Interactive Simulation for Teaching Engineering Economics

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Abstract

A game that simulates the economic decision-making that occurs in running a company has been developed and integrated, as a semester-long project, into a senior/graduate course on engineering economics. The game challenges students to not only learn engineering economic principles such as present worth, rate of return etc., but also to use them to make realistic economic decisions in a competitive setting. This creates a fun, engaging environment for active learning of the material and provides a framework that illustrates the importance of the material. In the game, each student starts with an identical sum of money, and is presented with a list of investment opportunities. Students apply the principles learned in class to the possible investments and make decisions such as how much to bid on a particular mine or factory in an auction. Additional investment opportunities are introduced weekly throughout the semester, with the required analysis growing in complexity as the students' knowledge base increases. The game is interactive in nature- for example; the owner of a factory must negotiate the price of raw materials he/she needs with the owner of a mine. Student response to the exercise was extremely positive; they found it both enjoyable and beneficial.

Introduction

Recent texts on engineering economics[1-4] all stress that the practical purpose of engineering economics is that it empowers the engineer to make sound investment decisions. End of chapter homework problems in these texts can be broadly placed to two categories: strictly computational problems, such as "calculate the rate of return of this cash flow diagram," and questions such as "should the equipment be replaced or not?" that ask the student to make a practical decision. The inclusion of some problems from the latter category is crucial both because they provide the more thorough test of the student's understanding of the material, and because they underscore the practical value of the material.

This paper describes a game that simulates practical economic decision-making. Students started the semester with $10,000 and "ran their company" for the semester, applying the principles learned in class to a series of investment possibilities presented by the instructor. The game thus filled the role of the traditional "decision" homework problems, but had some additional goals and benefits:

- It created a classroom environment that was fun, relaxed and informal while still being
- It allowed students to see first-hand some business world phenomena, such as monopolies, that aren't necessarily part of the traditional engineering economics course.
- It exposed students to some human challenges in economic decision-making that traditional homework problems would not.

These are discussed further in the Assessment of Simulation section below. The game described in this paper was integrated into a senior/graduate course on engineering economics in the spring of 2001. The following sections describe the game in more detail, discuss how it was integrated into the class, and summarize student response.

Description of Simulation

This section gives an overview of the mechanics of the game. The full simulation included over twenty distinct investment opportunities so this discussion is confined to illustrative examples.

Possible Investments

Each student started the game with $10,000. The semester was divided into twenty turns. The stated goal of the game was to finish turn 20 with as much cash as possible. Thus, all investments had a fixed, known planning horizon (and no salvage value unless otherwise stated). Students were given the option of placing money in a savings account- with no minimum or maximum balance and no restrictions on frequency/size of withdrawals- at 5% interest per turn. In addition, students had the option of borrowing an unlimited amount of money at 15% interest, compounded every turn.

Most investment opportunities were introduced into the game through auctions. Students received handouts describing the specifications for each of the assets that would be auctioned off in future class periods. They then applied present worth analysis to these assets and prepared a bidding strategy. Auctions were carried out during class using a sealed-bid format; each student wrote down one bid and then all bids were revealed simultaneously. The asset was then awarded to the highest bidder at his/her bid price. Each student then turned in his/her bids and an explanation of the bidding strategy, with supporting calculations, to the instructor for grading. Thus, all students had a fair opportunity to demonstrate their ability to apply the course material to practical examples, whether they ultimately won anything in the auction or not.

The complexity of the required analyses increased throughout the semester, reflecting new topics covered in class. For example, one of the first investment opportunities presented to the class was the theater, with these specifications (taken directly from a class handout):

> It costs $200 (this *includes* routine maintenance and security) to run the theater for each turn it is open for business. It takes a while for a theater to gain popularity. A theater will only bring in $75 of revenue in its first turn of operation (for a net loss of $125 that turn.) However, while the cost of running the theater remains constant, the revenues will double each of the next four turns, thus reaching $1200 in the fifth turn of operation. The revenue will increase to $1500 in the sixth turn of operation and remain constant at that level for the rest of the time the theater is open.

This investment has a single set of specifications with no uncertainty or risk. Present worth analysis is straightforward, and involves uniform series, geometric gradient series and the concept of equivalence. In a later example, the class had the opportunity to purchase an island, and had several options regarding how to utilize the land if they purchased it (various expenditures that could attract tourists etc.) Consequently they had to apply incremental analysis to determine the best use of the island before deciding on an appropriate bid.

Still later, risk and uncertainty were introduced through several examples. The distinction between risk and uncertainty is that "risk" describes a situation in which multiple outcomes are possible but the probability of each is known. Risk was introduced into the game through examples such as this:

> A gold mine produces $300 of revenue per turn, starting the turn it is purchased, and continuing for an unknown period determined as follows. Each turn, the owner of the gold mine must roll two six-sided dice. If the total of the two dice is seven, the mine yields $300 that turn but is worthless thereafter. On all other dice rolls, the mine remains productive the next turn and the dice are rolled again.

"Uncertainty" describes a situation in which multiple outcomes are possible but the probability of each cannot be quantified. This was illustrated in the game through opportunities such as mines and factories. The owner of a mine could make money only by selling raw materials (iron, wood, clay or stone) to the owners of factories. Factory owners were permitted to buy these raw materials for $5/unit in unlimited quantities from the instructor, however, mines were capable of producing up to 300 units/turn of these same materials for $100 + $2/unit. Thus, factory owners could buy these same raw materials from student-run mines at prices considerably below $5 and both parties would benefit. However, because the mines and factories were all auctioned off on the same day, it was impossible to negotiate *exact* terms prior to bidding on a mine or factory- one would not even know who to negotiate with. Further, there was more than one of each type of factory and mine in the game, and the total capacity of all mines was in some cases greater than the total demand for that raw material, and in some cases less than the total demand. These facts introduced elements of competition that made these investment opportunities more realistic and more challenging to analyze.

Risk and uncertainty were then coupled through an example involving the manufacture of drugs in chemical plants. The demand for each of the products manufactured in factories was a function of selling price but no chance was involved- the "demand curve" was constant throughout the simulation. For drugs, however, demand was not constant but was a uniformly distributed random number within a known range, illustrated in Table 1. Thus, aspects of this investment opportunity were subject to rigorous probability analysis, but because of the reliance on raw material providers, there was also the same sort of uncertainty found in the analysis of factories.

The simulation also included a 25% income tax rate that only applied to sale of a handful of specific products, which did not become available until halfway through the simulation. Thus,

early examples could be accurately analyzed with a tax-free analysis, but later examples required an understanding of after-tax analysis and depreciation.

Table 1: Demand per turn for each of four drugs manufactured in game.

Selling Price	Newellium	Marchesium	Heskethium	Farrellium
$11	400-440	300-500	100-600	0-500
$12	360-400	250-425	100-450	0-450
$13	320-360	200-360	100-350	0-400
$14	280-320	180-330	100-250	0-350
$15	240-280	160-300	100-200	0-300
$16	200-240	140-270	100-150	0-270
$17	160-200	120-240	100-120	0-240
$18	120-160	100-200	100	0-210
$19	80-120	80-160	90-100	0-180
$20	50-90	60-130	80-100	0-150
$21	30-60	40-100	60-100	0-120
$22	20-40	20-70	40-100	0-90
$23	10-20	0-50	20-100	0-60
$24	0-10	0-30	0-100	0-30

Turn Sequence

The class met once a week on Wednesday evening. In general, one turn was processed each week. On Tuesday, each student turned in a set of instructions, with rationale, describing his/her company's activity for that turn. This would include production rates in mines and factories, purchases from other students, etc. At the beginning of class, students received from the instructor written summaries of the status of their companies. These gave previous bank balance, expenses, revenues and interest for the turn, new bank balance, and a list of current assets. These summaries were also posted on the course web site. This was important because of the interactive nature of the simulation; students needed to be able to keep track of who owned what.

Any in-class activities, such as auctions, were considered part of the next turn. So, for example, often a student would spend more during a particular auction than he/she had in the bank. That student would have until instructions were due the next Tuesday to borrow money from another student, sell something or otherwise raise the cash. Otherwise his/her bank balance would be negative for that turn and the 15% loan interest rate would apply.

Evaluation of Student Work

The game was integrated into the course as a semester-long project, equivalent to one exam grade. The policy stated at the beginning of the semester was that the student who had the most money on Turn 20 would automatically receive an A, but that this would not necessarily be the only A given. All other students were graded on their demonstrated understanding of the subject matter, regardless of the final dollar amount. The intent of this system was to provide incentive for the students to take the project seriously without creating a system in which students benefited

from each other's mistakes. As hoped, the competition among the students remained spirited but friendly and fair.

Rationale for Current Format

An important decision in the creation of the game was whether to use real case studies as examples. It is clear from the preceding descriptions that all specifications for this project were in fact contrived, with no attempt to make the dollar values realistic. Indeed, in most cases, the products themselves are imaginary- the "drugs" in Table 1 are named after Rowan Engineering professors, and among the products manufactured in factories were "widgets," "gadgets" and "gizzmos." The rationale for framing the game in this manner had several facets:

- The instructor wished to insure that students had no basis for making decisions other than the given specifications and their knowledge of engineering economics. A student might know intuitively which of four real products is the most lucrative, but has no such basis for "widgets" and "gadgets," and thus cannot make good decisions without learning and applying the course material and doing calculations.
- The class was open to students from a variety of disciplines and backgrounds and discipline-specific examples could give some students an unfair advantage in a project that counted for one full test grade.
- Frivolous examples such as "purchasing a pirate ship to search for buried treasure" gave the class a relaxed and humorous tone, engaged the student's interest and, ultimately, demanded an understanding of economic principles that was as thorough as a practical example.

Naturally, realism in such activities has advantages too. In teaching operations management, Hartman and Galati[5] used a business game, adapted from Theusen[6], in which students ran companies that manufactured CD racks. This exercise, which was also very well received by students, examined many practical issues such as location of facilities that the game described here did not touch on.

Assessment of Simulation

The game was designed to provide a forum for active learning of the principles of engineering economics. It was highly successful as evidenced by the student response. When asked if the project was "helpful for the understanding of the subject matter" students assigned an average score of 4.83 on a scale of 1-5. Specific comments include:

> I took this class to learn more about economics, and what better way to learn than by actually doing it. I thought the project was an excellent idea. It helped me to apply economics in a way that I had never done before.
>
> The simulation was very useful. The teacher tricked us into doing homework by having us work on investment opportunities that were related to the lecture for that week, very clever.

> This course was great and well taught. The project added excitement to an otherwise dry subject matter.
>
> This was the best course I've taken. The project is incredible because… if I can do the project I am 100% sure to understand the material.

The main suggestions for improvement were requests for more specific feedback. Students liked the fact that a single grade was assigned for the semester but wanted feedback on how they were doing more frequently throughout the semester. There was also one student who suggested making the project more related to current events.

There were some additional benefits that were evident during the semester. One point was that the project exposed students to some real-world phenomena that are not necessarily covered by a traditional engineering economics course. The best examples were price-fixing and monopolies. The game contained no rules against these practices. The instructor's approach was to let them occur naturally and then discuss, with context, the negative consequences they had on the economy as a whole.

Another issue was that students got a taste of how economic realities can be at odds with human instinct. Sunk costs- in other words, money that has already been spent- have no role in an economic analysis. One should analyze the options currently available without being influenced by the specifics of how the current situation was reached. For example, selling an asset for less than the price one paid can be a correct decision, even though it may be tantamount to admitting a previous mistake. Students understand this readily enough but during the game found it difficult to follow the practice.

Summary

A game simulating economic decision-making has been devised and integrated with great success into a course on engineering economics. The examples in the game were contrived but were effective in exposing the students to realistic principles. Student response to the game was extremely favorable. It was both an effective and enjoyable tool for helping the students learn traditional engineering economy topics and also demonstrated some phenomena that are probably not covered in most engineering economy courses.

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