Quality Approaches in Higher Education

Assessing student perceptions of engagement, learning, and critical thinking skills of student projects using pop culture topics.

Curriculum-Evolving Case Study: Using Zombie Theme for Introduction to Operations Research Course

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Abstract

Increasing student engagement and participation as well as improving knowledge retention are important to student success/achievement in any mathematically rigorous course. This paper presents the development of a curriculum-evolving project that seeks to achieve higher levels of student engagement, learning, and critical thinking skills. Specifically, the pop-culture topic of "zombies" was used for the purpose of increasing student development with regard to operations research tools and methods. The goal was to develop a semester-long project that was highly correlated to topics covered in the course in an effort for students to demonstrate the implementation of the tools and methods in a systematic way to increase knowledge retainment. A student survey was utilized to quantify the students' perception of the project and the results are presented.

Keywords

Teaching Quality, Learning Outcomes, Operations Research

Introduction

There is substantial evidence that traditional pedagogy, which includes lectures, homework, and team projects, is ineffective to teach topics that are math intensive (Paas, 1992). Paas (1992) continues that relying solely on lectures and problem solving is not the most effective means to teach topics such as mathematics, computer science, physics, or engineering. According to Handelsman, Briggs, Sullivan, and Towler (2005), student engagement is considered an important predictor of student achievement of learning. Handelsman et al. (2005) provides a review of approaches that aim to increase cognitive engagement, critical thinking, and learning in students. In addition, the authors also present the Student Course Engagement Questionnaire (SCEQ) to measure student engagement at the college/university level and conclude that the SCEQ does supply insight into the student perceptions of engagement. However, Prince and Felder (2006) provide a thorough literature review as it relates to the most common approaches, definitions, and methodologies for teaching engineering. Specifically, the multitude of the research presented is given from two very distinctive points of view, which are inductive as well as deductive learning and teaching of engineering. Further, Bransford, Brown, and Cocking (2000) provide a comprehensive survey of psychological research that supports inductive methods. Specifically, Bransford et al. (2000) states that, "All new learning involves transfer of information based on previous learning;" and "motivation to learn affects the amount of time students are willing to devote to learning. Learners are more motivated when they can see the usefulness of what they are learning." Hence, effective education should seek to increase opportunities where students can transfer lecture information and topics, which motivate them to learn. Previous studies have concluded that traditional lecture materials and methods are ineffective; therefore, educators should seek to develop methods in which students can continuously apply the material outside of the textbook problems.

Student engagement, participation, and transfer knowledge is vital to the effectiveness of learning. As students perform poorly on tests, fall asleep during lectures, or as in-class participation decays, many faculty members seek to improve their in-class delivery in a last ditch effort to gain enthusiasm regarding the topic. Some faculties have incorporated social media to enhance learning (Guardiola, Murray, & Cudney, 2011; Griesemer, 2012). Stodolsky, Salk, and Glaessner (1991) provide an unnerving perception of young students in the K-12 grade levels, which suggests that many students perceive math to be boring. It can be assumed that this view is not dramatically changed at the college level. However, students differ greatly in their individual learning goals and have different expectations regarding their learning efforts (Ainley, 1993). Hence, it is unrealistic to expect all instructors to develop material that is relevant, rigorous, and is also engaging as it is a daunting task (Liebman, 1998).

In this article a curriculum-evolving individual project is presented. The project was developed as a means to assure that students applied the concepts and methods in the field of operations research (OR). Hence, the focus was on transferring the knowledge gained in the classroom into other problems. One of the most difficult aspects of teaching OR is that it is a balancing act between emphasizing general concepts or the mathematical rigor. In addition, OR topics require a high level of critical thinking as students must create mathematical representations from data to represent realistic decision-making processes. Therefore, both conceptual and mathematical correctness are necessary to develop the students' skills of modeling optimization problems. In OR, modeling refers to the development of a correct and relevant mathematical model formulation that seeks to determine the optimum decision, which is not trivial and is in many cases counterintuitive.

This article develops a parallel evolving story that contains relevant problems which allow students to refine their OR skills. Furthermore, the evolving portion allows for small, unique variations from one student to another. The students can still work together; however, their decision situations differ slightly due to the evolution of the project, differences in information, and the randomness created by their decisions as the project evolves from one primary task to the next.

Moreover, the primary research question is: What is the student perception of using pop-culture topics, which are often unrealistic, in their learning? Some students would consider such topics as childish and not take them seriously. Thus, it is important to understand how students perceive these topics as a learning tool. Do students feel like this type of project facilitates their learning of OR concepts and/or techniques? Therefore, a survey was used to gather the students' perceptions regarding learning, critical thinking, and engagement. The premise is that the project is well received by the students, and students perceive the case study as an educational tool.

The curriculum-evolving project (CEP), detailed in the latter section of this paper, was implemented in a traditional Introduction to Operations Research course. This course primarily contains undergraduate engineering students in their junior and senior years, which translates to the third or fourth year of their respective degree programs. It is a course that all students are required to take within the industrial engineering emphasis of the engineering management bachelor's program at the Missouri University of Science and Technology. The survey's results were gathered from the fall 2012 semester in which 21 students were enrolled. The course is only offered once a year.

This paper is focused on the development of an individual case study. The case study is unique to each student in the class. However, due to the similarities the students can work together to determine the best approach to formulation, solution, and analysis. The CEP is not a traditional group case study in which a group of individuals are given the same information and asked to derive one solution. The CEP is comprised of the same general problems; however, randomness in the data and the evolution of the problem results in a case study that seeks to increase the opportunity for students to learn OR tools, methods, and techniques. The students were surveyed for their perceptions regarding this learning experience to gain insight regarding whether the CEP was perceived as an effective general approach toward teaching OR.

This article begins with an explanation of what a CEP is and how to deploy it. Next, the optimization of the survival project is explained and its components tied to the syllabus topics. Finally, the results of learning, critical thinking, and engagement are provided. In addition, various student quotes are included to demonstrate engagement. The primary research question is to determine whether the student perceives the CEP as a worthwhile and constructive learning tool.

Curriculum-Evolving Project

The goal of the CEP was to supply an opportunity for students to develop their modeling and formulation skills further as they relate to the field of OR. Furthermore, another goal was to increase the students' capability to identify formulation approaches and solution tools correctly. Common topics in an introductory course of OR at the undergraduate level include, but are not limited to: linear programming, duality theory, sensitivity analysis, transportation and assignment, network optimization models, integer programming, and nonlinear programming methods. Hillier and Lieberman (2001) state that these topics supply a good survey of the OR field for upper-division undergraduates. Hence, the syllabus contained the aforementioned topics and in the respective order in which they are listed. Specifically, in Figure 1 the project parts are directly related to the topics contained in the syllabus. The proceeding subsections elaborate on the details of the project sections, which were titled *Fortify or Flee*, *Time to Move*, *There is Hope*, and *When Will it End?*

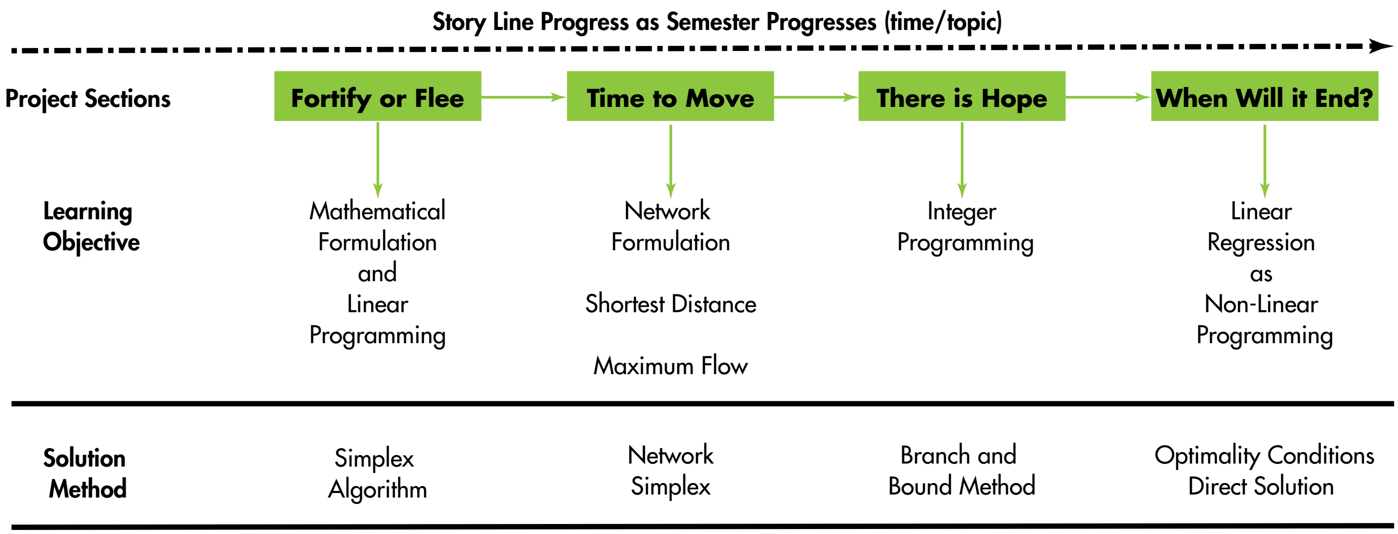


Figure 1: Project Sections as They Relate to Course Material

The Evolving Storyline and Methodology

The story begins with the Zombie Apocalypse taking place all over the world. The students unite as a group within the case. They begin with the entire class roster (e.g., a list of students in the class); however, losses of people are incurred at every stage. The students are given a simple random generator to determine which of their fellow students have fallen victim to the zombies, depending on some conditions explained in the latter part of this section. Thus, they have local and global decisions because each scenario presented asks the individual student to formulate the optimal decision for that stage. However, the overall goal of the student project is to maximize the number of students that survive the entire story. Hence, this global problem is not clearly given or explained and is left as an open problem. This global issue was proposed to determine how students deal with this larger problem and how it affects their conclusions in the smaller stages of the case. Subsections will later explain each stage of the case in detail.

This case study project is unique because the problems are interconnected and influence the subsequent problems throughout the semester. Specifically, a random generator drives the uniqueness of the case for each individual. For example, a student must determine the size of the zombie horde that will attack in the "Fortify or Flee" section. A uniform distribution is used to determine the size of the zombie $N(t_0) + xN(t)$, where $x \sim U(0,1)$, $N(t_0) = 300$, and $N(t) = 200$, where this will result in a horde of between 300-500 zombies. The students are given information about each type of fortification and how many zombies each fortification can eliminate. Each set of five zombies that is not eliminated by the fortifications results in a loss of one classmate from the original individual student's roster. Therefore, if 10 zombies were not eliminated by the fortifications then a loss of two individuals will occur.

Recall that this is unique to each student. Hence, each student may have a different number of zombies attacking as well as the fortification mixture may be different due to this small but significant change as the allocation of resources may result in different fortifications mixtures for each student. The student then must eliminate two students at random from his or her roster (again employing a random number generator). This results in a student beginning the next section of the project with only 17 individuals since he or she lost two from the original 19. Also, since many of the resources available depend on the number in the group, the student realizes that the loss of individuals also results in a loss of other resources. An example of this is the network problem posed in "Time to Move" as the number of individuals getting from the start to end of this section must be maximized; however, the number they begin with is critical to the formulation, solution methodology, and result. The network problem, therefore, results in a certain number of students surviving the journey by formulating a path through the network that optimizes (maximizes) the number of students that reach the end of the network. Similar to the previous case section, the necessary doses of the cure in the "There is Hope" section of the case study is based on the number of individuals still alive. Moreover, the number of students still alive at the end of the "Time to Move" section determines the amount of resources necessary for dosages and the sub-problem of gathering the resources in the "There is Hope" section. Lastly, the case section titled, "When Will it End?" allows the student to make use of the nonlinear programming; however, this problem varies as the data given to the students is different for each student. The students must determine the best model to predict the decay of the zombie population. The number of people left at this point and the supplies they have weigh on their survival. The more people, the more supplies. Thus, they can last longer until the zombies die off from hunger. In this sense, the students' optimal solutions attained in each section impact the next section and, more importantly, the goal (global consideration) to maximize the number of survivors.

The global view of the problem is to maximize the number of individuals at the end of the semester or story. Students must create a system of systems that takes into account the formulation of the local problem (e.g., case study section such as the Fortify or Flee) and assure that previous formulations relate somehow to the global problem posed, which is to increase the number of students on the roster who have survived all subsections of the case. This problem was left open ended to allow the students freedom to determine the best formulation and solution method. This mechanism was created in a similar fashion in the proceeding sections of the case. The interest here is to see if students are creating a global system problem or only local problems. This concept is visited in the lectures throughout the semester, as local solutions often are not the same as the global solution. Furthermore, it is important to assure that solutions to the local solution (e.g. case study section) result in the best global solution. By requiring the students to formulate both global and local programming models, the true concepts of OR are employed.

Fortify or Flee

The first decision is whether to stay at the university and fortify against a known attack from zombies of known size or to flee to another location. The students are given an individual attack size number. Then they must formulate an optimization problem to determine whether they can weather such an attack. Hence, in this part of the project the students must formulate and solve a common Optimal Mixture Model: Linear Programming Problem, in which the mixture of fortification and defense must be chosen in an effort to take on the large force of zombies. The problem information given included the following:

- Five fortification types are given, each with the following information:
  - Time it takes to build each fortification.
  - Amount each fortification requires in basic resources.
  - The amount of zombies each fortification can repel.
  - The amount of time available until the zombie attack.
- Two fortifications are not optional and must be completed.
- The following trade-off condition is given: If the group does not fortify and the decision to flee is taken, 30% of the group will be immediately lost as they are turned into zombies.
- Instructions regarding the information to be turned in for grading are given.

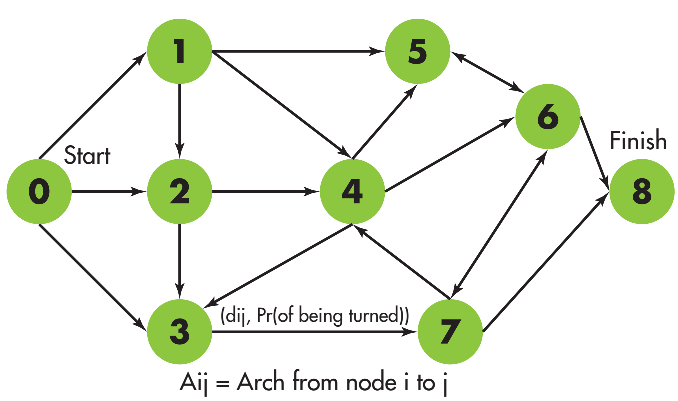
Time to Move

In this section of the project, the course topics have progressed to more complex concepts and solution methodologies, as well as formulation techniques. Thus, as the curricula has increased in complexity so do the corresponding sections of the case study. In this part of the story line, the students must assess their losses and begin a formulation to determine the safest route through a network of roads. The students receive a basic network topology, which is illustrated in Figure 2. The students are given d_{ij}, which denotes the distance between node i to node j. Similarly, P_{ij} denotes the probability of each person being turned into a zombie if he or she takes the arch between node i to j.

The students are not given clear directions regarding any formulation technique, no clear objective, nor solution methodology to be employed. The ideal formulations were to maximize the number of people expected to survive the travel from start to finish. However, students would formulate the problem as a shortest path, critical path problem, and maximal flow problem.

There is Hope

The students are told of a miracle cure that is able to stop the process of turning into a zombie. The students are given information about the recipe and what is required to make such medicine. This problem requires the students to develop a plan to gather the required supplies from nearby towns and storages using the widely-known traveling salesman problem. Secondly, the students are asked to develop a solution regarding the number of doses. Since each student is using a random number generator to determine the levels of supplies at the possible locations, the amounts differ from student to



Distance, d_{ij}, and probability, P_{ij} of turning into a zombie were provided

Figure 2: Simple Proposed Network of Roads

student. Furthermore, the amounts and dose must be integer values. The students must employ their knowledge of mixed integer problems to derive a solution. Their primary objective is to maximize the number of doses given when certain levels of ingredients are available. Hence, the students must employ the pseudorandom number generator to determine which locations are the ones with the highest amounts of supplies. In short, it is a facility location problem or assignment problem, which requires integer decision variables.

When Will it End?

At this point in the course the topics have fully evolved and have extended into an introduction to nonlinear programming methods. Hence, statistical data is given to the students regarding the population of the zombies. The zombie population is starving to death and their numbers are beginning to decrease. The students are given daily zombie population numbers, which are attained through a random number generator. The students' goal is to solve the unconstrained optimization problem.

$$Min\ F(x_i) = \sum_{i=1}^{N} (y_i - y_a(x_i))^2$$

Where, $y_a(x_i) = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 + \in$, which is a quadratic regression model. The goal is for the students to determine the link between optimization and statistical analysis. As most statistics is about deviations, this link makes students aware that OR easily overlaps with other disciplines. The students are asked to parameterize the model based on data. Hence, they are determining the optimal coefficients to the model that minimize the mean squared error.

Software and Methodologies

The students were instructed to employ all available software skills. The course covers the LINDO, LINGO, and Excel solvers to improve these optimization problems. Students were given one lecture in which they were taught to use the pseudorandom number generator, which was developed in the Mathematic 9 software platform. The students were also taught how to extract the results from the generator. An example of this implementation within Mathematica is the *RandomSample[Range[1,20],x]* function, which would supply a random sample in the range of 1-20 of length *x*. Lastly, students received a clear rubric on materials to be completed for grading purposes.

Student Collaboration

The students were encouraged to work together in groups and discuss formulation approaches and solution methods. In each lecture 10 minutes were set aside for students to ask the professor any questions regarding the case, which also facilitated group collaboration. Furthermore, the professor designated 30 minutes a week when students could ask questions or discuss current solutions in the study lounge. These sessions often resulted in more discussion among the students rather than with the professor as students would discuss their individual case details and others would weigh in on approaches or compare solutions. Since each student had a unique case but similar problems, the tools were the same. This was enriching as students often answered each other's questions and would pose questions to the professor on critical approach methodologies or concepts.

Results

A basic survey was used to gain insight into the student perceptions, specifically a survey first proposed by Yadav, Shaver, and Meckl, (2010) that has been employed in other studies such as Guardiola et al. (2011) and Guardiola, Dagli, and Corns, (2013). The survey was modified and results are detailed in

Table 1: Perspective of Learning

Learning	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I felt the use of the zombie project was relevant in learning about operations research concepts.	42%	58%	0%	0%	0%
The integration of the zombie project helped me analyze the basic elements of operations research concepts.	53%	47%	0%	0%	0%
I felt that what we were learning in using the zombie project was applicable to the field of operations research.	42%	53%	5%	0%	0%
The zombie project was helpful in helping me synthesize ideas and information presented in the course.	47%	47%	5%	0%	0%
The zombie project allowed me to retain more from the class.	58%	42%	0%	0%	0%
I felt that we covered more content by using the zombie project in the class.	42%	32%	21%	5%	0%

Table 2: Perspective of Critical Thinking

Critical Thinking	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I thought the use of the zombie project in the class was thought provoking.	37%	42%	16%	5%	0%
The use of the zombie project allowed for more discussion of course ideas presented in the class.	63%	32%	5%	0%	0%
The zombie project allowed me to view an issue from multiple perspectives.	32%	58%	5%	5%	0%
The zombie project allowed for deeper understanding of operations research concepts.	37%	47%	16%	0%	0%
The zombie project brought together material I had learned in other engineering courses.	16%	32%	26%	26%	0%
I was able to apply the operations research concepts and theories to new situations as a result of using the zombie project information.	37%	37%	26%	0%	0%

Table 3: Perspective of Engagement

Engagement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The zombie project added a lot of realism to the class.	21%	37%	37%	5%	0%
I was more engaged in class when discussing the zombie project.	32%	21%	42%	5%	0%
The zombie project was more entertaining than it was educational.	11%	16%	47%	21%	5%
I felt immersed in the activity that involved the use of the zombie project.	21%	42%	37%	0%	0%
I took a more active part in the learning process when we discussed/used the zombie project in the class.	26%	47%	16%	11%	0%
I was frustrated by ambiguity that followed when using the zombie project as a reference.	0%	11%	26%	47%	16%
I felt that the use of the zombie project was inefficient.	0%	0%	11%	53%	37%
I found the use of the zombie project format challenging in the class.	5%	32%	37%	21%	5%
Most of the student I know liked the use of the zombie project in the class.	21%	42%	32%	5%	0%
I needed more guidance from the instructor about the use of the zombie project in the class.	16%	11%	21%	47%	5%
The zombie project took more time than it was worth.	5%	21%	26%	32%	16%

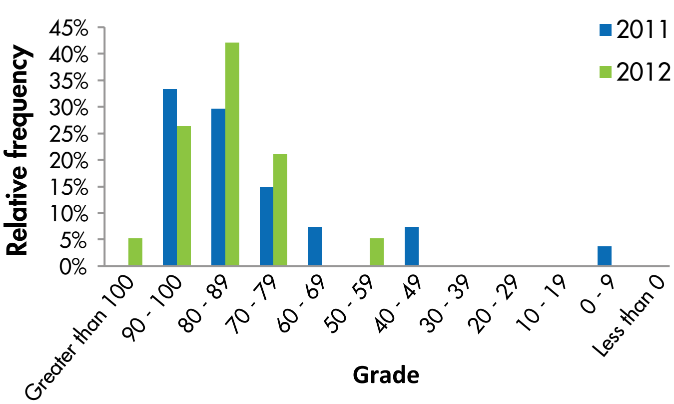
Tables 1-3, which contain student survey results regarding their perspectives of the case study. A total of 21 students enrolled in the course, and 19 or 90% of them completed the course in the fall of 2012. The survey was deployed using Blackboard 9.0. All 19 students responded to the survey. The students were requested to participate during the last week of the semester. This allowed for anonymity of the responder and also the capability to gather comments and suggestions.

It can be seen by the response that regarding learning, the students generally agreed or strongly agreed that the zombie project allowed them to learn the concepts of the OR field. Regarding critical thinking, the students agreed that the zombie project allowed them to view issues from multiple perspectives and the application of OR concepts and theories. However, regarding engagement, students were diverse in their responses. Specifically, when asked if the zombie project introduced realism, 58% of the students agreed or strongly agreed with the remainder being neutral and only one student stating that it did not. Similarly, when students were asked if this made them take a more active part in the learning process, 73% of students felt that the project did make them more active. The vast majority of the students did not see the project as inefficient. However, they had mixed opinions when it came to time and value, as many believed it took more time than it was worth.

In addition to the survey, students were given an area for general comments about the course. A few comments are supplied below:

- Student 1: "I like the zombie project and I think a supplement of a smaller assignment based on the material covered after the first test would help learn the concepts."
- Student 2: "I wish that it had been worth more points. It took 4X longer than the homework but was worth less. :("
- Student 3: "Fun Class! Great Class!"
- Student 4: "I liked the zombie project. It allowed students to work together in the class and; honestly, I think that when the class is working together to solve a problem, not only are we engaged in the learning process. We are also more satisfied as students. I picked up a lot more in this class after this project since I found it satisfying to work on it."
- Student 5: "I enjoyed the zombie project. It put concepts in perspective and helped me to remember them by putting them to a story line"

Figure 3 compares the grade distribution of the 2012 course to the 2011 course. Recall that 2012 was the year in which the zombie case was given to the students. The shift in the distribution is clear, as more students seemed to perform better in the course in 2012 versus 2011. In addition, fewer students fell below the 50-59 range in the year the CEP was employed. Note that in



The number of students was used to derive the relative frequency in each category because in 2011 only 19 students completed the course versus 31 students in 2012.

Figure 3: Student Grade Distribution for 2011 and 2012

2011 the course syllabus and textbook were also different than in 2012. The 2011 project was a simple case study taken from the text Hillier and Lieberman (2001).

Conclusions and Recommendations

The development of a project that was put to an evolving story line facilitated student learning of mathematically-rigorous topics. Specifically, the field of OR contains many tools, methods, and approaches, all of which must be employed in the most appropriate way. This approach allowed students to learn the topics to a higher level of complexity. They learned that the initial formulation often requires reformulation. The students were allowed to work together; however, due to differences in the data provided, no solutions were the same and small modifications were necessary to the main formulated models. Furthermore, students were able to discuss which methods were most appropriate and compare results. Lastly, and perhaps the most important outcome, was that students recalled the material more easily as the story helped in retaining their knowledge.

From the educator perspective this was not a daunting task. It took some planning, and assuring clarity in what was asked, and the information provided to the student had to be checked for errors. Overall, through something as simple as a story line, students felt more engaged and came to class with many questions regarding formulation techniques, solution methods, and interpretation of results.

Lessons learned included that undergraduates can deal with ambiguity to a certain degree, however, the old cliché, "practice makes perfect" remains relevant. The goals of assuring that students learned and increased their critical thinking skills were realized as the student perspective regarding these two measures was high, according to the survey. Specifically, the lesson learned from an educator's point or view was that students require practice, specifically opportunities to employ what they have learned from their lectures, texts, or homework into problems that are not always clear. In addition, more preparation was necessary as wording can easily confuse the students. Providing clear expectations regarding what will be graded and how it will be graded would reduce the students' worries. Furthermore, perhaps incorporating examples in the classroom that demonstrate multiple formulations, solution methods, and results should be done to show students how each OR tool can be used with similar data but seek to answer different questions.

Educators seeking to employ such a case study should remember that preparation is key. The educator should assure that ample time is given to the methodologies the students will employ within the traditional lecture period. In addition, the use of a teaching assistant who will monitor student progress may also facilitate the deployment of such a case study. Furthermore, the educator should not fear making more complex problems, but rather ensure that students have had relevant assignments and lectures to aid their success in solving more complex problems.

The surprise in this case study was that students sought tools not covered in the classroom; they used outside resources to determine additional tools that could be employed. This was observed as one individual formulated a single global problem with sub-problems and solved the complex system using software. In addition, students perceived the use of zombies as a serious educational tool, which was demonstrated by the reply to the survey as large percentages of students saw it as an effective means to learn and increase their critical thinking (see Tables 1 and 2). Overall, the response to the CEP and the pop-culture topic of zombies seems to have captured the interest of the students, and many took it seriously and approached the problem from a unique point of view. Furthermore, the goal was to determine if the students would take such a problem or topic seriously and could rigor/discussion be brought about from the use of such topics in the classroom. It appears from this first deployment that students liked the problem.

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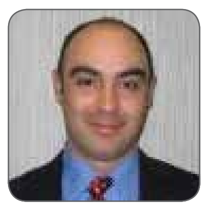

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