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AC 2011-94: USING SOCIAL NETWORKING GAME TO TEACH OPERATIONS RESEARCH AND MANAGEMENT SCIENCE FUNDAMENTAL CONCEPTS

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Using Social Networking Game to Teach Operations Research and Management Science Fundamentals

Abstract

This paper presents our experience using the popular game FarmVille by Zynga® to teach the fundamentals of linear programming and integer programming concepts to undergraduate students in an introductory operations research course. FarmVille is a popular game within the social networking website Facebook®. A month-long contest was introduced amongst the students with the goal to be the best individual farmer by striving to reach high levels of revenue, experience, and aesthetic appeal of their own unique farm. The contest is to demonstrate the concepts of problem formulation, solution methods, multiple and competing objectives, implementation of policy, and reformulation. The students were surveyed at the beginning of the semester to gain insight into their perceptions of the course. The students were also surveyed regarding the "FarmVille Challenge," to gauge the effectiveness of the pedagogy and students' opinions of the hand on approach. The paper demonstrates through surveyed results that the students favored this instruction. The students surveyed agree that this was an engaging and thought provoking exercise and saw the true application of multiple key fundamentals of operations research.

Introduction

The field of operations research is prevalent within our industrialized and globally networked economy. Logistics, scheduling, routing, distribution, and many other topics are highly ingrained within our global economy and present a need to educate undergraduate students in the inherent topics that encompass the Operations Research (OR) field. In addition, the capability to interpret and derive solutions in this ever changing and emergent behavior environment possesses new challenges and requires new methods to attain solutions to complex problems. As stated by Bordogna[3] , "We need a model of engineering education suitable to a new world in which change and complexity are the rule, a world continuously transformed by new knowledge and the technology it makes possible, a world linked globally, where differences and divisions that have not been integrated can have immediate and large-scale consequences." This effort to integrate social networking and gaming, which are both highly popular among many students today and present them with an ill-defined ever changing problem, seeks to begin to evolve current instruction of operations research topics within undergraduate engineering students in order to teach them in higher-level skills. Specifically, Farmville has a basic mechanic developed under the Graphic User Interface (GUI) of a farm and growing crops. It is up to the player how much land to plow, which/how many seeds to plant, and when to harvest the plants once they have matured. The game leaves the player with potential to grow anything. Without a pass/fail mechanism to end the game, decisions are completely up to the player.

Games located within social networking are simple in interface and mechanics so that they can be contained within the web-browser. This leads the player to have less of a learning-curve and makes the game more responsive to improvements in the player's methods of play. These games often mimic the situations with which a player would already be familiar in order to help immerse players. These known situations in the game are used by developing a simple mechanic that will respond as the player expects.

These high level skills correspond to the Taxonomy of Educational Objectives (Cognitive Domain) developed by Bloom and colleagues[5]. Bloom *et al.*[5] defines a hierarchy of six levels: 1. Knowledge- repeating memorized information; 2. Comprehension- paraphrasing text, explaining concepts in jargon-free terms; 3. Application- applying course material to solve straightforward problems; 4. Analysis- solving complex problems, developing process models and simulations, troubleshooting equipment and system problems; 5. Synthesis- designing experiments, devices, processes, and products; 6. Evaluation- choosing from among alternatives and justifying the choice, optimizing processes, making judgments about the environmental impact of engineering decision, resolving ethical dilemmas. Levels 1-3 are commonly referred to lower-level skills and Levels 4-6 are considered to be higher level skills. It is through the use of games that instruction into the higher levels is possible as they present the students with continuous change, reflection on decision making, strategy, and other key components of the higher-levels. Thus, gaming presents a unique opportunity to not only effectively teach these higher level skills to undergraduate students, but also presents the students with active learning, which has been shown to be an effective method of instruction within science and engineering[8]. Furthermore, as presented by Liebman in order to learn operations research, one must acquire all three types of knowledge. They illustrate this point by providing a list[6]:

(1) Procedural knowledge includes, for example, knowing how to analyze a system, select a model, formulate a model, select an algorithm, perform sensitivity analysis, select solution software, use computer software, develop a hypothesis, and prove a theorem.
(2) Declarative knowledge includes, for example, knowing the historical development of operations research, basic definitions, notation, properties, concepts, relationships, principles, conditions, theorems, and classic models.
(3) Conditional knowledge includes, for example, knowing when and why to do systems analysis, when and why to use linear programming, and when and why to perform a simulation.

The FarmVille project coincides with lectures easily and allows students to immediately apply what is learned in class. The immediate application of classroom information reinforces learning with repetition and real experience using procedures. . The survey presented in the latter section helps to measure this effectiveness.

The instruction of undergraduate students in operations research is a balancing game of mathematical rigor and application. On one end, it is believed that if the rigor of the topic is emphasized; the student will internalize the concept and then be able to apply it at will. On the other is that if students are introduced to a range of applications through short homework style problems, they will develop sufficient breadth to internalize the concept and likewise apply it at will. In reality, both of these are concepts to an extent, are flawed and somewhere in the middle lay the use of operations research lies in formulation, modeling, and interpretation of the effectiveness of the model or formulation. Modeling and formulation are messy, and are used as a supplement to traditionally focus on emphasizing the mathematical skills through rigor. This results in the students often being capable of applying mathematical solution concepts and tools, however, lack in the direct emphasis in teaching how to derive and model from un organized data or teaching the student how to determine relevant data for modeling versus irrelevant data. However, the importance of students being able to derive a formulation from raw non-formatted data as well as ill-defined problem scopes and understanding trade offs from competing objectives is extremely relevant and supplies a more realistic applicable implementation of operations research methods and tools. Please refer to Figure 1 for illustration of the Operations Research Process[2]. Thus, using a popular social networking game FarmVille by Zynga® we are able to give the students just the dynamic environment in which all of these key features are present.

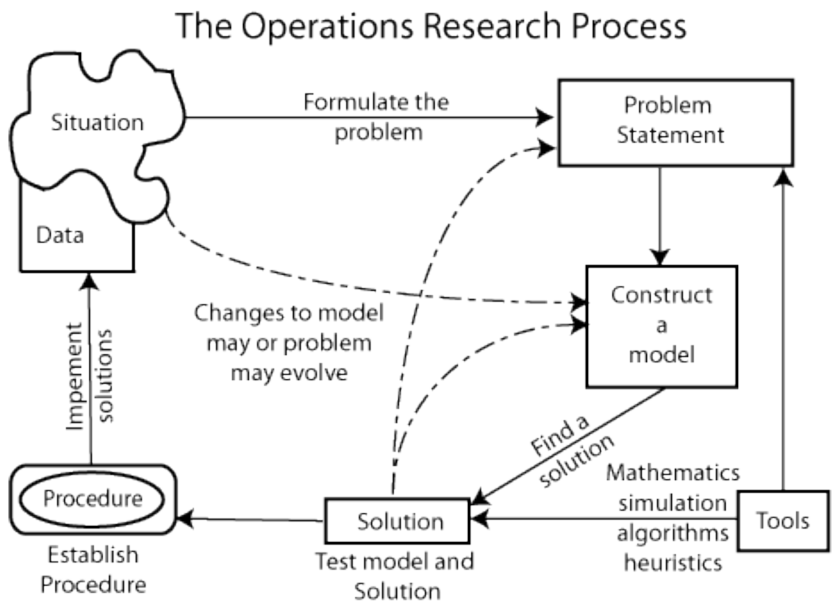

Figure 1: The operations research process: The figure depicts the operations research process in its entirety. That is an ill-defined situation lead to a problem statement and formulation of model. Then once a model is constructed we use mathematics and other tools to evaluate and attain a solution. The solution leads to a procedure, which must be implemented. However, modifications to the model may occur as well as the problem may evolve.

This paper supplies a brief look at the implementation of the popular FarmVille by Zynga ® game as an instructional tool for students in some of the key underlying fundamental topics of operations research through a competitive environment to become the best farmer. The paper seeks to introduce and reveal the basic principles that were sought by the educators in teaching effectiveness. The paper provides a detailed description of the educator's pedagogy and goals of implementing the contest in the course, and followed by a detailed description of the contest rules and supplies examples of real student deliverables. Described as a class activity students are likely to collaborate or support others. Students will be dissuaded from this when the project is presented as a contest between individuals. A thorough description of the evaluation criteria of the deployed student survey is also expended. Finally, the paper concludes by giving insights on challenges, and personal opinions regarding the effectiveness of the "FarmVille Challenge," as a means to teach operations research fundamentals.

FarmVille as a teaching tool

As the name deftly insinuates, FarmVille is a game in which you pretend to run a farm. FarmVille is one of the most popular games on Facebook, it claims to have almost 80 million active users[4]. The game aims to simulate basic farming tasks such as planting, maintaining and collecting animals, increasing the aesthetic appeal of the farm, and harvesting. Each of these tasks results in the gamer attaining gains in the form of experience points, FarmVille coins and Ribbons. There are many forms of gains as well as tradeoffs embedded within the game. As you gain experience and profit more, choices appear to the gamer in order to reach new levels faster. The levels therefore constitute the allowable combinations of crop types, gifts to be received or given, and also increase the allowable dimension size of the farm. Hence, as a gamer evolves in the game so do the tasks and goals. This poses an interesting optimization problem as formulation of the abstract mathematical model must continuously also evolve. The changing goals are driven by personal preference and goals, which contribute to the gamers' potential for developing a "business culture," that is, developing optimization models, which reflect and encompass the student's goals. These unique attributes of this game make it ideal for presenting the students with a problem that evolves, aims to define the student's decision making rational, develop key concepts regarding goals and formulation relevance, allows the student to address conflicting and competing objectives within the mathematical abstract model, and presents continuous change that must be addressed in order to increase the relevance of the mathematical model and its solution. Thus, this game has multiple characteristics that have high relevance in the instruction of basic and advanced operations research such as linear, integer, nonlinear, and stochastic programming. However, due to the course implementation being an introduction course, students were instructed to focus on integer and linear programming.

Methodology of Implementation

The implementation of FarmVille consisted of three primary components: 1. Initial formulation and mathematical model from gathered data, 2. Implementation of model and optimized solution, and 3. Evolution of model and policy implementation. Through these primary components the students were exposed to the realistic application of operations research methods. The game requires that the formulation of the model be changed as students accelerate through the ranks of the game.

In component 1, students were asked to derive a mathematical model from gathered information on the game. This included gathering information about start-up capital and limitations of the game regarding proposed objectives. The students were given two objectives which consisted of gaining as much revenue as possible, and the other was to gain as much experience as possible. However, they were also given the conflicting objective to gain aesthetic appeal of their farm, which involves of spending on buildings, trees, decorations, and other available items for purchase. The students were then asked to derive an optimization model relative to these objectives. However, these initial formulations had to be in accordance to some sort of policy associated with their farming timing and strategy. For example, some students combined both the revenue and experience within the objective function. Others on the other hand, decided their formulation was to be based on experience only in order to reach higher levels faster. In a sense, these initial formulations determined their particular goals and objective as well as presented the students with the problem of clearly defining their management strategy. For example, some students employed the management strategy to only plant long-term crops, that is, crops that take a long time (1-2 days) to mature in order to reduce the farming instances. This initial formulation expanded a great deal, which is illustrated below. In some cases some students reached out beyond the scope of the class and began discussions about dynamic programming and stochastic models, which were not covered in detail in the course. Hence, by presenting the students with only objective goals written in natural language the student sought to seek the most appropriate model. Many students began with the application of integer programming and linear programming. Hence, every student developed multiple formulations, yet, most displayed commonalities. It was a mixture problem at the beginning; however, as time progresses and crop types ranged a great deal, the policies became more reflective to productive farming. They needed to shift into assignment problems and/or demand-supply problems.

Table 1: Initial Formulation for XP

MAX Z = Stw+ (2)Egg + Wht + Soy + Pnt S.T.	Variables:
(1) 4Stw + 46 Egg + 12 Wht + 23 Soy + 16 Pnt <= 24 (2) 25Stw + 40Egg + 28Wht + 30Soy + 35Pnt – Gold = 0 (3) Stw+ Egg + Wht + Soy + Pnt – Plw = 0	Gold-spend Amount of Money in Farmville to Plw- Number of Plots of land to plow Stw- Number of Strawberry seeds to plant Egg- Number of Eggplant seeds to plant Wht- Number of Wheat seeds to plant Soy- Number of Soybean seeds to plant Pnt- Number of Peanut seeds to plant

The former is the initial formulation for Experience (XP) maximization. Constraint 1 limits the time Constraint 2 costs. Constraint 3 limits the number of plants to the number of places Plowed (Plw).

Students had to deal with other constraints and problems other than just the optimum planting solution. Crops will “wither” and fail to return a profit after a variable time from their maturation. Initially, Coins and Experience (XP) are inversely related and that the plants return more of one or the other. These changes with more XP and unlocked plants begin to offer returns on both. Students who focused on XP soon found that scheduling and repetition could compensate for lower returns on individual plants by repeated plows; XP was gained for each place plowed. They soon replaced the plants of the Initial Formulation with high turnover plants.

Table 2: Secondary Formulation for XP

MAX Z = Pump + Spi + Plw S.T.	Variables:
(1) 8 Pump + 2 Razz + 14 Spi <= 288 (2) 30 Pump + 20 Razz + 35 Spi + 15 Plw <= Gold (3) Pump + Razz + Spi – Plw = 0	Gold-spend Amount of Money in Farmville to Plw- Number of Plots of land to plow Razz- Number of Raspberry seeds to plant Spi- Number of Spinach seeds to plant Pump- Number of Pumpkin seeds to plant

The former is the secondary formulation for Experience (XP) maximization. Notice that Raspberries (Razz) are not in the Optimization Function and any XP gain from Razz must be from places Plowed (Plw). Constraint 1 limits the time available to the next 12 hours, but multiplies by the number of plots available (24*12=288).

As apparent from the formulation, students replaced the previous plants with new unlocked plants. At each juncture, the student must choose which seeds to evaluate. This leads a variable to potentially last through to the Final Formulation.

Table 3: Final Formulation for XP

MAX Z = 381 Pea + 170 Grp + 26Razz S.T.	Variables:
(1) 23 Pea + 2 Razz + 23 Grp <= 11086 (2) 190 Pea + 20 Razz + 85 Grp + 15 Plw <= Gold (3) Pea + Razz + Grp – Plw = 0	Gold-spend Amount of Money in Farmville to Plw- Number of Plots of land to plow Pea- Number of Pea seeds to plant Razz- Number of Raspberry seeds to plant Grp- Number of Grape seeds to plant

In component 2, students were given the capability to use any of the covered computer programs to solve their evolving problem. Hence, throughout the course various examples on the use of LINGO, LINDO, MatLab, and Mathematica software were presented. The students had to choose the appropriate solution methodology within these software packages. The employment of these software packages allowed the students to obtain detailed solutions to their formulations. However, interpretation of the solution became the key learning aspect as students quickly found out that the solution attained often needed to be modified in an effort to fit their monetary management policy. This reflection of the effectiveness of the model quickly took hold as student sought to gain further understanding through the use of more detailed solutions such as performing sensitivity analysis. Thus, they were asked to attain solutions to their models and formulations via assistance of software. Once, these solutions were obtained they had to implement them within the game. These solutions gave them insights into the amount of each crop to plan in order to realize higher profits or experience points, and include fixed costs of beautification.

Finally, component 3 consisted of students focusing on the evolution of the problem during a period of one month. Thus, each student was required to keep a "farmer's log," which was to be a table consisting of each implementation of the game where key changes had occurred. The students were asked to maintain information regarding addition of variables, constraints, shifts in policy, and model modifications. In addition, students had to maintain a profit growth data list as well as experience point data. This allowed them to keep track of their changes in the model as well as maintain a clear record of profit growth and experience growth during the month. A requirement of this log is that not only have the mathematical model and formulation, but the rational for the modifications or changes in the model. It also allowed them to keep track of friend's activity that is within the game as your social friends have the capability to give you gifts. These did not cost in-game resources but included consumption of time, which became relevant to some students and was also included in their formulations through tweaking the management policy students had adapted at the beginning of the project.

It was through these major project components that many items in the specific knowledge list stated by Liebman[6] were realized in order to effectively learn operations research. The implementation of this project was quite easy as the majority of all students had Facebook accounts and adding the FarmVille game was simple to do. The students were asked to maintain a farm and a farmer's log for the duration of one month. Furthermore, various discussions arose during this month where students sought to have specific questions and answers regarding why certain formulations do not work as effectively as others.

The competitive aspect of the project, which was important as it assured variability in the policies developed and employed, was to become the best individual farmer in the class. This was judged through three main factors each contributing specifically to their rank. 40% of the ranking of each student was based on the revenue they attained in one month, 40% was attributed to the level they had reached in one month, and finally 20% was allocated to the aesthetic appeal of their farm. The aesthetic appeal was based on judging. Students were asked to submit a picture or screen shot of their farm at the end of the month. A power point slide presentation was given that contained all students' farms and the class voted on a scale of 1-10, where 10 was the best looking and 1 was the converse. Thus, a simple weighted average revealed the winners of the contest. In order to motivate the students to participate in the project, prizes were to be given to the top three students in the class. This game provides unique attributes that allow the students to apply the operations research process in its entirety.

Survey and Concluding Remarks

The use of FarmVille to teach the entire operation research process resulted in students gaining knowledge beyond the mathematical rigor but also encouraged students' interests. Hence, upon the conclusion of the project a survey was presented to the students in order to gage the effectiveness of the FarmVille Challenge. The survey consisted of multiple questions that were designed to validate the effectiveness of the project. The survey consisted of modified questions previously presented by Yadav *et al.* 2010[1]. The survey was modified to fit the context of the introduction to operations research course and case study was modified to FarmVille Project. Table 4 contains the results from the student survey. The survey was taken in order to gather the student's perceptions regarding this project as a learning tool. This was the first implementation of the project within this course and still needs further refinement regarding specific outcomes and tasks to be accomplished. The students supplied a great deal of insight regarding future implementations of the project. One particular student stated, "The project should encompass more constraints regarding crop types. The project should be a supply and demand problem where some students are customers and some are the farmers." The suggestions are relevant and should be addressed in future implementations of this project structure.

Figure 2: Screen Shot of Student's Farm

Table 4: Survey Results

LEARNING	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I felt the use of Farmville Challenge was relevant in learning about the course concepts.	0.00%	18.18%	4.55%	59.09%	18.18%
The Farmville Challenge helped me analyze the basic elements of the course concepts.	4.55%	9.09%	9.09%	68.18%	9.09%
I felt that what we were learning in the Farmville Challenge was applicable to my field of study.	0.00%	4.55%	27.27%	59.09%	9.09%
The Farmville Challenge was helpful in helping me synthesize ideas and information presented in the course.	0.00%	9.09%	27.27%	50.00%	13.64%
The Farmville Challenge allowed me to retain more from the class.	0.00%	18.18%	27.27%	45.45%	9.09%
I felt that we captured more of the applications of OR through the Farmville Challenge.	4.55%	18.18%	31.82%	45.45%	0.00%

CRITICAL THINKING					
I thought that the use of the Farmville Challenge in an OR course was thought provoking	0.00%	4.55%	22.73%	45.45%	27.27%
The use of the Farmville Challenge allowed for more discussions of course ideas in and out of the classroom.	4.55%	9.09%	31.82%	40.91%	13.64%
The Farmville Challenge allowed me to view an issue/ problem from multiple perspectives.	0.00%	4.55%	31.82%	50.00%	13.64%
Farmville Challenge allowed for a deeper understanding of course concepts.	4.55%	9.09%	18.18%	63.64%	4.55%
The Farmville Challenge brought together material I had learned in several other courses.	18.18%	31.82%	27.27%	22.73%	0.00%
I was able to apply the course concepts and theories to new situations as a result of doing the Farmville Challenge.	13.64%	9.09%	27.27%	45.45%	4.55%
ENGAGEMENT					
The Farmville Challenge added a great deal of realism to the application of OR and Management Science.	0.00%	13.64%	27.27%	50.00%	9.09%
I was more engaged in class during the Farmville Challenge.	9.09%	31.82%	40.91%	4.55%	13.64%
The Farmville Challenge was more entertaining than it was educational.	0.00%	31.82%	22.73%	27.27%	18.18%
I felt immersed in the activity that involved the Farmville Challenge.	9.09%	9.09%	31.82%	31.82%	18.18%
I took a more active part in the learning process that was associated with the Farmville Challenge.	9.09%	13.64%	45.45%	13.64%	18.18%
I was frustrated by ambiguity that followed when doing the Farmville Challenge.	0.00%	22.73%	27.27%	36.36%	13.64%
I felt that the use of the Farmville Challenge in the course was inefficient.	4.55%	40.91%	31.82%	18.18%	4.55%

I found the use of the Farmville Challenge format challenging in the class.	9.09%	22.73%	31.82%	31.82%	4.55%
Most of the student I know liked the Farmville Challenge.	0.00%	18.18%	50.00%	27.27%	4.55%
I needed more guidance from the instructor about the Farmville Challenge in the class.	0.00%	22.73%	18.18%	40.91%	18.18%
The Farmville Challenge took more time than it was worth.	9.09%	9.09%	45.45%	18.18%	18.18%

All students were asked to complete the survey and also to include feedback regarding the project within their final project document. An example of this feedback is a student stated in his/her final report, "As I planted and harvested more crops, I gained more XP (experience points), causing additional crops to become available for me to plant. I reevaluated my formula every time I moved up in level to include the new crops that became available." Another student stated, "I followed the policy not to plant any crops that come to harvest in less 24 hours throughout the entire project." Finally a student wrote, "I performed sensitivity analysis. This was relevant to the project because it showed me how many additional plots I could afford to plow and plant." Thus, throughout the project, students had to stick to their original policy and if any modification took place to their policy they had to have logical justification. This was clearly evident as most students submitted long logs with great deal of detail regarding the evolution of the formulation and models. In addition, most students were very clear to state their management policy and logged a great deal of information regarding shifts in their policy and managerial decision process. The overall purpose of the project to engage students in higher level thinking as well as determining when model and formulation is relevant. Determining the proper procedure to attain solutions was also a key are of focus for this project. In these key concepts the FarmVille game was successful.

The survey results revealed that most of the class agreed that this was a good learning tool. However, because this was the first implementation of the project some open-ended questions arose. These questions focused primarily in the students wanting to know exactly what was amount of XP as well as revenue would be required to attain high marks in the course. Thus, due to this in the next implementation students will be given strict requirements regarding minimal XP. This would transform into a rubric for grading effort (i.e. 3000 XP is a (Taylor, 2007)C; 4000XP is a B, and so on). It is known that most undergraduate students often dislike open ended or ill-defined tasks. The students showed positive thoughts regarding that this was an engaging project, but some improvements are available to be made. For example, over 36% of students thought that the Farmvile Challenge took more time that it was worth. The time period of the project can be shortened without significant loss of learning opportunities. Most of the students gained a static management plan for the majority of the time which doesn't improve understanding with repetition. Perhaps, of all the presented surveyed results the more relevant was that most students saw it as helpful in understanding the course concepts.

Conclusions

The FarmVille project presents students with a realistic application of operation research tools and methods. The project did well to teach the students regarding the relevance of knowing when, why, and how we use operations research. Due to the competiveness of the game, students remained engaged and sought clarity regarding more complex concepts. Furthermore, the game appeals to the students as it is presented within their social networking medium and joins their regular life with school tasks.

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