A Gamification Approach for Experiential Education of Inventory Control

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Abstract

In this educational research project, game-based in-class and after-class learning activities are developed to teach selected inventory control strategies to undergraduate and graduate students. Students from Supply Chain Management and System Simulation courses are targeted, who are taught by different instructors. The activities include teaching the inventory control policies to students in a regular class setting, then providing an overview on a game developed on MS Excel. In the game, the lead time and customer demand variables are defined uncertain, and not given to students, which make the assignment an ill-structured problem. A 12-month planning and execution period is given to students with qualitative and quantitative information about 3 products. The students are given a 1-week period to play the game. The game simulates selected inventory control strategies with reorder point and order quantity parameters for 12 months. The learning outcomes of the course related to inventory control, and students' experience with the game are surveyed. Survey results are statistically and visually analyzed. Overall results indicated that the proposed gamification approach is found to have positive impact in learning effectiveness in the majority of evaluation categories. In addition, the contribution of the proposed gamification approach was found to be effectively supporting the learning outcomes of the course.

Introduction

Use of gamification in higher education has gained credible attention in the past two decades as computational, visual, and virtual capability of instructional resources become widely available and student-centered education paradigm has been substantially adopted in most of the engineering programs across the United States of America. Among the modern educational tools and techniques, serious games and gamification have been among the most popular and most argued ones [1][2], [3]. The term "serious game" is defined in the literature as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."[4]. The definition clearly indicates that serious games can be used in various contexts from training to education. While the use of games varies substantially depending on the purpose(s) and benefit(s) of the game provider and gamer, recent a recent literature survey indicates that majority of attention has been paid on the affordance of the games in other words developing and evaluating prototypes, while focus was comparably less on the actual use and effectiveness of games [1]. Regardless of the effectiveness and generalizability of educational games, more and more serious games are integrated into engineering curricula as computer-based, manual, and virtual reality-type; and a scientific consensus is established on the fact that games and interactive simulations are more dominant for cognitive gain outcomes [5]; [1]. Even though it has undeniable advantages, the literature suggests that both learning effectiveness and

gamification aspects need to be addressed when learning modules are developed with serious education games [6]. It is also important to note that, the effectiveness of serious games could vary among the disciplines and depend on the way that is integrated into the lecture setting.

Background

A recent literature survey classifies the characteristics of serious educational games as *transfer of knowledge, skills and attitudes from games to real world tasks; effects on cognitive processes such as visual attention, spatial visualization and problem solving; facilitating performance & learning in various topics; uses of games in instructional situations; effects of playing games on school learning, and attitude change* [7]. It is also evident that not all educational game designs carry these characteristics as the objective(s) and the learning outcomes (LOs) of the educational game typically determines which of the characteristics are covered. In another literature survey [6], over 40 studies published between 1995 and 2005 were reviewed and it was found that no consensus exists on the type of analytical method that is used to analyze the effectiveness of the games on learning. On the other hand, a recent survey of 40 studies published between 2002 and 2012 found out that serious games has positive impact on learning regardless of analysis technique used to assess learning effectiveness [7]. However, the motivation to develop a serious game needs to be supported with the sufficient evidence that the learning requirements can be at least equally satisfied compared to a traditional lecture setting [6]. Educational games used for various courses in Industrial Engineering curricula such as lean manufacturing and six sigma [8][9][10]; operations management [11][12], [13] [14].

The studies related to teaching supply chain management, inventory control concepts are abundant in the literature. In one of the works, Merkuryev and Bikovska [15] focused on explaining a business simulation game used to teach and train Supply Chain Management concepts. Even though the details about how the game was developed and what it is features are provided thoroughly, the educational impact assessment of the game was not discussed. On the other hand, [16] developed a complex supply chain management game, where a larger sample group was used for assessment. Results of the learning effectiveness assessment indicate that traditional teaching methods are effective in simple decision-making skill acquisition; complex and dynamic situations can be more effectively covered with simulation games. In an earlier work, [17] focused on the relationship between game playing and operations management education. Their findings focused more on the following categories: application focus, complexity, role of IT, role of competition, and incorporation of physical processes. However, the paper lacks discussion on how effective the games were on the education of OM. [8] proposed re-application of simulation-based game, which focuses on lean six sigma education. Several suggestions to improve the game's effectiveness on learning are proposed but not evaluated. Furthermore, a simulation-based learning activity in global industrial management is developed [13]. The researchers used the simulation-based game to understand how students seek information adapt to changing conditions and make informed decisions accordingly. Evidence of learning was found on all learning objectives. Learning effectiveness was not kept as part of the focus since the students' approach to the game was primarily investigated to be used to further improve the game to the expectations of the students.

Serious games are critical for experiential learning as well. Experiential learning is termed as the process, whereby the knowledge is created through the transformation of experience [18][19][10]. Experiential gaming models are also proposed in the literature, where gaming and experiential education principles are integrated. One of the early works proposed an experiential gaming model which was based on integration of experiential learning theory, flow theory and game design [20]

In this study, we focus on developing a serious game that can be used as part of classroom teaching, homework assessment and a class-wide competition in a graduate level course. The instructional focus was inventory control policy making. Specific objectives include teaching students:

1) how to determine order quantity, reorder point, and safety stock for a product whose past sales data is given in advance,
2) How to visually evaluate inventory policy effectiveness from physical and financial standpoints,
3) How to deal with lead time and demand uncertainty when making inventory control policy for a product over multiple periods,
4) How to create a scenario-based portfolio solution that can be used for further decision-making activities such as risk assessment.

Methods

The Course: Supply Chain Management

The researchers attempted to implement the Inventory Management Simulation Game (IMSG) in graduate level Supply Chain Management course, where 22 students were enrolled. Course was taught in a face-to-face learning environment in fall semester of 2017. Course Learning Outcomes (LOs) are as follows:

Upon satisfactory completion of this course, students should be able to

1. Identify issues involved in the relatively new and growing area of supply chain management (Student Outcome H, J),
2. Develop solution techniques to some of the problems in logistics and supply chain management. (Student Outcome C),
3. Understand the tradeoffs inherent in supply chain management and a facility with quantitative analysis tools required to address these tradeoffs. (Student Outcome C, G),
4. Formulate the techniques currently used throughout industry in addressing the many complex supply chain problems in multidisciplinary teams. (Student Outcome D.

Considering the course learning outcomes, following learning outcomes were developed for the learning activities that will be accompanied with the IMSG.

Activity Learning Outcomes:

a) Solving Economic Order Quantity (EOQ) equation
b) Identifying Reorder Point
c) Identifying and interpreting important parameters of an inventory management policy
d) Developing conceptual understanding about Fixed Period Review policy
e) Developing quantitative understanding about Fixed Period Review policy
f) Developing visual understanding about Fixed Period Review policy

g) Developing conceptual understanding about Continuous Review policy
h) Developing quantitative understanding about Continuous Review policy
i) Developing visual understanding about Continuous Review policy
j) Assessing and discussing profit and cost of an inventory management policy over time
k) Assessing and discussing demand and inventory level over time
l) Applying a practical knowledge on how lead time uncertainty (Uncertainty Level) affects the inventory management performance.
m) Developing, testing and evaluating an inventory management strategy for a product

Following table was developed to indicate how the course LOs were covered and addressed with the experiential learning activity LOs. Table 1 indicates that each LO of the course was addressed by 3 to 4 experiential learning activity LOs.

Table 1. Experiential Learning Activity LOs with Course LOs

Course LOs	Experiential Learning Activity LOs
1	c, d, f, g, i
2	a, b, e, h, m
3	j, k, l
4	a, b, e, h, m

Inventory Management Simulation Game (IMSG)

IMSG is developed on MS Excel as a simulation game. Students simulate inventory control policy of a product over 1 to 12 months. There are three products are sold to customers, namely: watch, Xbox, and TV. The student's responsibility is to formulate an inventory management strategy, which will maximize the profit. IMSG features and assumptions include the followings:

- ✓ Two inventory management strategies were covered, namely: Fixed Period Review and Continuous Review.
- ✓ In the fixed period review, the inventory is reviewed weekly. After 1-week of simulation run, you will be prompted with a question whether you want to place a new order or not.
- ✓ In continuous review, the new order placement decision will be made automatically by the model based on reorder point (ROP). Whenever inventory level drops below ROP, a new order is placed and will arrive after Lead Time (LT).
- ✓ LT is randomly generated between 1 and 6 days, where expected LT is 3 days.
- ✓ ROP is equal to the Lead Time Demand (LTD)+ Safety Stock (SS). You will need to make a decision on SS, which will automatically update the ROP.
- ✓ Placing a new order to replenish the inventory will update the inventory level after the lead time (LT) amount of days.

Graphical User Interface of IMSG:

The IMSG excel file consists of two work sheets, namely: Annual Strategy Review and Weekly Strategy Review.

1. In the first worksheet (Annual Strategy Review, see Fig. 1), the annual behavior of demand and inventory level is graphed, and strategy selection is decided and finalized in this worksheet. This worksheet provides quantitative information about historical and forecasted demand, price and cost information (order cost, unit cost, stockout cost, and holding cost), annual inventory and demand graph, inventory policy options (Periodic vs.

Continuous Review), and parameters (Order Quantity, Lead time, Lead time demand, and Reorder Point). User can select the inventory policy and enter Order Quantity, Safety Stock, and ROP parameters.

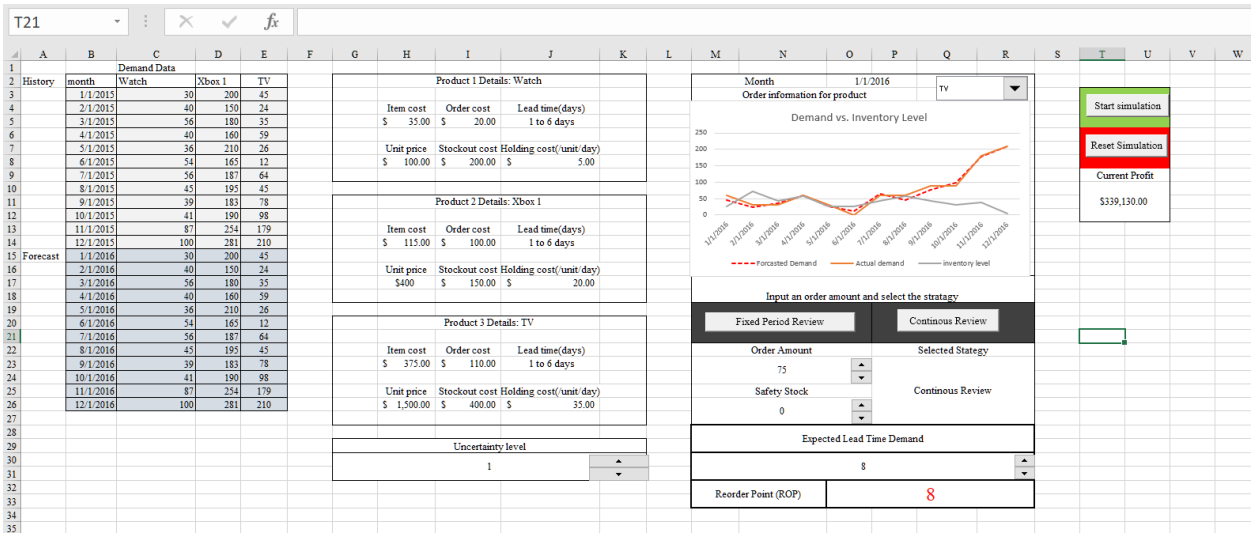

Figure 1. Annual Strategy Review Module

2. The second worksheet is named as *Weekly Strategy Review*, where the simulator can *numerically* and *visually* review the changes in various inventory management variables for 1-month. This worksheet provides the detailed information about day of the month, demand, inventory level, profit, and cumulative profit, and all the inventory management cost categories (See abbreviation list).

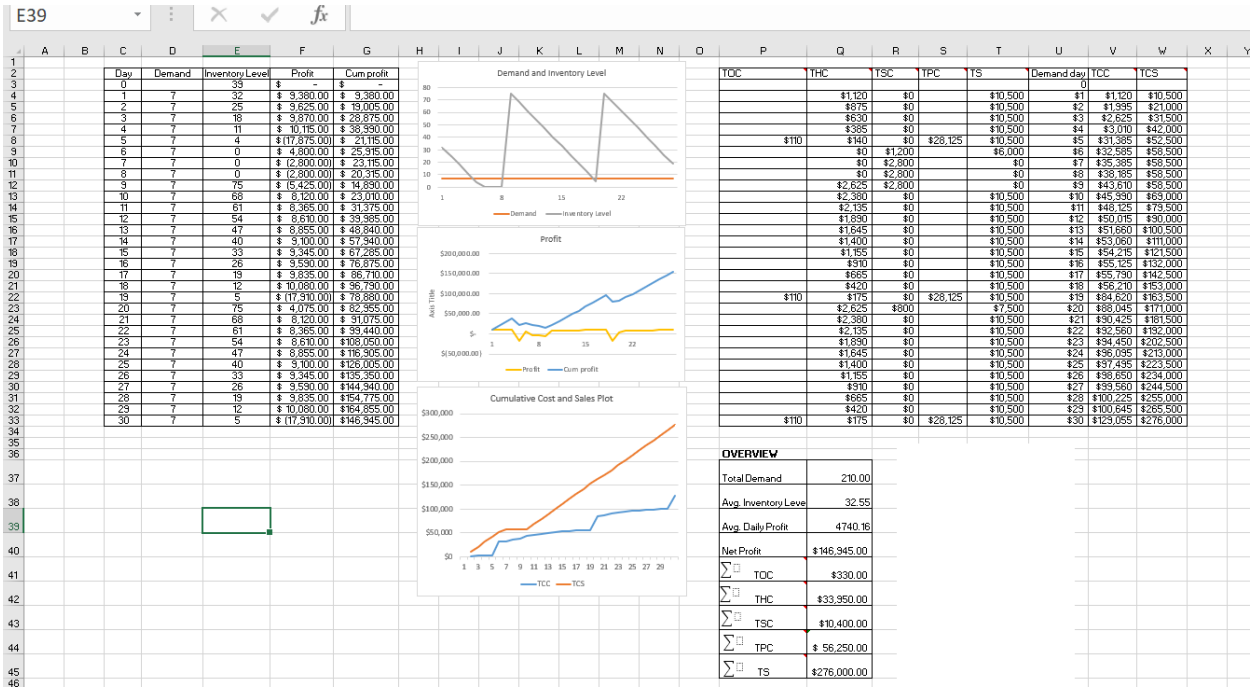

Figure 2. Weekly Strategy Review Module

3. Abbreviations used in the IMSG:
    a. TOC: Total Order Cost
    b. THC: Total inventory Holding Cost.
    c. TSC: Total Shortage Cost
    d. TPC: Total Purchasing Cost
    e. TS: Total Sales
    f. TCC: Total Cumulative Cost
    g. TCS: Total Cumulative Sales
    h. The Current Profit at the end of 1-month is equal to the TCS-TCC.

Experiential Learning Activities

The experiential activities were planned to make sure that the students would first get to practice playing the IMSG in classroom, where they could have interactive communication with the instructor and provide/receive feedback. Then HW assignment was given. The researchers believe that students will be able to build a sound knowledge and practical understanding, playing the IMSG after a traditional lecture on inventory control policy making is given. Therefore, experiential learning activities are performed a week after the traditional lecture was provided to the students.

In-Class-Activity (ICA):

ICA session took 40 minutes and provided in regular lecture day. Dr. Egilmez and Dr. Gedik (Course instructor) ran the ICA session together. Story-telling was used in providing the ICA to the students (See Fig. 3).

Dear Friends,

First of all, please Go to BB and download IMSG.xlsx file. Open the file, and make sure to enable the macros if you are asked.

In this ICA, you will play a serious game on inventory management. You are the inventory manager of ASOS retail store, where three products are sold to customers, namely: watch, Xbox, and TV. ASOS is a local retail store in a small town Canakkale, in western Turkey. The store sells the three products and your responsibility is to formulate an inventory management strategy, which will **maximize** the profit. There are **two** inventory management strategies in the IMSG, namely: **Fixed Period…**

Figure 3. The introduction section of ICA

The planned time for ICA included following activities:

1) Introduction of the IMSG (*5 minutes*),
2) Demo (instructor runs the IMSG for 1 product for 1 month) (*5 minutes*)
3) Question and Answer session (*10 minutes*)
4) Student's practice (*10 minutes*)

5) Short Quiz on Student's Findings (*10 minutes*)

The focus of ICA was on product 1: Watch. Students were given a step-by-step guide on how to work with IMSG.

HW Assignment:

The HW consisted of four parts, namely: A, B, C and D. Parts A and B require students to work on pre-defined solutions and study and interpret their impacts on the profit and average inventory level. In part C, students are given with an open-ended question, where they will be developing their own inventory management strategy, report the results of experiments with the IMSG, and enter their results into class-wide competition, where the student with the maximum profit is given a small gift. In Part D, students participated in an online survey where they will answer short questions about their learning experience. Results of part D is used to assess the learning effectiveness.

Part A: Evaluation of EOQ strategy (30 points): In section A of the HW, following tasks are used to have students reach the ALOs. The focused product was Xbox.

- Task 1: Calculate EOQ for all products. (ALO 1)
- Task 2: Calculate the expected Lead Time Demand (LTD) for all months for all products (*Expected Lead Time is assumed to be 3 days).* (ALO 2)

Part B: Fixed Period Review (FPR) vs. Continuous Review (CR) Policies (30 points): The focused product was, product 3: TV. Students were asked to run the IMSG for 3 months with given parameters similar to ICA. The tasks address the ALOs 3-10.

Part C: In part C, students are not given any instructions but a problem data for the product 3: TV. There were expected to develop an inventory management strategy for 12 months. In parts A and B, they worked for planning for 1-month and 3-month periods. The objective was to have students develop an inventory policy strategy for 12 months that maximizes the total net profit ($\sum_{i=1}^{12} Net\ Profit_i$, where i indicates month.). Once they finalized their parameters, they run the IMSG for 12 months and submit the Month Inventory Management Policy (FPR or CR?), Order Quantity (OQ), Safety Stock (SS), Reorder Point (ROP), Net Profit, and Avg. Inventory Level for 12 months. Part C was also the competition part of the HW, where the student with the highest profit result is given a small gift.

All in all, the learning activities (ICA, Quiz, HW, and competition) is designed to gradually increase the level of complexity and decrease the level of assistance to make sure that students can build up the knowledge, and practical understanding first, then implement their opinions on inventory control policy making (HW part C). The last part of the HW was Part D, which asks students take the learning effectiveness survey. The survey results are shared in the following section.

Results

Results of Survey

Results of survey is analyzed both visually and statistically. In the beginning part of the survey, students were asked to evaluate their overall experience with the IMSG. The second part of the survey further investigated their learning experience against the activity learning outcomes (ALOs).

Overall Experience with IMSG

Initially, students were asked whether the IMSG overall positively impacted their learning in inventory management policy making. Results are provided in Fig. 4. It is shown that majority of students (90%) agreed that IMSG has positive impact on learning. Furthermore, the impact of IMSG on the course was evaluated. The results are depicted in Fig. 5, which indicates that over 80% of the students agreed that the impact was positive. Then, students were asked whether the game positively contributed to the curriculum of EOM program (See Fig. 6). The contribution to the EOM curriculum was found positive by 81% of the students. The last question investigated whether they enjoyed playing the IMSG (Fig. 7). Similarly, 81% has agreed.

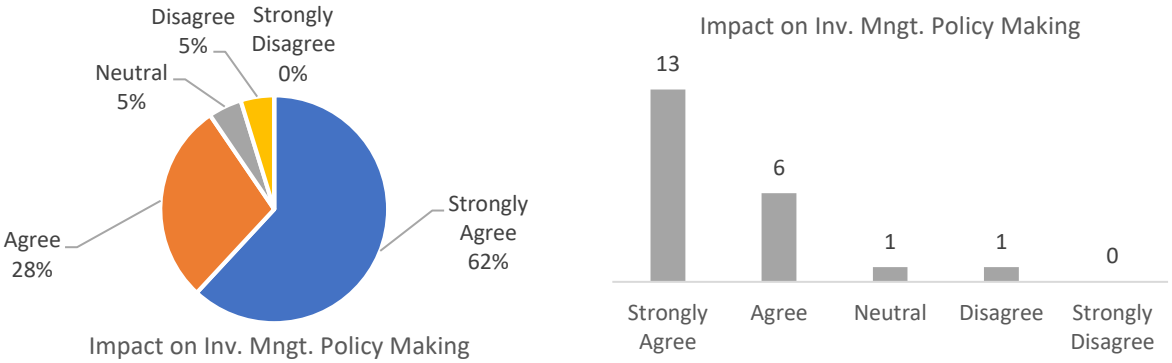

Figure 4. Impact of IMSG on inventory management policy making

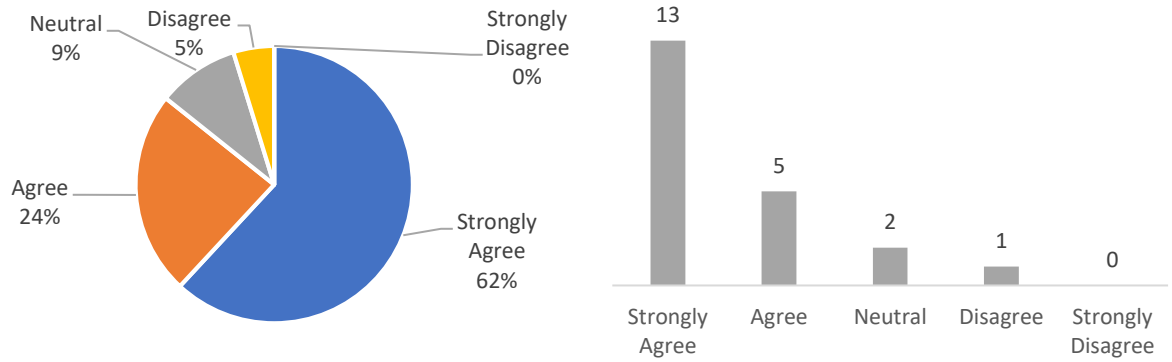

Figure 5. Contribution to the Course

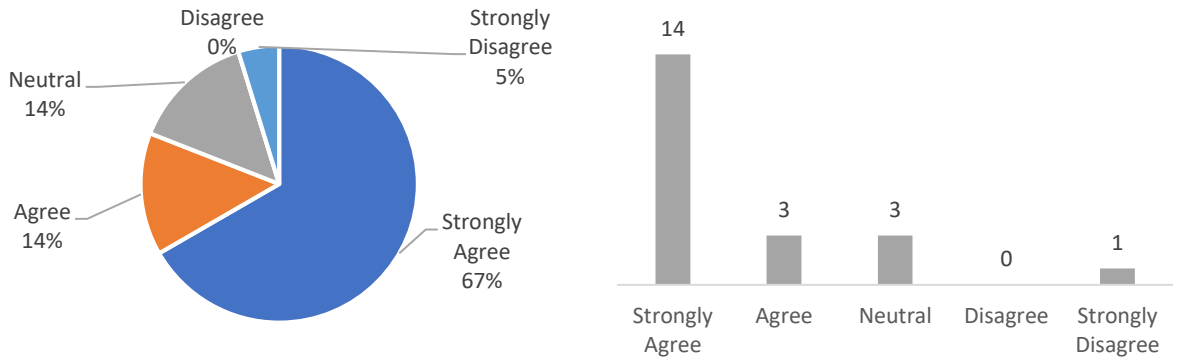

Figure 6. Contribution to the Engineering and Operations Management Program

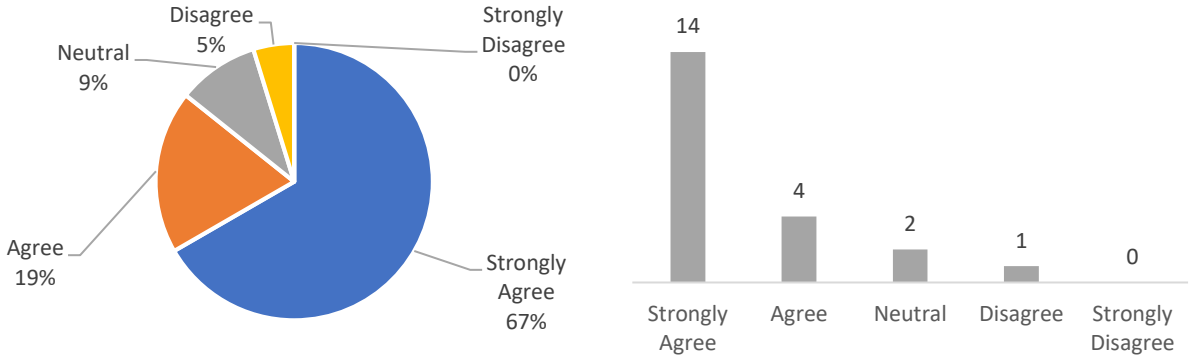

Figure 7. Assessment of enjoyment

Learning Effectiveness

The second part of the survey focused on the relationship between the students' learning experience with the IMSG and the ALOs. Results of ALO assessment is provided in Table 2. It was indicated that majority of the students found the activities effective and well-aligned with the activity learning outcomes. As highlighted in Table 2, majority of the students were able to engage themselves in maintaining the inventory control policy of a specific product by developing, testing and implementing it over a well-known product.

Table 2. The Effectiveness of IMSG on reaching the specific activity learning outcomes

	Activity Learning Outcome (ALO)	**EE**	**VE**	**SE**	**ME**	**NE**
1	Solving Economic Order Quantity equation	11	4	5	0	1
2	Identifying Reorder Point	12	4	4	1	0
3	Identifying and interpreting important parameters of an inventory management policy	7	9	4	0	1
4	Developing conceptual understanding about Fixed Period Review policy	11	4	3	1	1
5	Developing quantitative understanding about Fixed Period Review policy	12	5	3	0	1
6	Developing visual understanding about Fixed Period Review policy	11	6	3	1	0
7	Developing conceptual understanding about Continuous Review policy	12	5	3	1	0
8	Developing quantitative understanding about Continuous Review policy	10	6	3	1	0
9	Developing visual understanding about Continuous Review policy	12	4	4	1	0
10	Assessing and discussing profit and cost of an inventory management policy over time	10	6	5	0	0
11	Assessing and discussing demand and inventory level over time	11	4	5	1	0
12	Applying a practical knowledge on how lead time uncertainty (Uncertainty Level) affects the inventory management performance	12	5	4	0	0
13	Developing, testing and evaluating an inventory management strategy for a product	15	3	2	1	0

(EE: Extremely Effective, VE: Very Effective, SE: Somewhat Effective, ME: Minimally Effective, and NE: Not effective)

This activity enhanced the learning of a difficult subject such as inventory management by providing students just the right amount of flexibility and guidance towards achieving their goals. The second most effective activities are found in identifying reorder point, developing quantitative understanding about fixed period review policy, developing visual and conceptual understanding about continuous review policy, and applying a practical knowledge on how lead time uncertainty affects the inventory management performance.

In the later part of the survey, the favorite learning activity was assessed. Results indicate that (See Table 3), In-Class-Activity (ICA) was found to be the most favorite activities. We also asked students how much time they spent on each part in HW (See Table 4). The time spent on Parts A, B and C was found to be 1-3 hours by the vast majority. And, this is quite reasonable for HW that is assigned to be turned-in by the next class.

Table 3. Favorite learning activity?

ICA	HW (Parts A, and B)	HW Part C: Competition
8	6	6

Table 4. Time Spent on Specific Learning Activities

	< 1 hour	1-3 hours	3-6 hours	6-10 hours
HW - Parts A and B	1	13	6	1
HW - Part C: Competition	2	15	4	0

Instructor Evaluation

In this section, instructor's qualitative and quantitative evaluation of the impact of IMSG on learning effectiveness and experiential education are discussed. Before exposing students to the IMSG, inventory management lectures spanned two weeks of class time in which we discussed the reasons of keeping inventory, how to eliminate them, the pros and cons of having manageable inventory in the systems, inventory types, costs associated with inventory, newsvendor inventory model, single period fixed and continuous inventory policies, multi period fixed and continuous inventory policies and finally the ABC approach in order to classify the inventory types.

The effectiveness of the IMSG on role-playing i.e. convincing students that they are the only person in charge with managing the inventory of three different products truly helped the instructor to keep students fully focused during the activity. At the beginning of the activity, there were some technical questions on how to handle the decision tool. After clarifying them and making students comfortable with the tool, they immediately started trying several approaches to answer the questions. From the instructor point of view, this is highly valuable since it addresses the needs of kinesthetic learners in the class. During prior lectures, the derivation of the total cost or economic order quantity formulas did not make sense to a minority of the students. With the help of the IMSG, those students immediately understood the need for the formulas and therefore used them.

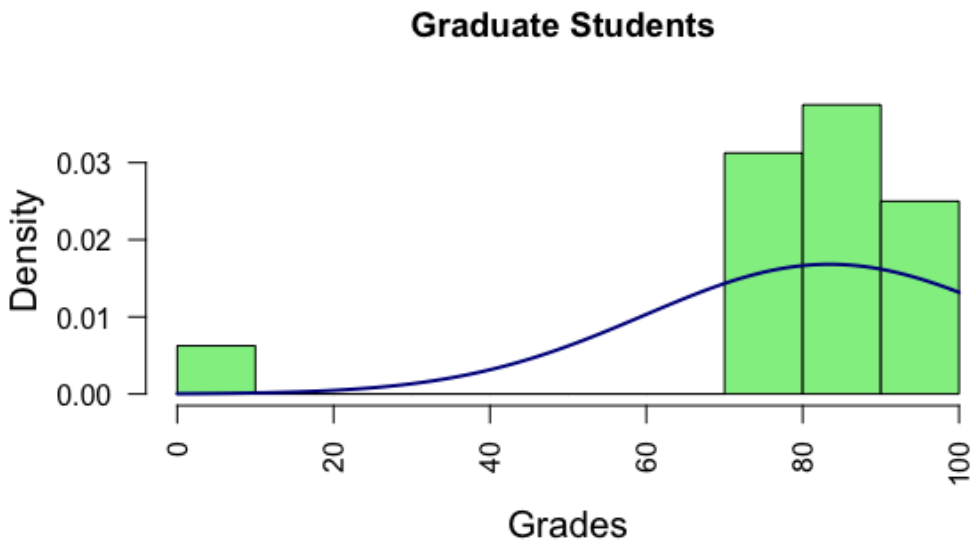

Figure 8. Assignment Grade Distribution of Graduate Students

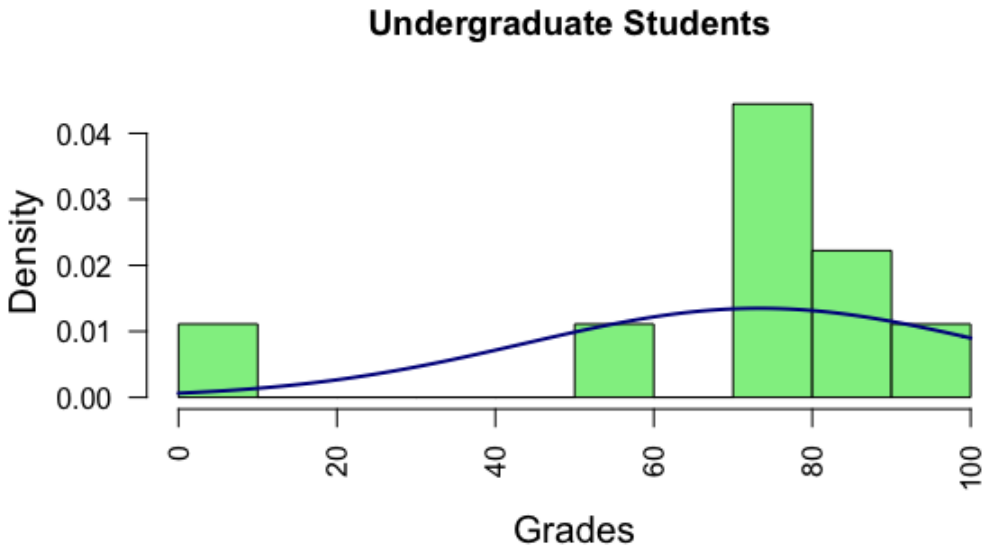

Figure 9. Assignment Grade Distribution of Undergraduate Students

Figures 8 and 9 demonstrate the assignment grades for graduate and undergraduate students, respectively. Histograms and the adjusted normal probability plots demonstrate that both cohorts were very successful in securing high grades. One student from each group did not turn in the assignment and therefore received zero.

Table 5 summarizes evaluation results both the course and instructor received at the end of the Fall 2017 and Fall 2016. In total, 23 students responded to the questions and filled out the online survey

out of 25 registered students in Fall 2017. On the other hand, 20 out of 27 students responded to the questions at the end of Fall 2016 in which the IMSG was not offered as an activity to the students. The results indicate that the overall teaching evaluation slightly increased at the end of Fall 2017. However, there is a significant increase on the satisfaction level of the students to the criteria titled "Assignments and other graded activities gave me an opportunity to demonstrate what I learned." and "*Overall, I was satisfied with the educational experience provided by the instructor.*".

Table 5. Instructor Course Evaluation Results

	Fall 2017		**Fall 2016**	
Questions	**Mean**	**STDEV**	**Mean**	**STDEV**
The objectives of the course were clear.	4.7	0.6	4.63	0.68
The course materials (as listed on the syllabus) contributed to my learning.	4.7	0.6	4.63	0.6
Assignments and other graded activities gave me an opportunity to demonstrate what I learned.	*4.7*	*0.6*	*4.53*	*0.61*
The grading system for the course was clear.	4.4	0.7	4.63	0.6
The instructor was prepared for each class.	4.8	0.4	4.74	0.56
The instructor's presentations were understandable.	4.8	0.4	4.74	0.69
The instructor provided helpful feedback.	4.7	0.5	4.63	0.56
The instructor used class time effectively.	4.7	0.5	4.68	0.6
My interest in the subject matter was enhanced by the instructor's enthusiasm.	4.8	0.4	4.53	0.58
The instructor raised questions or problems that encouraged me to think critically.	4.6	0.6	4.68	0.7
The instructor explained the relevance of the subject matter.	4.6	0.7	4.61	0.58
The instructor established a positive learning environment.	4.7	0.5	4.68	0.61
The instructor was accessible outside of class (for example: held office hours, communicated via email, or offered to meet via video conferencing).	4.7	0.5	4.63	0.58
Overall, I was satisfied with the educational experience provided by the instructor.	*4.8*	*0.4*	*4.58*	*0.6*
Overall	**4.7**	**0.5**	4.63	0.61

Correlation Analysis

In this section, we provide the correlation analysis conducted between the grades of the students and their responses to the questions in the survey. It could be expected that the students who obtained good grades could find the IMSG very useful and vice versa. Therefore, 17 correlation analysis conducted, since there were 17 questions where students provide Likert-scale evaluation. Results are provided in Table 6. Results indicate that in all the questions, the coefficient of determination (R-squared) values were found to be less than 8%, which indicates no correlation.

Table 6. Correlation Analysis Results (Student Grades vs. Evaluations of Survey Questions)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
GRADES	0.5%	1.1%	0.1%	0.2%	1.2%	2.5%	7.4%	0.8%	1.4%
	Q10	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	
GRADES	0.0%	0.4%	1.7%	0.0%	5.8%	0.8%	0.0%	0.1%	

Discussion, Conclusions and Future Work

In this paper, a serious-game-based experiential learning approach is presented. The proposed approach is used to teach the inventory control and policy making to students with a list of learning activities. The students' feedback was collected via survey. The survey was provided to the class of fall 2017. The feedback of students indicated that they enjoyed playing the IMSG and competing. Not only it has increased their attention to the topic, IMSG positively supported the activity learning outcomes, thus course learning outcomes, significantly. The quantitative feedback indicates that IMSG is perceived as effective in teaching inventory control policy making. The qualitative feedback of students include that the graphical user interface would be improved. Other suggestions include spending more time with the in-class-activity and increasing the uncertainty levels in lead time in competition section. The instructors' suggestion is to teach the inventory control theory basics prior to having students work on the IMSG components. In addition, it is highly advised that students are given a practice session (ICA) in class prior to assigning them a HW assignment. All in all, when the student group who played the IMSG in fall 2017 were compared with the previous' year's student group who took the same class but did not play the game (control group). The class evaluation results indicate that the IMSG has improved the students' learning effectiveness in majority of the evaluation criteria (See Table 5).

Future work of this research includes having IMSG used in other course setting at other institutions to compare the results of current study. In addition, the researchers are working on creating an assessment metric that could be used to compare the IMSG with a control group (another section of the same course) in terms of its effectiveness on learning. Current study focused on assessing the learning effectiveness from students and instructors' perspective.
Current study has a list of limitations, which need to be addressed in the future works. First of all, the bias that a student's grade could have on their response to the survey was not treated in the results' analysis. Additionally, the sample size of survey was less than 30, which could be improved by conducting the same experiment with more samples in the following semesters and re-analyze the results of multiple samples.

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