

Teaching Engineering Economics Using a Web-Based, Interactive Simulation

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Abstract

A game simulating practical economic decision-making has been devised and integrated into a Rowan University course on engineering economics. This paper describes the game itself, as well as a software package currently under development that will manage the game. The game 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 actual software is currently being developed through an NSF-CCLI sponsored project. The software will be web based, and will be a combination of standard HTML and Active Server Pages with a Microsoft Access Database. The program is designed to include an easily navigable interface for the student, and web based methods for the instructor to make changes to the overall game as necessary.

Introduction

Recent texts on engineering economics¹⁻⁴ 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.

This paper describes a game, integrated into an engineering economics course as a semester-long project, that simulated 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 role of the traditional homework problems, 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 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 paper describes the game as it was presented in the spring 2001 and spring 2002 semesters, and discusses software, currently under development, that will administer the game with very little time and effort required on the part of the instructor.

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 has been published previously.⁵

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 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 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, 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 revisited” 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, farms, casinos, 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 (taken directly from a class handout):

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 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. 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 randomly, either from a uniform or a normal 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.

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 well into the simulation. Thus, most examples could be accurately analyzed with a tax-free analysis, but later examples required an understanding of after-tax analysis and depreciation.

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 upcoming 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.

Integration of Simulation into Course

The economic simulation described here was integrated into a senior/graduate elective on engineering economics in the spring 2001 and spring 2002 semesters. It was a semester-long project equivalent to one exam grade. The student who finished the semester with the most money automatically received an A, however, this was not necessarily the only A given. All other students were graded 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 described in the following sections will not require this or any other grading scheme. It will facilitate running the simulation by collecting and processing students' instructions, but will not evaluate the students- any individual instructor using the software can choose whether, and how, to grade the activity.

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.”

While this activity has been 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. The authors are currently writing software that will automate all these tasks, allowing instructors at other universities to try this activity with a minimal investment of time.

Web-Based Software Development

The software is being written in ASP, primarily because it is a built in feature of Microsoft Windows and is a common language for developing programs of this nature, and is suitable for interacting with data. Microsoft Access was chosen to create the database that records the assets and actions of all students. Using this environment, a student will be able to view all information regarding his or her company, enter instructions through the use of HTML style menus, and the database will be updated automatically through the ASP scripts.

Tables 1 and 2 summarize the pages that have been written, or are in progress, to date. All of these pages were constructed using a standardized HTML template. Most of the pages listed in the tables are single-function pages that the student can use to either view specific information (e.g., see all the raw materials currently stored in his/her warehouse) or complete a specific task (e.g., purchase a fishing boat.) The “Main” page is essentially a menu that allows the student to navigate to these single-function pages, and access to it is password protected. The “Manager” page, which is also password protected, will only be accessible to the instructor. This will allow the instructor to set up the simulation at the beginning of the semester (e.g.- the number of items available in the economy is dependent upon the number of students in the class) and also has an “end turn” button. The instructor can specify whatever schedule he/she wishes (e.g.- one turn per week ending Tuesday, two turns per week ending Tuesday and Friday, etc.) and simply needs to press this button at the appropriate times. This will run a script that processes all actions for the turn. For example, it compares the bids submitted and determines the winner of any auctions, awards the asset to the winner and deducts the bid price from their bank account, it assesses the interest on savings accounts and loans, and so on.

Thus, an activity that has required 6-8 hours per week of professor time in the past will require only a few minutes with the software, and will not be a substantially different experience for the students. Indeed, the automated approach to managing the simulation, in addition to taking less time, will be less prone to miscommunications and errors than the previously employed system of receiving written instructions from students and transcribing them into a spreadsheet.

Summary

The economic simulation described here has been successfully integrated into a course on engineering economics. 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. Software that administers the simulation is now being developed at Rowan University. This 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.

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Table 1: List of all ASP pages completed to date.

Auction	Indicates what is available in current and future auctions, allows students to enter bids.
Borrow	Asks the user to confirm a request for the user to borrow funds from the Bank of Dahm.
BuyBoats	Asks the user to confirm an order for a boat. Also checks to see if the user has the necessary funds
Checkpoint	Checks to see if the password the user entered is correct. If it is, the user can enter the game, if not the user is told that the password is incorrect
CompleteBoat	Notifies the user that they have bought a boat, removes the money from their account and places the order for the boat.
Gofish	Processes fishing expeditions, determines revenue for each boat.
Main	Menu providing access to all other functions.
Manager	Asks the instructor to confirm password.
Ordercomplete	Processes the orders for raw materials and sends a message to the user confirming their order
Password	Asks the user to confirm their password before they are allowed into the game.
Placebid	Allows student to enter a bid for an auction and confirms the bid has been entered.
PlaceOrder	Processes a proposal made by one student to another- the other student accepts or declines using the AcceptOrder page.
Produce	Allows a student to specify rate at which materials are produced this turn in mines and factories.
Purchase	Allows student to request purchases of raw materials at the flat rate of \$5/unit.
Removebid	Processes a request to cancel an auction bid and confirms this has been done.
Result	Checks to see that the login name/password are valid, returns "yes" or "no."
SellGoods	Allows a student to specify the price at which products are to be sold next turn.
SetProduction	Splash page that confirms the results from the "Produce" page.
Ships	Processes the purchase of pirate ships and fishing boats from the shipyards.
SimpleForm	The student login page.
Sold	Splash page that confirms that a new sale price has been set for a product.
Stats	Shows a summary of the student's current assets and liabilities.
Transaction	Handles borrowing money from the bank.

Table 2: List of all ASP pages currently in progress.

AcceptOrder	Allows you to accept or decline an offer from another student.
EndTurn	Processes results when Manager has indicated the turn is over.
Fish	Allows a student to organize fishing and treasure-hunting expeditions.
Manager2	Menu page for instructor actions.
Orders	Allows a student to view transactions that have been proposed to you, accept or decline, and make proposals of your own.

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Biographical Information

Kevin Dahm is an Assistant Professor of Chemical Engineering at Rowan University. He received his B.S. from Worcester Polytechnic Institute in 1992 and his Ph.D. from Massachusetts Institute of Technology in 1998. His primary technical area is in chemical kinetics and mechanisms. His current primary teaching interest is integrating process simulation throughout the chemical engineering curriculum, and he is receiving the 2003 Joseph J. Martin Award for work in this area.

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