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Game-Based Supplementary Learning Activities to Increase Student Engagement in an Engineering Course

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Abstract

At Iowa State University, "Engineering Economics" is a compulsory course for civil and environmental engineering students at the sophomore level. One of the main objectives of this course is to introduce the concepts of microeconomics in civil and environmental engineering projects. However, most of the topics may seem to be abstract and difficult to digest for the students since they have little to no background in economics. In addition, narrowly focused, textbook-style problems typically provide an interest rate to be used in the solution, neglecting the very real-world issue of identifying a reasonable time-value-of-money for a given context. To address these issues as well as to enhance engagement and collaboration, some game-based extra-credit activities were introduced to supplement the course. The students were divided into teams of two to three individuals and were issued an initial sum of virtual money. Then, throughout the semester, events that mimic real-life situations occurred that would require the students to decide what they would want to do with the virtual money. At the end of the semester, the group of students with the most virtual money won the game. Actively managing opportunity costs, liquidity, and risk in a low stakes yet competitive setting provided a new dimension to the conventional course. These activities were shown to be well-received by the students based on the end-of-semester survey, enhancing the relevance of regular coursework, and broadening the students' perspective.

Introduction

Although the course title might vary, engineering economics is a common component of many engineering curricula across the United States. The topics in engineering economics are sometimes combined with topics in professional ethics and licensure in a semester-long course offering. In the ABET accreditation criteria, two of the seven student outcomes are related to economic issues [1]. Furthermore, for a civil engineering program, the curriculum must include basic concepts in project management and business [1], and engineering economics is typically the first course to introduce the principles of microeconomics to civil engineering students if they have not taken an introductory course in microeconomics as an elective. Much of the content in the engineering economics course revolves around the topics of time-value-of-money and risk analysis, which are important to civil engineers as they deal with project management and proposals.

While the fundamental concepts in the course have remained mostly unchanged throughout the years, the students have not. A vast majority of the college students today belong to 'Generation Z' with its unique challenges. Thus, Moore *et al.* [2] recommend five strategies instructors can integrate into the classroom: (1) fostering active and problem-based learning, (2) helping with extracting answers from a plethora of information, (3) providing regular assessment and

feedback, (4) engaging creativity, and (5) helping students make connections among learning objectives in the course.

Game-based learning and/or gamification of learning activities are known to enhance the learning process by adding game elements or game-like activities to the existing learning objectives, with the intention to make the class more fun and engaging, increase student interactions, and broaden students' perspective; all while enriching appreciation for the usefulness of fundamental principles. Therefore, perhaps, an indirect consequence might be improved test scores; however, since the game has an element of luck, that correlation may be weak. A commonly accepted game model was proposed by Garris *et al.* [3] and is shown in Figure 1. Game-based learning and/or gamification of learning activities have been shown to improve student participation, motivation, leadership, and performance in engineering with a varying degree of success [4] - [11]. Thus, in this study, game-based learning activities in the form of an investment game were implemented to supplement the regular class activities in an engineering economics course. The addition of these supplementary learning activities helps students to be more active and engaged, as well as relates the selected learning objectives from lectures to the real-world examples, as illustrated in Figure 1, while not lowering the course expectations. Such activities have also been recognized to provide students with independent, self-developmental learning opportunities, which improve students' motivation [12].

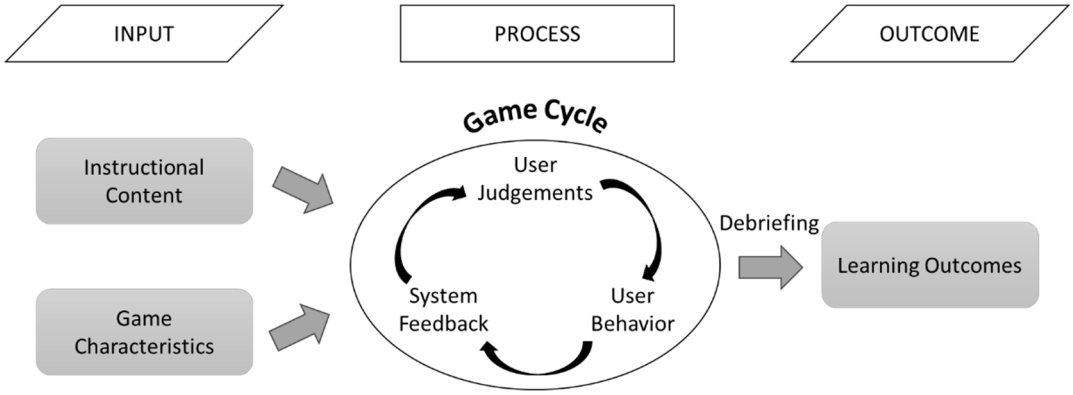

Figure 1. Game model: input-process-outcome [3]

Methodology

To collect initial information regarding the students' background knowledge, a low-stakes, ungraded pre-course terminology inventory quiz was given on the first day of class. Then, throughout the semester, several game-based supplementary learning activities were implemented, in the form of an investment game. Both aforementioned activities are described in the subsequent subsections. To measure the effectiveness of the implemented game-based supplementary learning activities, a post-course survey was carried out at the end of the semester. This survey was carried out online but was not anonymous since there was a small extra credit incentive that was given to those who responded. However, the survey was

administered by a third-party faculty member (not the instructor-of-record and never participated in class activities) so that students' remarks could be decoupled from their names when shared with the course instructor. Survey participants were informed of this anonymization, so the students could express their thoughts freely and possible bias in grading could be minimized. The methodology is illustrated in Figure 2.

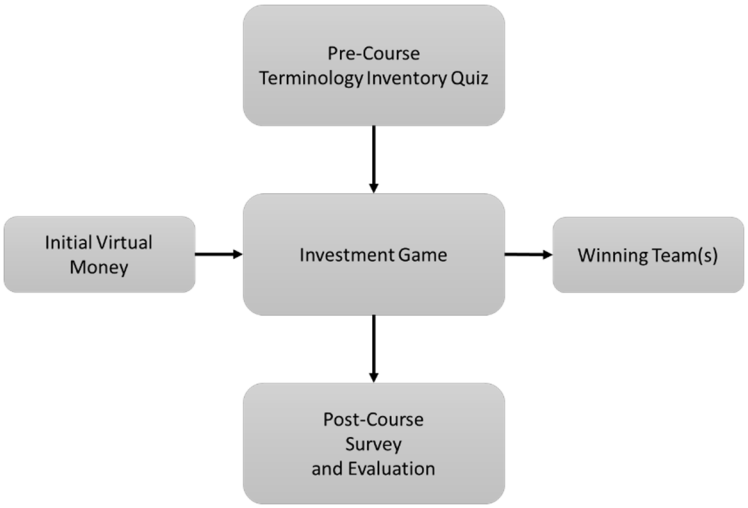

Figure 2. Methodology flowchart

Terminology Inventory Quiz

Engineering students are generally not highly familiar with common jargon and terminologies in economics if they have not taken elective, introductory-level economics or business course(s). Most students feel that the microeconomics concepts are foreign to them, as compared to the more mechanics-based concepts they have learned thus far. To obtain an idea of how much background information the students are familiar with prior to the start of the course, a set of matching questions consisting of ten common terms (i.e., questions) and twelve possible definitions (i.e., answers) was given on day one. Some sample terms or questions are "rate-of-return", "liquidity", and "time-value-of-money", which the students had to match with its respective definitions. Although the quiz was not graded, each correct answer was given 1 point with a maximum possible score of 10, to analyze the data. The mean score was 4.3 with a standard deviation of 1.9. This, in general, indicates that students' awareness of microeconomics terminologies is low, and potentially they have not been exposed to the engineering economics (or general economics) concepts prior to this course.

Investment Game as Supplementary Learning Activities

Once the students were given sufficient material that covered the concepts of time-value-of-money, the game was started. The students were randomly assigned into teams of two to three

individuals. Each team was issued a sum of virtual money of $10,000 as the initial account balance in the "Course Bank". The virtual money in the "Course Bank" was safe but only earned a low (e.g., 0.5% per annum) rate-of-return. Then, several events would occur throughout the semester, like an example shown in Figure 3, that required the teams to choose what decision they wanted to make with the virtual money they have available. Each event represents a real-world example of things that could reasonably occur in their life. The periodic events also highlighted the importance of developing an accounting system to track past and future cash flows.

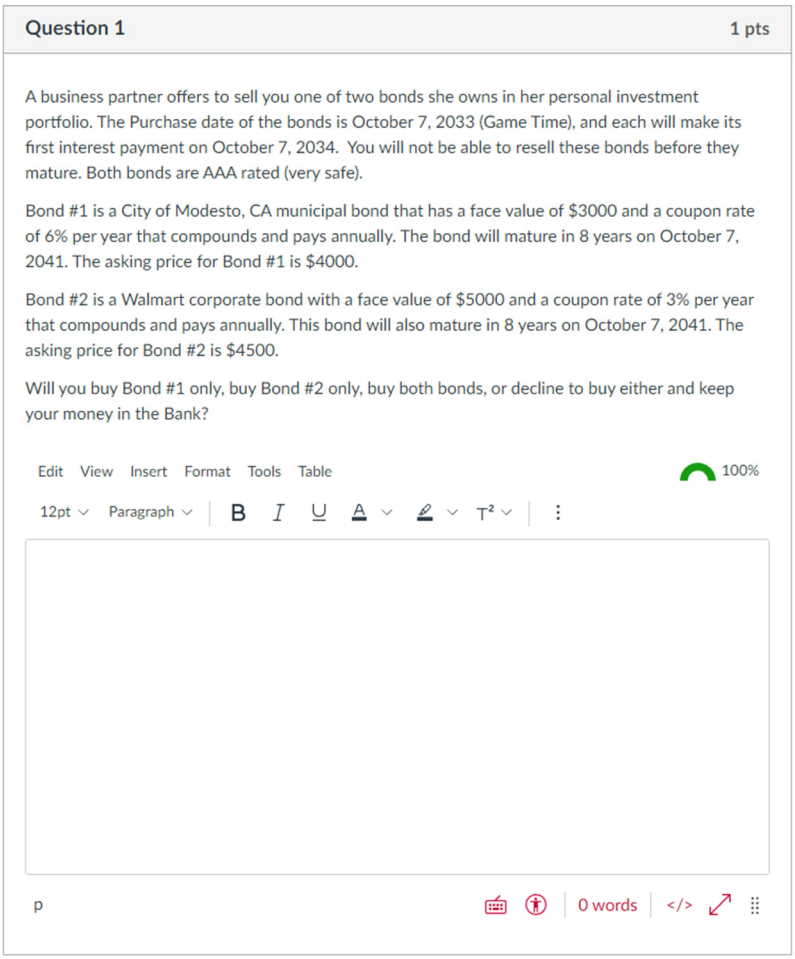

Figure 3. An example of a scenario that was given to the students as part of their investment game via Canvas

The students can apply the knowledge from class to make the best-informed decision or take a wild guess of what would be most advantageous. To respond to the events, each student had to submit their selection in Canvas, the course learning management system. To ensure that each team member communicate with each other and to build teamwork, if members in the team

submitted different responses to the event, then no action would be taken to the virtual money in the "Course Bank", hindering the progress of their game. At the end of the semester, each team had a chance to participate in an auction with the amount of virtual money in their "Course Bank" account to purchase merchandise, such as mugs, t-shirts, or jackets that were donated by the department. As an alternative to purchasing merchandise, students could keep their virtual money in the "Course Bank" in an attempt to win extra credit in the course as the two teams with the highest account balance could earn up to 3% of their overall course grade in extra credit points. In contrast to solving typical textbook-style homework problems in which, through necessity, an interest rate is given, the investment game activities required students to consider what time-value-of-money would enable them to maximize their virtual money considering both risk and opportunity.

Data Collection and Results

The post-course survey at the end of the semester was carried out to assess the students' perception of the effectiveness of the game-based supplementary learning activities and its correlation with the course learning objectives. Each survey participant received a 2-point extra credit towards the homework score (only about 0.2% of the overall course grade, also to minimize the potential participation bias). The responses from the survey participants were kept anonymous from the instructor-of-record since the survey was administered by another faculty member. About 87% of the students in the course participated in the survey. A set of Likert scale questions was given to gain students' perception of the investment game and the results are shown in Table 1. The Likert scale ranges from 1 to 5 where 1 indicates "strongly disagree", 3 indicates "neither agree nor disagree", and 5 indicates "strongly agree".

The overall responses indicate that the students viewed the investment game as a positive addition to the course. The majority felt that the game increased their interest, motivation, and curiosity in the course. Moreover, students also felt that they can relate the knowledge they learned in class to solve practical real-world problems, as exemplified in the game events. However, it seems that many students did not spend too much time in analyzing the events in the game to make the best decision.

To gain more information on the students' effort in the course, another set of questions were posed, and the results are presented in Table 2. Here, the students had the options to select whether they had participated in none, less than one-third, between one-third and two-third, more than two-third, or all of the stated activities. It can be interpreted that while most students are attending in-class lectures and submitting homework assignments, there are more students that did not participate in the investment game activities. This is not surprising because the investment game did not directly affect their grade in the course and was only framed as a set of optional, supplementary activities. Therefore, students who did not participate did not get penalized in the course. In a separate question, students also responded that 16.67% of them spent between 0 to 3 hours per week outside of class for any course-related activities, while

68.75% said they spent between 4 to 6 hours and 14.58% reported 7 to 9 hours per week outside of class.

Table 1. Results of students' perception of investment game

Statement	Mean	Standard Deviation
Problems posed increased my interest in course issues	3.94	0.52
Problems posed piqued my curiosity	3.77	0.74
I felt motivated to explore content-related questions	3.56	0.93
I spent time to analyze the problem and/or do some calculations before submitting my response	3.83	0.94
I utilized a variety of information sources to explore problems in these activities	3.04	0.98
Brainstorming and finding relevant information helped me resolve content related questions	3.54	0.93
Combining new information helped me answer questions raised in these activities as well as in the course	3.69	0.87
I can describe ways to test and apply the knowledge created in this course through these activities	4.00	0.74
I have developed solutions to these activities that can be applied in practice	3.90	0.92
I can apply knowledge created in this course to my work or non-class related activities	4.25	0.80
I enjoyed participating in the Investment Game activities	3.96	0.76
These Investment Game activities are beneficial for this course	4.17	0.59

Table 2. Results of student participation in the course

Statement	None	<⅓	⅓ to ⅔	>⅔	All
Attending in-class lectures	0%	0%	8.33%	52.08%	39.58%
Submitting homework assignments	0%	0%	0%	14.58%	85.42%
Participating in investment game	0%	10.42%	18.75%	33.33%	37.5%

The survey also asked the students to describe why the investment game is beneficial for the course, and some of the representative responses are: "It helps you visualize a real world example and it allows you to use concepts learned in class to calculate the different scenarios given in order to maximize profit", "I think it engages students in the content and gives real life examples of analyzing financial decisions", and "It applies what was learned in class to a fun, realistic activity". Last, students were asked to provide their thoughts on changes that might improve the investment game. These responses may be used to change how the investment game is run in the future. One significant group of respondents wanted more competition in the game with weekly updates on the account balance ranking among all teams. Another significant group

of respondents wanted more collaboration within their team, suggesting that the game activities be required rather than optional.

Concluding Remarks

A preliminary evaluation of the game-based supplementary learning activities in an engineering economics course has been presented. From the survey responses, students valued and enjoyed the learning opportunities from the investment game given throughout the semester. More importantly, the students felt that the investment game is beneficial for the course. These responses on their own justify the game considering the primary objective was to enhance engagement and applicability for the students. Whether the game activities improved student performance on other course deliverables is more difficult to assess. In general, students who won in the investment game received high grades in the course relative to the mean, but causality cannot be established from the data collected, partially because there is an element of luck involved in the game. A continued effort to improve the implementation these game-based activities is ongoing. In the future, the instructor-of-record plans to make the game component as mandatory for students and collect more data at the end of the semester to further correlate with the measurable course outcomes. Logistically, the activities were implemented within the Canvas learning management system; however, the authors may consider other platforms, such as Google Forms, for a more streamlined data collection. Anyone interested to use the activities may contact the second author for more details.

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