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Teaching Engineering Economics through Role Play in a Senior Design Class

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Work-in-progress: Teaching Engineering Economics through Role-Play in a Senior Design Class

ABSTRACT

This work-in-progress study analyzes students' performance on a carefully chosen test question over two years, revealing concerning results regarding key learning objectives. The traditional chemical engineering curriculum exposes students to the concepts of engineering economics only during their final year, potentially leading to misconceptions due to limited exposure. To address these issues, a teaching technique was implemented that involved graded in-class problems and role-playing scenarios focused on a ride-share venture. This work outlines the problem, the pattern of the mistakes, and the interventions. Preliminary results indicate some improvement in the test score, suggesting potential effectiveness of the interventions. However, significant further analysis and data collection may be necessary to understand the challenge and offer better solutions.

1. INTRODUCTION

Engineering economics is a critical component in senior design courses within chemical engineering programs. This significance is underscored by ABET's requirement for engineering graduates to integrate economic considerations into their capstone designs [1-2]. Despite its significance in both the curriculum and real-world applications, students in chemical engineering programs often go through economic concepts only during their final year when they take Engineering Economics as part of their senior design course. The limited exposure time and absence of other contexts can result in a less comprehensive understanding of engineering economic analysis, potentially leading to misconceptions. Previous research has explored various teaching strategies to enhance students' grasp of engineering economics, such as the use of concept inventories [3], employing Excel for teamwork and financial modeling instruction [4], and incorporating real-world examples in the teaching process [5-6].

In this study, we analyzed the students work for a test question over two years, providing insights into their thought processes. Building on the analysis, two teaching techniques were employed: (i) selected in-class problems (for grades) similar to concept inventory questions, and (ii) engagement of students in role-playing scenarios centered around a business proposal. In-class written assignments were reported to improve students' ability in problem identification and interpretation [7]. Additionally, the integration of business concepts into the engineering classroom has previously shown significant positive impacts on student learning [8]. Furthermore, role-playing naturally gamifies the learning scenarios, stimulating interest and motivating students to problem-solve and learn. The game also positively impacts teamworks [9-10].

The role-play idea we studied involved developing a business proposal by the students for a ride-share venture to attract investment. The overall hypotheses were that while the graded in-class problems would enhance student participation and active learning, the role-playing game would provide students a nuanced understanding, potentially addressing the lack of understanding in this particular context.

2. STRUCTURE OF THE COURSE

The course primarily focuses on applying engineering principles to the preliminary design of a chemical process, emphasizing environmental considerations and conducting economic evaluations from a business perspective. It is offered once in a year (in the Fall semester) at author's institution. The course utilizes textbooks and reference materials [11-13] to introduce students to concepts related to process synthesis and economic analysis. Additionally, supplementary materials are provided as needed to enhance the learning experience.

Table 1 outlines the general structure of the course, while the topical outline of the engineering economics section has been expanded for the scope of this paper. The engineering economic section consist of four major subsections: cost estimation, time-money relationships, comparing alternatives, and profitability analysis. These topics are typically covered in the second half of the semester over a period of about six weeks.

Table 1. Topical outline of the course.

PROCESS DESIGN	**ENGINEERING ECONOMICS**			
	Cost Estimation	**Time-Money Relationships**	**Comparing Alternatives**	**Profitability Analysis**
- General design considerations - The Structure and Synthesis of a Process - Process Flow Diagram - Design, and sizing of: o Material Transfer and Handling Equipment o Heat Transfer Equipment o Reactors o Separation units - Process optimization o Process parameters optimization o Energy optimization.	- Estimation of Capital Cost (FCI) - Estimation of Manufacturing Cost (COM)	- Simple and compound interests - Nominal and effective interest - Present and Future Values and equivalences (P/F, F/P) -Annuities and equivalences (F/A, A/F, A/P, P/A).	- Basic concepts of comparing alternatives - Cost benefit analysis o General analysis o Cases when useful lives are equal or unequal in the study period.	- Estimation of o Depreciation o Tax - Cash Flow o Before tax o After tax - Net Present Value (NPV) - Rate of Return on Investment (ROROI) - Payback Period (PBP) - Dealing with uncertainty (sensitivity analysis)

3. PROBLEM IDENTIFICATION AND INTERVENTION

3.1. Problem Identification

In our everyday life, we experience a myriad of problems that varies in diversity and complexity, making precise classification challenging. However, Newnan et al. categorized the economic problems in three categories by their level of complexities [14]. According to them, *simple problems* involved straightforward decisions, such as choosing between cash and credit cards for a purchase or deciding whether to buy a semester parking pass or use parking meters. *Intermediate problems*, on the other hand, require a higher level of economic analysis to make decisions. Examples include deciding whether to buy or lease a car from a purely economic perspective or selecting a desired product from multiple options. Lastly, *Complex problems* require not only economic analysis but also encompass political and human aspects. An example provided by the authors was Mercedes-Benz's decision to build a car plant in Tuscaloosa, Alabama. This decision-making process extended beyond mere financial considerations and involved government regulations and reactions from other local industries.

In this study, the problem selected for the test that can be categorized as lower intermediate complexity. It was tied to ABET Student Outcome 2, where students should be able to apply economic principles to produce solutions and make decisions. The problem statement focused on a fictitious company's (CBEE Chemical Company) investing in Pickup Trucks for business. The problem statement on the test was the following:

"CBEE Chemical company invested (i.e. purchased) in a Pickup Truck for $50,000 five years ago to transport their products. The Truck was expected to have a service life of 10 years at the time of purchase, with an expected salvage value of $4,000. There is a $500 annual maintenance cost required for the Truck throughout its lifespan.

(a) What has been the equivalent annual operating cost (EAOC) for the Pickup Truck based on the above information? Assume an effective interest rate of 10% per year.

(b) If the service of the Pickup Truck will no longer be required in the future, at what price the Pickup Truck must be sold ***now*** *to recover the remaining invested capital?*

(c) Comment on the resale value of the Truck. What percentage is it compared to the original price?

You must show your work with a cash flow diagram(s)."

The problem aimed to assess the students' work through the following three performance indicators (PI):

1. Draw a cash flow diagram by interpreting the time of references.
2. Recognize and apply the appropriate time-money relationship to estimate the equivalent annual cost for the investment.
3. Apply appropriate analysis to calculate the resale price.

Analyzing students' work from Fall 2022 class revealed concerning results. While students drew the cash flow diagrams correctly, the following issues were observed:

1) 25.8% failed in PI #2 (i.e. could not calculate the EAOC)
2) 84.4% failed in PI # 3 (i.e., students estimate the resale price)

Their work also revealed some patterns of mistakes that needed further analysis to realize if there were any potential misconceptions. Two anonymous examples of students' work are presented in

Figure 1 that shows: (i) lack of understanding of the reference time pf cash flows, and (ii) lack of understanding of cost of service or unused service life.

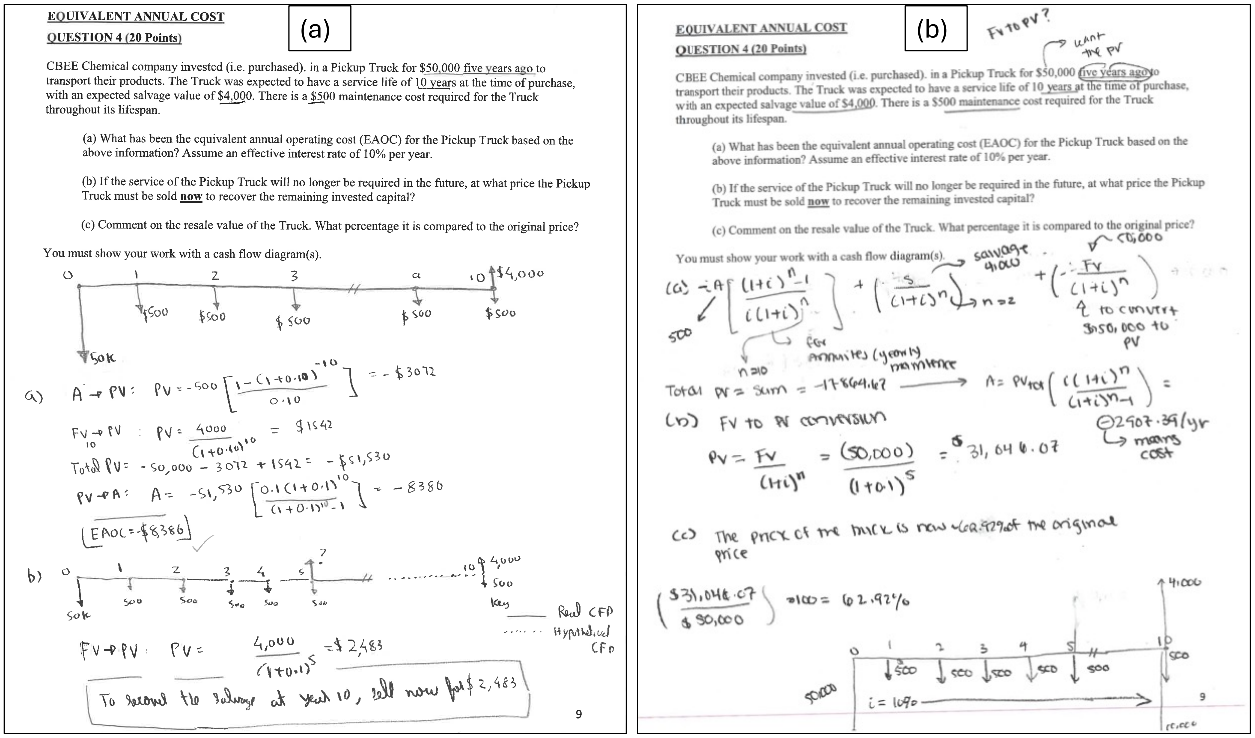

Figure 1. Two examples of students' work: (a) calculated EAOC correctly, both (a) and (b) drew cash flow diagrams correctly, however, took interesting approaches to estimate the incorrect resale price.

3.2. Intervention

Two teaching techniques were implemented as interventions in the class in Fall 2023. First, a series of carefully chosen problems were solved during the lecture, and these problems were graded to ensure students took them seriously. This encouraged students to complete the work during the lecture with fellow students, enhancing active learning. Second, a role-playing game was utilized. The activities and outcomes are described below:

Graded In-class Problems. The in-class problems were designed to align with the concept inventory questions and learning objectives, integrating them into the final course grade. Grading criteria, which considered both the level of effort and accuracy, were shared with students. Despite the expectation that students would take these assignments seriously due to their impact on grades, it was surprising to find that only an average of 69% of students (n = 32) submitted their work immediately following the class. Additionally, among the students who did submit their work, the class-average of the assignments ranged between 65-85%, as shown in Figure 2. The data clearly indicates significant room for improvement in future semesters in both student participation and the accuracy of their work.

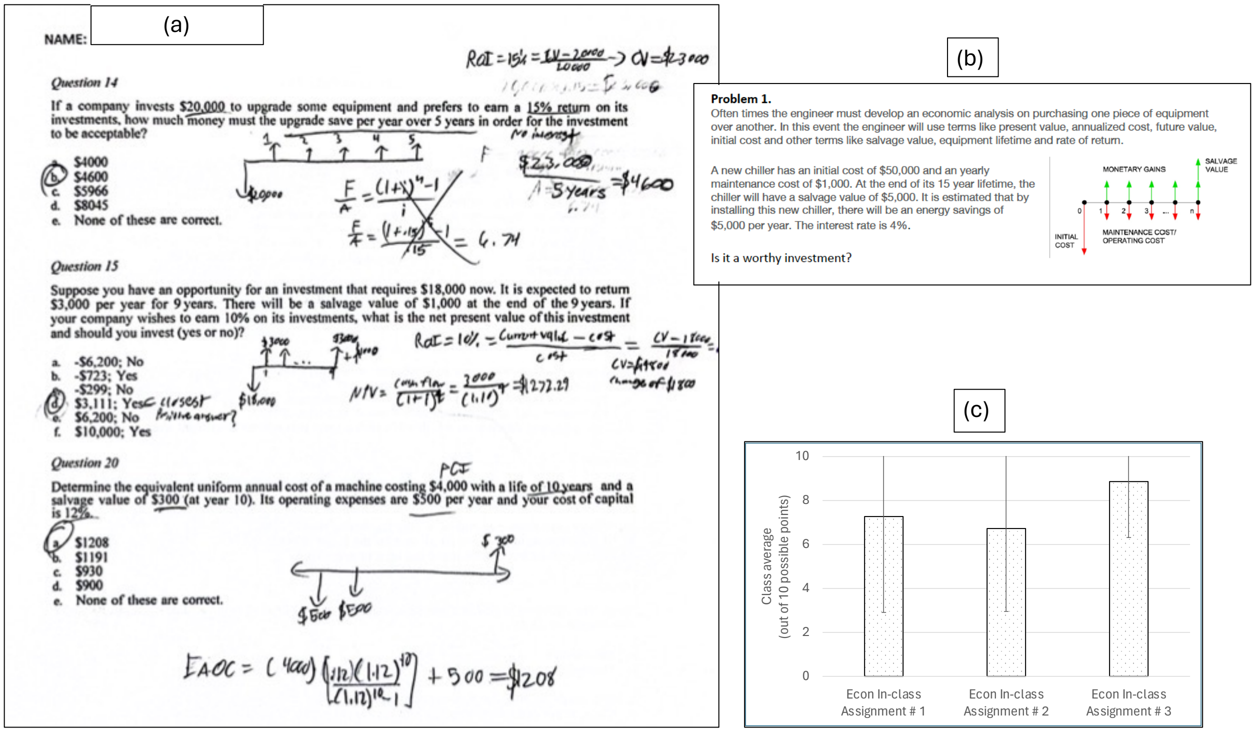

Figure 2. Examples of in-class problems based on: (a) concept inventories [3], (b) cost-benefit analysis; (c) average grades in three assignments.

Role-playing activity: In this role-playing game, students were tasked with assuming crucial roles within a ride-sharing car business. The challenge was to collaboratively develop a proposal for running a profitable ride-sharing venture within a fixed budget. Their task involved estimating all cash flows, taxes payable, and net profit. As the instructor, my objective was to familiarize students with the concept of diverse cash flows and instruct them on accounting methodologies to estimate tax and profitability within the game's context. Table 2 provides an overview of the various roles undertaken by the students.

Table 2. Roles played by students and their job descriptions.

Roles	Job Descriptions
Investors	Maximize returns on your investment and ensure the company's financial stability. Work closely with the CEO to assess profitability and financial health of the investment.
Chief Executive Officer (CEO)	Lead the company to success. Collaborate with everyone, and the Accounting Specialist to ensure financial transparency and sound accounting practices.
Customer	Represent the voice of the customers, providing feedback on price etc.

IRS Representative	Enforce tax regulations and ensure compliance with tax laws. Collaborate with the CEO, and the Accounting Specialist to address tax-related challenges and opportunities.
Accounting Specialist	Their role was crucial in tracking the company's financial performance and ensuring profitability. Maintain accurate financial records, prepare profitability statements, and analyze key financial metrics.

After implementing this intervention and comparing the formative assessment data with the previous cohort (a control group; Fall 2022 class, n = 59), improvements were observed in the performance of the treated group (Fall 2023, n = 32). Weekly quiz scores saw an increase of approximately 18%, and the average grade on the mid-term exam rose by about 11%. These improvements trend were satisfactory and we attribute this to increased active learning and participation facilitated by in-class problem solving.

However, as illustrated in Figure 3, analysis of the final exam question that prompted this study indicated only an approximate 10% improvement in two performance indicators (PI 2 and 3) compared to the preceding offering. This suggests that there may be confounding factors at play, necessitating further investigation. Since this study is ongoing, additional analysis and data collection are crucial to fully comprehend the results and refine our teaching strategies.

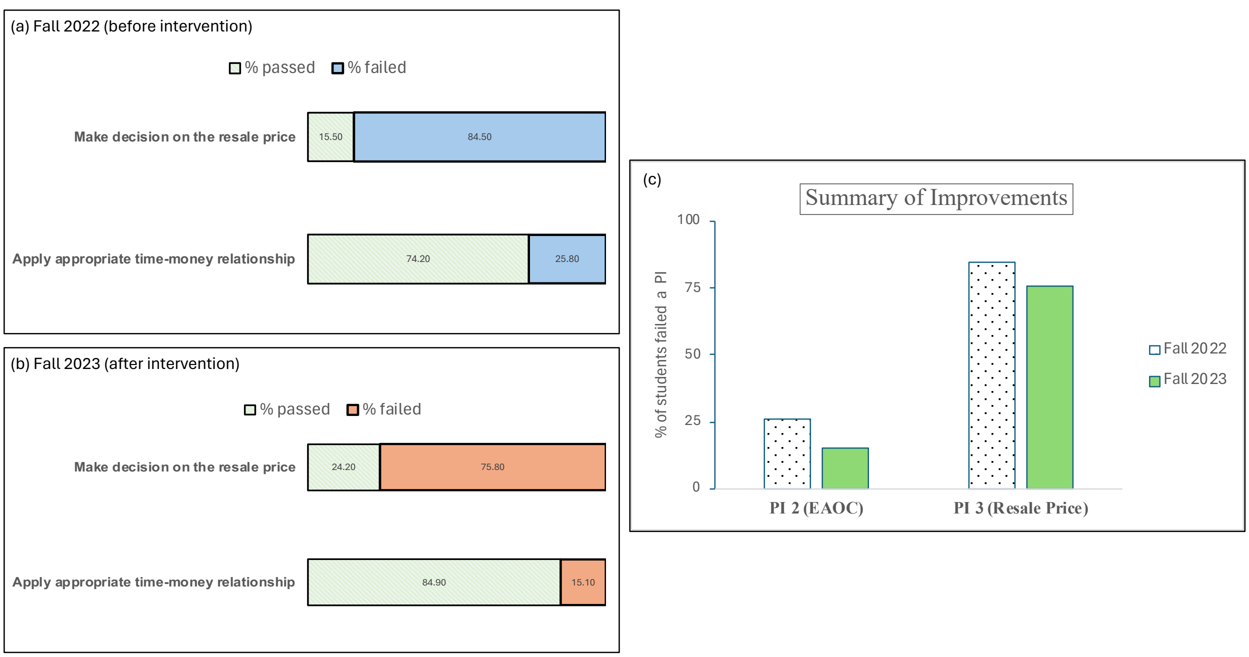

Figure 3. Percentage of students passed and failed each performance indicators before and after the intervention.

In conclusion, the identification of issues, the implementation of targeted interventions, and the subsequent assessment of student performance provide valuable insights into enhancing the teaching of Engineering Economics. As this study represents an ongoing effort, continuous refinement and evaluation are crucial to optimize the educational outcomes for future engineering students.

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