but lacked some judgment relating to basic engineering economic analysis and effective project management. They had difficulty recommending solutions to their employers beyond technical input and analysis. The employers' significant point was that engineering and business are practiced in more complex and interconnected ways than we typically address in the current engineering curricula.

There are several studies of engineering economics education within the published literature that have shown interest in engineering economics and its development in the engineering curricula. Recent engineering economics textbooks, as early as 2011, highlighted engineering economics as

part of decision-making analysis [5] – [6]. Basically, engineering and design include the evaluation of multiple alternatives (including their economic impact, social impact, etc.). Engineers need to be skilled decision-makers and evaluators, emphasizing the evaluation of economic impact of those recommendations and decisions as taught in engineering economics.

Course Development

Developing a new course for undergraduate engineering students from many different programs can be burdensome with the amount of coordination required across different academic units. Some of the departments wanted their students to take a course like this early in the curriculum, so the course was developed with first- or second-year engineering students in mind with limited exposure in any specific degree plan. This removed any minimum math requirement and allowed the course to be developed to focus on basic engineering economics and project management principles. Some of the knowledge and skills desired by different academic programs for a new course led to the research questions posed in this paper:

1. Can a new engineering economics course appeal to students from different engineering programs?
2. Will this course be useful in other courses and programs throughout the college?

Two instructors were identified to develop a new course, and they had industry experience in project management and entrepreneurship. The instructors developed the course with ideas that the course should be relevant to future work in the engineering curricula and that engineering economics was essential material graduates could use in their professional careers. The students knew their careers would require them to make many important decisions with deep economic consequences. Before the course offering, the instructors already were familiar with students approaching them attempting to apply basic course content in project management and entrepreneurship classes to their personal lives. The instructors developed the course on two themes to reflect the capabilities of the NSPE.

a. Engineering Economics

Engineering economics is central to the engineering design process and to perturbations in operations or processes. Engineers must understand and be able to assess initial capital costs; annual operation, maintenance, and repair costs; and lifecycle (periodic replacement) of equipment or other components costs and determine the remaining economic value at the end of the period. Design alternatives typically have different tradeoffs: capital and operating costs, maintenance, and replacement costs. Engineering economics is an analysis tool in the design process to compare alternatives on a corresponding basis (present worth or equivalent annual cost), using interest rate assumptions to justify the least costly and optimal design, using the time value of money and the estimated expenditures [1].

Exposure to and calculations of basic economics from a real-world perspective are also covered in the class as this also affects engineering economic decisions. Understanding the current cost of

capital and interest rate implications, along with the economic factors influencing these need to be understood to make timely engineering economic decisions. Understanding how the global economies are interrelated is also key knowledge for an engineer managing a supply chain. These are just a few examples of the importance of basic economic knowledge for engineers.

Engineers can expand on engineering economics after alternative selection to project financial economic effects from their decisions. This involves: total project costs, incorporating the cost of designing and manufacturing, other implementation costs such as management requirements, bonds and insurances, contingencies for undefined project requirements, and financing. The engineering economics process is frequently iterative as cost estimates are updated as projects proceed from planning to design to manufacturing. Engineers often work with other professionals to offer project economic information and opinions of project costs. Engineers may also help evaluate life-cycle costs [1].

b. Project Management

NSPE uses the Project Management Institute's (PMI) definition of a project as "a temporary endeavor undertaken to create a unique product, service, or result." Examples of projects include creating or modifying a process to make a product, manufacturing a product, and construction. Similarly, project management is "the application of knowledge, skills, tools, and techniques to meet the project requirements." Project management is the process by which engineering organizations provide products and services on time and within budget. Project management is an essential engineering function where engineers are expected to: identify work tasks and budgets, compare the benefits and challenges of alternative options, and monitor project schedules and costs [1].

Integration of Engineering Economics and Project Management

The Engineering Economics course introduced project management as a motivator for traditional engineering economics topics and was named Introduction to Project Management and Engineering Economics. The goal was to show students a bigger picture or broader perspective on economic activity and the business side of engineering. The basis is that the course provides an exposure to analyze alternatives and make decisions from the time value of money and time value of technology perspective for individuals and organizations. Having the course co-taught took advantage of the teaching styles and expertise of the different instructors. Thoughtful content and assessments allow the course to be taught in large or small sections.

Course Description:
This course examines how organizations satisfy their customers' wants in the face of economic factors. Project Management is a consistent set of methods and tools that is valuable in analyzing certain types of problems related to decision-making, resource allocation, and the production and distribution of goods and services. An introduction to microeconomics and macroeconomics is provided discussing issues including federal reserve policy, inflation, supply and demand, regulation impacts, corporate investments, time value of money and interest rates, and the effect

of all of these on individuals and firms. The course moves into engineering costing and pricing and the project management necessary to effectively perform engineering projects, including payback and return on investment for these projects.

Course Objectives:

1. Identify and define key concepts in microeconomics, macroeconomics, and engineering project management, including supply and demand, economic indicators, financial statements, project lifecycle phases, and basic financial metrics.
2. Explain the relationships between economic principles, such as supply and demand, and financial concepts like time value of money and return on investment, and their impact on engineering projects and financial decision-making.
3. Use basic economic and financial formulas to calculate costs, revenues, and return on investment for engineering projects, and interpret the results to make informed decisions.
4. Compare and contrast the effects of different macroeconomic conditions (e.g., inflation, interest rates) on the financial viability of engineering projects, considering the time value of money.
5. Critically assess the economic feasibility of an engineering project by integrating microeconomic, macroeconomic, financial analysis, time value of money, and return on investment, and make recommendations for engineering project management strategies.

In Class Topics and Discussions

- Foundations of Economic and Social Decision-Making
    - Colors of Money and Depreciation
    - Opportunity Cost and Business Decisions
    - Supply and Demand driving the Economy
    - Decision Making: Economic, Social, Psychological, Environmental factors

- Economic Influences and Policy Impacts
    - Macroeconomic indicators and their effect on Microeconomics
    - Government policy and its effect on the economy
    - National Economies and their interaction
    - Public money funding private contractors
    - Incentives, their benefits and challenges of unintended consequences
    - The impact of externalities on decision making

- Project Management: Principles and Practices
    - Introduction to Project Management, Scheduling, Costing, Budgeting
    - Project Management Phases
    - Project Management Tools (MS Excel, MS Planner)
    - Traditional and Agile Project Management (Focus on Agile Scrum)

- Financial Analysis and Project Evaluation: Socio-Economic Dimensions
    - Time Value of Money
    - Return on Investment and Payback
    - Intrapreneurship and Funding Projects

By scrutinizing microeconomic concepts like supply and demand, resource allocation, and constrained decision-making, students achieve a deeper comprehension of how individuals, groups, and organizations operate within today's intricate economic environments. Moving beyond purely technical applications, the course probes the social and behavioral aspects of project management, analyzing how stakeholder interactions, power dynamics, and ethical considerations impact project outcomes. The course investigates how economic factors, including U.S. Federal Reserve policy, inflation, and regulatory impacts, shape individual and corporate decisions, particularly within the technology and manufacturing sectors. Through a critical lens, the course explores the social implications of economic models, examining how these models reflect and shape our understanding of social, political, and economic institutions. The course analyzes the lifecycle and product development processes, focusing on how economic pressures and social trends influence innovation and market dynamics. The course also addresses how individuals and firms make decisions to maximize utility and profit, considering the ethical and social consequences of these choices.

In addition, students cultivate critical thinking and analytical skills through the application of economic modeling and project management tools, promoting a comprehensive understanding of how social, political, and economic influences shape individual, organizational, and national contexts. By analyzing real-world case studies and participating in group projects, students learn to dissect complex problems related to decision-making, resource allocation, and the production and distribution of goods and services. While parts of the course focus primarily on introducing foundational concepts and theories, the project management principles and special topics emphasize real-world applications of these theories within the context of technology solutions and the manufacturing industry. For example, project management introduces concepts such as Opportunity Cost and Return on Investment, providing the economic basis for informed business decisions. The course leverages these theoretical concepts to explore current patterns of product development and lifecycle analysis.

This course also fosters critical and analytical thinking by immersing students in the complex interactions between technology, economics, and society. Students move beyond technical comprehension to critically evaluate the implications of technological advancements. Diverse scenarios are analyzed, requiring students to identify key issues, evaluate solutions, and consider consequences, while structured discussions promote debate and challenge assumptions. In this course, students analyze scenarios and explore the intersection between product development, project management, and the lifecycle and societal impact of technology. Real-world case studies demand in-depth analysis of technology-related dilemmas, challenging students to consider ethical dimensions and balance economic, social, and technological factors.

To reinforce engineering economic concepts, weekly activities in project management topics allow the students to analyze engineering economics and integrate answers into the project management learning activities. The project management activities are typically worked in groups, allowing the students to interact with classmates and learn from them as well. Students also gained an appreciation for Excel and its ability to help them in this course and several others. Instructors delivered some basic instruction, and the students related several times how valuable this was to other classes. Often, professors just assume they know it. The basic Excel introduction at the beginning of class was great preparation for almost any engineering discipline.

Student Survey Results

The results of the first semester of the course were analyzed in this paper. The assessment method included student mid-semester and end-of-course survey data that was collected and focused on measuring students' interest in the material and their assessment of meeting course objectives. In a section of 35 students, the data from 25 students who responded to the surveys was included in this study (Table I). A standard five-level Likert Scale (5 = strongly agree – 1 = strongly disagree) was used to assess the level of agreement or disagreement for the questions. The rating scale is a normal set of responses used at the institution for student surveys.

TABLE I:
Student Survey Result

	Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5	Average
The overall structure of the course (content and materials, assignments, activities) promoted a meaningful learning experience for me.				7	18	4.72
The instructor created a welcoming and inclusive environment.				3	22	4.88

When students of the course were asked in a formal, mid-semester course evaluation, "I am confident that I understand what I am expected to learn in this course.; the average was 4.79 on the 5- point Likert scale. This evaluation result showed a very positive reception of the course from the beginning to the end. The 4.72 rating is significant, and it clearly shows that the students felt the course was valuable. Part of the indirect feedback received from this new Engineering Economics course was the fact that throughout the course, student attendance was

excellent. Further, the numerical results were reinforced by students' free text comments in reference to their course rating:

- "This course is super fun and creative. I love how the class is structured and how it is very interactive. It makes learning easier and the information actually sticks with me."
- "I've learned so much about economics and project management. The setup for the class of Tuesdays economics and Thursday's project management keeps things fresh and dynamic."
- "The class was kept light, yet it was a serious learning environment. The interactivity among peers was well liked among most students and I wasn't an exception!"
- "The instructors made the material very easy to grasp and gave insightful feedback when required. The group activates allowed me to be hands on with the topics and my classmates allowing me to fully understand the material and ask questions to my classmates if needed."

A career as an engineer requires people who can use engineering economics to analyze options and make informed decisions for their organizations. Unfortunately, many engineering programs tend to undervalue the need for engineering economics and project management. As discussed in earlier sections, the engineering profession of the future will rely on engineers who have stronger technical and professional skills.

Some potential improvements were offered by the students, as well, in free text responses:

- "I think that having some type of worksheet or online guide to fill out during lectures would be very beneficial. A lot of the lectures go over a lot of information and it can be hard to remember it all. I think that a simple fill in the blank guided sheet would also keep the class engaged throughout the period."
- "The only thing would be to have more activities, and less book break down days as towards the end of the semester Tuesdays became repetitive to an extent."
- "add one or two more minor projects to help with student understanding."
- "Excel has given me a bit of trouble in terms of getting it to do what I want it, but that's just because I haven't used the program before."

Research Question 1 attempts to determine if such a broad course in engineering economics and project management can appeal to students from different engineering interests. Results from student surveys indicate a very positive experience. The instructors connected the material to the students' lives with real world examples, allowing them to critically analyze implications resulting from economic factors and project management exercises. Some practices noted by the students that have helped them personally include:

- "I've become more collaborative and communicative in group work."
- "Paying more attention to the economic news."

Research Question 2 will take time to determine if this course is useful in other courses and programs throughout the college. Academic programs have been positive and receptive to the launch of the course but will need to incorporate and further develop the student skills in their projects and more advanced courses. Academic programs have additional opportunities to further this knowledge with specific minors and other design courses.

Preliminary Conclusions

The new Introduction to Project Management and Engineering Economics course has had a very positive and successful reception by students from multiple disciplines. They have found the delivery enthusiastic and content useful. They have made connections from the content to their personal lives and to where engineering economics will be necessary in their professional careers. Students provided constructive feedback on course administration and delivery, which are being considered. Similarly, the instructors have gathered their own notes and have ideas to improve the content.

The material and knowledge gained from the course can be infused throughout the engineering curricula, but because it is a new offering in the college, many programs are unaware that some of their students will have this background when they take their discipline specific design courses. It is too early to determine the impact this course has on upper-level programs, but some suggested reinforcement of course material would occur through professional minors, junior design, and senior design / capstone courses.

In summary, Introduction to Project Management and Engineering Economics contains critical topics that should be common to all undergraduate engineering majors not only for the Fundamentals of Engineering Exam or accreditation and aspirational outcomes, but also for broad application in many fields. It is an area that has an opportunity to grow and add relevance to engineering programs for the importance of decision making, entrepreneurship, and technology innovation.

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