Teaching Engineering Economy Principles Using a Web-Based, Interactive Simulation

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Abstract

A game simulating realistic economic decision-making was devised and integrated into a Rowan University course on engineering economics in 2001 and 2002. The activity was extremely well received and the NSF provided a CCLI grant for development of software that automates the game, making it suitable for widespread dissemination. In order to test this software, the game was integrated into an engineering economics course at the University of Kentucky during the fall 2003 semester. This paper will describe the game itself, the software, and their use in the classroom.

The game itself challenges students to not only learn engineering economic principles such as present worth, but also to use them to make realistic economic decisions in a competitive setting. Each student starts with $10,000, 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 item in an auction. Additional investment opportunities are introduced weekly throughout the semester. The required analysis grows in complexity as the students' knowledge base increases. The game is interactive; for example the owner of a factory must negotiate the price of raw materials he/she needs with the owner of a mine.

The software is web based, written using a combination of standard HTML and Active Server Pages with a Microsoft Access Database. Students use the software to manage their company, taking such actions as placing bids in an auction, borrowing money from a bank, purchasing raw materials, and setting production rates for mines and factories. Students can also use the software to access reports on the current status of their company, viewing lists of assets, the current bank balance, etc.

In the fall of 2003, the game was integrated into a course at the University of Kentucky, with 10 senior chemical engineering students participating. In general the activity was popular with the students. The game and software are currently being modified in response to feedback obtained from this test.

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 into two categories:

1) Strictly computational problems, such as "calculate the rate of return of this cash flow diagram," and
2) Questions such as "should the equipment be replaced or not?" or "Which of these three possible designs is best?" 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.

In the spring 2001 and spring 2002 semesters, an economics game was developed and integrated, as a semester-long project, into a senior/graduate engineering economics course at Rowan University. The game simulates practical economic decision-making. Students started the semester with $10,000 and "ran their company" throughout the semester, applying the principles learned in class to a series of possible investments presented by the instructor. The game thus filled the roles of the traditional homework problems discussed above, but had some additional goals and benefits:

- It created a framework for active learning of the material. Students had to not only learn various economic analysis techniques but also determine which ones were most applicable to the case at hand.
- It created a classroom environment that was fun, relaxed and informal while still being instructive.

This activity was very popular with the students, but very time-consuming for the instructor. With the support of an NSF-CCLI grant, a team at Rowan University developed web-based software, written with Microsoft Access and ASP, that automates the game. The simulation, using a completed first version of the software, was integrated into a course at the University of Kentucky in the fall of 2003. This paper describes the game, discusses the use of the software in a classroom setting, and provides student responses.

Description of Simulation

This section explains the mechanics of the game and provides details about some of the investment opportunities that made up the simulation. A more complete description of the simulation as it was offered in the spring of 2001 and 2002 has been published previously.[5,6]

Possible Investments

Each student started the game with $10,000. The game 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 or 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.

Many investment opportunities were introduced into the game through auctions. Students received a set of rules at the beginning of the semester describing the specifications for each of the assets that would be auctioned, as well as the turn in which it would be auctioned off. They then applied present worth analysis to these assets and prepared a bidding strategy. Auctions were carried out using a sealed-bid format; each student submitted a bid through the web, without being able to see what others had bid. The asset was then awarded to the highest bidder at his/her bid price. Each student then turned in an explanation of his/her bidding strategy, with supporting calculations, to the instructor for grading. Thus, every week, all students had an opportunity to demonstrate their ability to apply the course material to practical examples, whether they ultimately won anything in the auction or not.

Other investment opportunities were introduced as fixed-price options (e.g.- do you wish to buy this for $1000, yes or no?) rather than through auctions. For example, in the "municipal bonds" investment, students were given a list of several bonds with a variety of purchase prices, maturity values and maturity dates, and told they could purchase these bonds in any combination, but could not spend more than $2000. The purpose of the $2000 restriction was to create an example for which students would be rationing limited capital, regardless of their bank balance at that particular point. Other "fixed-price" investment opportunities introduced later included pirate ships, fishing boats, and ice cream trucks. Such examples were important to the game because they meant every student would definitely have the opportunity to make investments- relying on competitive auctions was not a necessity.

The complexity of the required analyses increased throughout the semester, reflecting new topics covered in class. For example, risk and uncertainty were introduced through several investment opportunities. 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 $500 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 "craps out;" it yields $500 that turn but is worthless thereafter. On all other dice rolls, the mine remains productive the next turn and the dice are rolled again.

Examples like this were used as the first introduction to risk because the rolling of dice was a familiar everyday activity and students can readily determine the probability of rolling a 7. Later, pirate ships were introduced into the game to illustrate more practical probability distributions. Students could purchase treasure maps that would allow them to "find a buried treasure," the value of which would be determined from a uniform probability distribution.

"Uncertainty," by contrast, 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, stone or crude oil) 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.

Turn Sequence

The semester was divided into 20 turns. The first 11 turns were processed one per week. At any time during the week, students could log in to the game. The "main" page, part of which is pictured in Figure 1, is a password-protected page. It tells the student which turn it is and how much money he/she has, and provides a menu that allows the student to see a summary of his/her assets and perform actions necessary for the running of his/her company, such as:

- make bids in auctions
- set production rates in mines or factories
- propose transactions with other students
- respond to proposals from other students
- borrow money
- purchase raw materials

Some actions, like purchasing raw materials, take effect instantly- the student can immediately see their bank balance decrease and the new material added to their warehouse. Other actions only take effect at the end of the turn.

Every week, on Wednesday morning, the turn was processed. This simply involves the instructor running a script that performs actions like these:

- Processes the auctions, awarding the assets to the winners and deducting the money spent from their bank balances.
- Virtually rolls the dice to see if the gold mines continue operating
- Checks to see if anyone sent out a pirate ship or fishing boat, and determines the outcome if so
- Determines the number of orders that all factory owners have to fill in the following turn
- Calculates interest on all bank accounts

Thus, this script produces an updated summary of each student's assets as of the end of the turn. The students can then access this information through the web site and begin work on the next turn.

After turn 11, no NEW investment opportunities are introduced. Turns were processed three times a week for the last nine turns. This accelerated schedule was considered reasonable because the students by this time were familiar with the software, and because at this stage they were simply maintaining the assets they had acquired, with no new investments to analyze. The purpose of these turns is largely to allow students to use assets acquired late in the semester. If there were only 12 turns, an asset obtained in Turn 11 would have little use, and so the activities late in the semester would have little impact on the outcome of the game and might be ignored by students. This would be unfortunate in that every investment opportunity in the game was designed to illustrate at least one critical concept. Processing 9 turns rapidly at the end of the semester ensures that all assets would have a meaningful useful life.

Integration of Simulation into Course

The economic simulation described here was created at Rowan University and integrated into a senior/graduate elective on engineering economics. In the Fall of 2003, however, it was used in a senior, chemical engineering course on engineering economics at the University of Kentucky. This was both the first time the game was administered using the software, and the first time it was used by a professor other than the creator of the game.

Participation in the simulation was a semester-long project worth 25% of the student's grade. However, the students were not graded strictly according to their final bank balance. Grades were based upon weekly submissions to the instructor in which they explained their decisions in running the company that week and the reasoning and calculations behind each. Thus, each student had a weekly opportunity to demonstrate his/her understanding of the course material. The basis of the grade was not success or failure, but the soundness of the approach. For example, if two students bid $3250 and $3255 respectively on a particular item, with essentially identical reasoning and calculations, then only the higher bidder would actually receive the item in the game, but both would be viewed equally for grade purposes.

Note, however, that the software does not require this or any other grading scheme. It facilitates running the simulation by collecting and processing students' instructions, but does not evaluate the students- any individual instructor using the software can choose whether, and how, to grade the activity.

Assessment of Simulation

The game was designed to provide a forum for active learning of the principles of engineering economics. In the spring 2001 and 2002 offerings of the course, there was no traditional homework; the only required activity outside of class was participation in the game. The game was found to be an effective and fun way to fill the role of traditional homework problems. There were some additional benefits to the project that became evident during these two semesters. 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. Inevitably, people engaged in these practices, and in fact during one semester some students

went so far as to attempt to organize a trade embargo against the student who was winning the game. The approach taken was to let these things occur naturally and then discuss, within context, the negative consequences they had on the economy as a whole. Thus, the game provided examples that demonstrated why these practices are in reality illegal.

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 doing so may be tantamount to admitting a previous mistake. Students understand this readily enough but during the game found it difficult to follow the practice.

The student responses demonstrate that the use of the game in the spring of 2001 and 2002 was effective. 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. (A total of 19 senior and graduate engineering students from several different engineering disciplines took the course and participated in the game during these two semesters.) Specific comments included:

> "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."

While this activity was popular with the students, and apparently effective, it was also very time consuming. The instructor would typically spend 6-8 hours per week collecting the students' instructions, processing them to determine what exactly occurred, quantifying the results on a spreadsheet, and distributing the results to the students via handouts and the course web site. When the software is used, only 2-3 minutes per week of instructor time is generally needed to process each turn. Naturally, answering student questions and grading materials still required significant time.

Ten senior chemical engineering students at the University of Kentucky participated in the fall 2003 offering of the game. Table 1 summarizes the results of a semester-end survey of these students.

Overall, the response was favorable, though not as uniformly favorable as in the earlier offerings at Rowan. There are several likely reasons for this less favorable response:

- When the creator of the game and the course instructor were the same person, the game was integrated seamlessly into the course. In the Kentucky trial, things were more disjointed. The creator of the game was available to the students only via email, and the course instructor was not always able to answer questions concerning the game.
- This was essentially a beta-test and three bugs were revealed during the course of the semester. Five of the 20 turns were processed incorrectly due to these minor bugs.

While these errors were corrected through manual editing of the database, there was inevitably some frustration on the part of the students.

Despite the difficulties, the students were generally positive. The consensus of the students, as shown in Table 1, was a recommendation that future offerings of the course continue to use the game. It was a generally favorable experience, and should only improve in the future, as the software is currently being revised in response to lessons learned through the beta-test.

Summary

The economic simulation described here has been successfully integrated into a course on engineering economics, using web-based software developed at Rowan University. It was popular with the students as a vehicle for presenting the material in an interesting way and emphasizing the practical value of the material. The software is currently being revised and debugged in response to feedback from students who used it in the Fall 2003 semester. The completion of the software will make the simulation available for dissemination to other universities, and allow its adoption with a minimum investment of time on the part of the instructor.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 0126697.

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Biographical Information

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Table 1: Summary of Student Feedback (5=strongly agree, 1=strongly disagree)

Question	Mean Response
The game helped motivate me to learn the course material.	**3.7**
In order to do well in the game, you needed to have a good understanding of the course material.	**3.9**
I would recommend that future offerings of the course continue to use the game.	**4.1**

Figure 1: Screen capture of "Main" page.