Integrating Costing into an Engineering Economics Course

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Introduction

The Engineering Technology department at Tarleton State University has been working with its industrial partners for over 20 years to allow students the opportunity to engage in real world projects during their senior capstone projects. Over the past few years, the projects have increased in complexity and have shifted from facility layout and safety based projects to now include tool and process design, with the added benefit that many of the companies are taking the projects and implementing them at some point after students have completed the projects and graduated. Often, the students' cost estimates come back up in the process of the companies selecting the projects for inclusion in their work load.

A topic of discussion with some of our industry partners has been in regards to the economic analysis students have provided on their projects. Many of the projects showed that our students are technically competent to perform the design analysis required for the projects but the students' costs and estimates of the work required have not always been complete. Because the economic data from the senior projects was not controlled, two of the junior design courses were selected to evaluate how the students performed on the economic analysis, both from deciding on design criteria as well as determining engineering and manufacturing costs for the projects. There is evidence of similar work by others in their engineering economy courses [7] as well as the discussion and use of project based learning to teach the applications of engineering economy [4], [15], [6].

A project that was shared between two of the junior level courses was selected to evaluate what our partners were saying on the economic analysis of the projects. The project included elements of product, process, and manufacturing design. There were several design criteria that were requested by the customer but one of the critical requests was in regard to costs. This project allowed students to see courses that they thought were unrelated were actually interrelated and that economics and money is core to all of them.

The project was composed of six main groups of 6 to 7 students per functional group. During the design phase of the project, student projects were evaluated by the professors to see how they incorporated engineering economic analysis into the project. This was done by looking at how costs affected material selection, design technique, and estimated budget. In the prototype and production readiness phases, the estimates for the labor and material costs were analyzed to see how the costs were developed. During this phase, the methods students used to determine labor rates, salaries, and vendor costs were evaluated. The last critique of the students' use of economic analysis came in the form of a design review of the product through the use of engineers from an industrial partner. The expected outcome was that the students would be able to provide a legitimate cost estimate of the product. This meant that the method the students followed was an appropriate method and that the costs used in the estimate were reasonable for the processes used.

The results of the project were not as good as expected. In particular, the inability of the students to perform the relevant cost analysis showed us that we needed to re-evaluate how we taught that material. In this paper, the ability of students to provide an economic analysis during their projects is evaluated. The paper is formatted to discuss our reasoning for project based learning in engineering economy in the Background, the layout of the project used to evaluate our industry partners' concerns in the Methodology, a discussion of the results from the project used and how we are addressing any deficiencies found is in the Results, and our next steps are in the Conclusion.

Background

Engineering and manufacturing projects often boil down to the financials when determining which projects will be selected and implemented. To ensure that the correct projects are selected, a valid economic analysis has to be performed. In the early phases of these projects, it is incumbent of the engineering groups to be able to provide reasonable cost estimates to program managers. As is referenced in literature, experience and time often dictate how accurate these estimates will be [10]. For engineers straight out of school, this is an area that often needs to be strengthened because they have very little experience and make errors in what they account for. Many times, the only experience that the engineer may have was as a student in their engineering economics course or in their senior capstone course.

Two approaches seem to have historically been used to teach economic analysis in engineering and technology curricula: traditional lecture and problem based learning. From the literature reviews there appears to be little in the way on how to teach engineering economic methods, especially when it comes to teaching and building the knowledge, skills, and abilities that students need to perform an adequate economic analysis [2]. There are always discussions about how the newest generation of students learn differently than the previous generation.

The traditional method that persists in many engineering economy classrooms is the introduction of theory and problem solving. This method uses the instructor to introduce theoretical concepts and then show how those classroom problems are applicable [3]. During this process, there is a gap between theory and practice because the link between the theory and practice is only discussed and not often reinforced by doing. Raju and Sankar (1999) wrote that the ""Lectures by telling" is the traditional and most widely-used mode of instruction in engineering colleges." [14]. In addition, cultural factors, i.e., cultural changes; students now learn differently; less reading, more visual interaction; less imagination in play, more virtual reality; etc., have meant traditional lectures have become less effective. While it is still possible for students to academically excel, e.g., students in top-tier universities, can be at least somewhat successful, this approach does not address a growing population of students who may be potentially left behind.

The literature lists pros and cons about concepts in engineering economy is taught. Methods used to improve a student's learning include the use of spreadsheets, simulations, and cases. A two year study was conducted to learn about the status of the teaching of engineering economy in engineering and found evidence of spreadsheets, projects, and case teaching amongst those whom were involved in the survey [9]. The "lack of focus in real-world problem" still remains in the areas of science, technology, engineering, and mathematics [17]. Hartman (1999) discussed some of the disadvantages that students may see when they actually face economic decisions in the real world setting. This included that the efforts for improving how engineering economy is taught, specifically cost analysis, has not been advancing. Suggestions for teaching cost analysis and the evaluation of alternatives in engineering economy in undergraduate courses were included in Hartman's discussion.

Prince and Felder (2006) classified two different teaching methodologies; deductive and inductive. Deductive teaching is traditional lecturing whereas inductive teaching is used to expose students to scenarios where the student solves a problem typical of a real situation [13]. One instance of teaching real world situations is through the use of cases. Case teaching has proved to be a greater asset to students than traditional lectures [7]. Kim et al argue that case use in the classroom provides students the opportunity to develop "high-order reasoning skills." The authors supported the use of cases in classroom because "students can get involved and can learn by doing." [7]

Typical engineering and technology curricula include only one course in economic analysis. In addition, the first opportunity to apply economic analysis in capstone courses comes too late in the students' coursework. More practical use of the economic analysis tools is needed before asking the student to decide upon and apply the various economic analysis tools in a real life situation. One of the potentially more productive types of projects that students can learn from is their capstone course, particularly if they get to interact with an industry partner. From the economics standpoint, students see the tools in use and often see multiple tools used to tell a more complete story. The various companies use the tools in their own specific manner and will often dictate how they want specific data reported back to them during the project [4].

Methods

To mimic the initial project, a product was selected that students would not necessarily have common knowledge of the manufacturing processes used. In this case, a composite structure was selected for the students to perform the cost analysis for. It included multiple steps and multiple processes to manufacture. To aid the students, additional lectures and exercises were included for them to have a better understanding of how to do cost analysis and what the expected outcomes should be. The lectures borrow heavily from SME's *Realistic Cost Estimation for Manufacturing*. This allowed for additional content in life cycle costing, product costing, estimating, cost analysis of parts for manufacturing, and further discussions and examples of direct and indirect costs and overhead.

To understand the product, they were required to interview other students in the composites course in order to know how much time and what types of materials would be needed to manufacture the product. Students were also provided the drawings and work instructions necessary to build the product.

The students were required to submit a detailed cost analysis. After their detailed cost analysis was performed they were provided the actual costs of the product and asked to reconcile the differences between their estimated costs and the actual costs. The students were measured on the accuracy of the cost analysis, their ability to rationalize their cost analysis, and their reconciliation of the differences between the estimates and actuals.

Results

The results of the project are expected to show improvement in the students' understanding and skills in performing cost analysis. Preliminary results show that students can look up and bring in material costs. These costs have included taxes and some recognition of shipping and delivery for the appropriate materials. It has not included price breaks for quantities of materials and, as expected, does not include negotiated economies of scales. Labor costs still show that work needs to be done to increase the students' understanding behind estimating labor, both for the initial estimates and the resulting standard hours.

The students' reconciliation of the costs also show improvement. There is a better understanding of the costs and why the students did the work that they did. They utilized the drawings and work instructions to identify the material costs. They were able to explain how they came up with the labor costs and through discussion they were able to explain why they were off and what they would have done differently to get a more accurate cost. Many of the students turned to using spreadsheets to build and track their costs and were able to quickly modify their existing work.

Conclusion

Projects are often difficult for professors to implement in courses due to any number of reasons but their payoff can be tremendous to students and faculty. Besides giving the students an introduction to what they may potentially see in the "real" world, it also allows the professor a vehicle to see what topics are understood by the students and where changes to the curriculum can be made to improve the program.

In this case, we found that the students were not learning and retaining the materials that we believed they were. Most students pass the exams and turn in their homework, but as expressed in the Ryan study, "Students have been conditioned to handling structured problems..." [15]. Students tend to rise to perform at the levels we expect them to perform at. By adding in some abstract thinking, we break up the structure that they've come to expect. By modifying the project in our engineering economics course, we believe that the students will be more accustomed to having to sort through data so that they can find information more easily.

It was also recognized that students do not necessarily understand the reasons behind nor do they know how to look at an economic analysis after it has been implemented. As many of our partners implement and utilize the capstone projects, it is important for our students to understand how the projects are evaluated so that they can conduct a better analysis of the projects in the beginning. As we continue to look at our courses and implement projects, we will continue to bring more examples into the course.

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