Integrating a Factory and Supply Chain Simulator into a Textile Supply Chain Management Curriculum

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ABSTRACT

Educational games have the potential to increase student learning by providing competitive experiences that motivate students to learn material and apply their knowledge to more complicated scenarios than are often found in textbooks. Both Responsive Technologies' Littlefield Technologies Game (LTG) and Supply Chain Game (SCG) challenge students to integrate problem-solving techniques to manage complex scenarios. Integrating these educational games into an undergraduate and a graduate operations/supply chain management class was the focus of this study. Implementing the LTG in the graduate class improved performance in both making capacity and inventory decisions. Slight improvements in making capacity decisions occurred upon incorporating LTG in the undergraduate class, but an improvement was not seen in overall inventory decision-making skills. The SCG was deemed not to fit into the graduate class curriculum, and thus, its effectiveness was not assessed.

1. INTRODUCTION

Educational games have the potential to increase student learning by providing competitive experiences that motivate students to learn material and apply their knowledge to more complicated scenarios than are often found in textbooks. While I believe that class lectures are necessary, the more you can actively involve a student in the learning process, the better they seem to understand and retain material. In my past experience, I have found that students who are not successful in learning textbook concepts often do not understand how learning the material might help them in the future. Seeing how these concepts could help them solve more realistic problems should help motivate them. Even for students who are successful in learning textbook concepts, I have evidenced that they struggle with applying them to more realistic problems where the information is not as straightforwardly given or when they have to apply multiple concepts together. Because most real world problems fall into both of these categories, strengthening these problem solving skills is important to their future career success. Since most students these days have played video games since they were small, they are very comfortable with using the computer and competing against one another on it. Hence, using computer simulations to teach supply chain management concepts actively engages students in a familiar way. Both Responsive Technologies' Littlefield Technologies Game (LTG) and Supply Chain Game (SCG) challenge students to integrate problem-solving techniques to manage complex scenarios. Integrating these

educational games into an undergraduate and a graduate operations/supply chain management class was the focus of this study.

1.1 Description of Educational Games

Both the LTG and the SCG are simulations that are accessed over the Internet. The LTG was developed by Sunil Kumar and Sam Wood, current and former professor, respectively, at the Stanford University Graduate School of Business. The SCG was developed by Sunil Chopra and Philipp Afeche, professors at the Kellogg School of Management at Northwestern University. Each allows for 1 or 2 week games, which run 24 hours per day. Students are divided into teams and make decisions on operational policies that affect the profitability of their enterprise. (Teams only need to monitor their enterprise a couple of times per day, and thus, the time commitment is not excessive.) Customer demand and operating capabilities are the same for each team. Teams compete against one another to see who can make the most money. Decisions that are made in the LTG include ones related to inventory, capacity, sequencing, lotsizes, borrowing money, and choosing contracts based on lead times. In addition, the SCG adds more complexity involving running distribution centers, selecting transportation modes, forecasting, and serving multiple types of customers in different locations.

At any point in time, students can check their ranking in terms of cash position relative to the other teams. In addition to the teams of students, there is a "Do Nothing" team, which simply represents what the cash position would have been if no changes to the operational policies were made during the game. A minimum goal is therefore to make changes to the operational policies so that by the end of the game, a team's ranking is better than the "Do Nothing" team. Additional descriptions of both pieces of software can be found at http://www.responsive.net.

1.2 Background

1.2.1 PI

I am an Associate Professor in the Department of Textile and Apparel, Technology and Management. I teach classes primarily in operations and supply chain management. My Ph.D. is in Industrial Engineering and Operations Research, and I mainly do supply chain-related research in production scheduling and inventory control.

1.2.2 Undergraduate Students

The undergraduate students involved in this project were the students that took TAM 380, Management and Control of Textile and Apparel Systems, in Spring 2007. There were approximately 50-52 students in this class, including sophomores, juniors, and seniors. The class consisted of entirely Textile and Apparel Management majors and Textile Technology majors, both of whom are required to take TAM380. The class is an introductory operations management class covering topics including inventory and capacity management. Therefore, the students have limited operations management knowledge before taking the class. In the past, the class has consisted primarily of

lectures based on material in the textbook, and grades have been largely determined by performance on homework and tests covering the lecture material.

1.2.3 Graduate Students

The graduate students involved in this project were enrolled in TTM761, Supply Chain Management and Information Technology, during Spring 2006 or Spring 2007. These classes consisted primarily of Institute of Textile Technology (ITT) students working on their masters degree. In Spring 2006, a total of 13 students were enrolled. Ten of the students were ITT masters students, 2 were non-ITT Textile masters students, and 1 was an Industrial Engineering masters student. In Spring 2007, a total of 9 students were enrolled. Seven of the students were ITT masters students, and 2 were Textile Technology Management Ph.D. students. The backgrounds of the students were very different. Most did not have a lot of previous operations/supply chain knowledge, but a few did. In the past, the class has been a combination of textbook and experiential learning, with the grade being determined from a combination of performance on tests and projects, including LTG projects.

1.3 Objectives

The objectives of this project are two-fold:

- To actively engage students in the learning process
- To make students better decision makers by having them solve complex problems that are more like the ones they will encounter in the real world

1.4 Student Learning Outcomes

There are two primary student learning outcomes for this project:

- Students will be able to make good capacity management decisions for realistic problems.
- Students will be able to make good inventory management decisions for realistic problems

2. METHOD

In this section, the project design and assessment method are explained. The project design includes general details of the case studies and information the students were presented, along with descriptions of their assignments. The assessment provides details of how the student learning outcomes were measured.

2.1 Project Design

After each educational game, students turned in an assignment that had them explain, among other things, their decisions to increase and/or decrease capacity and their inventory management decisions, both in respect to their determination of the order quantity and reorder point they used. Then they reflected upon their actions and explained how they might have improved their decisions. For the undergraduate class, I tried to create more straightforward assignment, while the assignments for the graduate class were somewhat more open-ended. My overall impression of what they learned and

their effort are the primary factors in determining their grade, rather than their ranking in terms of cash balance at the end of the game. Between the first and second time they played the LTG, important calculations and tools were discussed to facilitate better decision making.

2.1.1 Undergraduate Class

In TAM380, the students played 1 week versions of the LTG twice. Although the basic scenarios were the same, the parameters of the two games were completely different (e.g. demand rate, processing time of machines, etc.). Before the first game, I spent approximately 30 minutes providing a general overview of capacity and inventory decisions. I defined utilization and what a queue was. I also talked about buying machines. I explained that if your utilization is nearly 100% and your demand is not decreasing, then you need to buy another machine. In addition, I defined what an order quantity and reorder point were. I explained that you need to set your reorder point high enough to have sufficient inventory to satisfy demand during the lead time to receive the order. Students were randomly assigned to 13 groups of 4.

The first assignment can be seen in Appendix A. It was divided into 3 parts, each worth 12 points. (To put the points in perspective, there were a total of 1060 points possible during the semester, and the grading scale was based on 1000 points. Thus, there was a curve of 60 points built into the grading scale.) The "Changes" section required them to monitor their factory through the course of the week and gave them points for making two changes to the operational policies at the beginning, middle, and end of the game. The grade for this section was entirely based on their participation in the game. The quality of changes made was not evaluated here. This "Changes" section was created to motivate the students to actively participate in the game by rewarding them with points for doing so. I anticipated that the scores for this section would be very high since it was very easy to get 100% correct in this section. The other two sections consisted of questions asking the students to explain their inventory and capacity management strategy throughout the game. Specifically I asked to explain their buying, selling, reorder point, and reorder quantity strategies and whether, in retrospect, their strategies worked well. In addition, to reward students who had high cash balances at the end of the game, I included up to 5 points of extra credit based on their ranking at the end of the game.

Before the second LTG in TAM380, students were exposed to inventory and capacity calculations. Their textbook contained calculations for determining the optimal economic order quantity and reorder point under deterministic, stable demand (i.e. EOQ). They also were introduced to calculating reorder points under normally distributed demand. Furthermore, I taught them a queuing theory approximation to help them better make capacity decisions. This was not part of the textbook usually covered since the theory is too complicated for an introductory class. So instead of having them read the information in the textbook, I provided a simplified handout that was directed at the LTG. Based on the parameters of the first game, I did example inventory and capacity approximations in class, after I showed them how to estimate the demand throughout the lifecycle of the product. I required the students to do these types of calculations in their second assignment and strongly suggested that they do them before the game began so that they could develop a more proactive strategy. The students were allowed to pick

their own teams. About half did, and the remaining students were randomly assigned. There were 11 groups of 4 and 2 groups of 3, since 2 students dropped the class in the middle of the semester.

The second assignment can be seen in Appendix B. It was worth significantly more total points than the first assignment (65 versus 36). The "Changes" section was completely the same as in the first assignment, including the number of points it was worth. Question 1 involved calculating demand throughout the product's lifecycle and was worth 5 points. Questions 2-4 related to capacity decisions for machines at stations 1, 2, and 3, respectively, within the factory. Questions 5-6 related inventory decisions, namely reorder point and reorder quantity, respectively. Capacity and inventory decisions were each worth a total of 24 points. Although it is not written on the assignment, I allocated a total of 12 points for calculations and 12 points for their strategy explanation when I graded both the capacity and inventory questions. Thus the 12 points for the strategy explanations are somewhat comparable between the first and second assignment. As in the first assignment, it was possible to earn up to 5 points of extra credit based on team ranking. However, this time I limited extra credit to those teams that receive 100% in the "Changes" section and did better than the "Do Nothing" team. This modification was made because some groups whose effort I believed was poor received extra credit on the first assignment, which I felt did not make sense.

2.1.2 Graduate Class - LTG

In TTM761, students played a 1 week version of the LTG and then a 2 week version. In the 1 week versions that I create, students can make decisions about managing inventory, capacity, and sequencing. In the 2 week versions I create, students have the additional options of changing lotsizes, borrowing money, and choosing contracts based on lead times. Each year, I completely change the parameters of the game. (The parameters were also different from the games played in TAM380.) However, many of the parameters are kept the same in the 2 week version as in the 1 week version for that semester. Notable exceptions include the demand rate and the amount of capital initially available. I feel the additional options make the 2 week scenario sufficiently complicated without having to change all the parameters. For both games in 2006 and 2007, students were randomly assigned to different groups. Groups consisted primarily of 2 students, with 1 group of 3. An exception to this was that 1 student wanted to work alone on the 2 week version of the game in Spring 2006. Before the first game, I teach students inventory calculations for deterministic, stable demand. (These are the same inventory calculations taught before the second game for TAM380.)

The first assignment can be seen in Appendix C. (LTG assignments from Spring 2006 and Spring 2007 were nearly identical, and thus I only included those from Spring 2007.) I ask the students to explain their capacity, inventory, and sequencing strategies and to reflect on how good they were. I also ask them to think about if there was anything they could have done to make more money. The capacity and inventory questions are similar to those in the TAM380 assignments. However, I do expect a lot of calculations and in-depth analysis, without having to prompt them as to what specific calculations I think they should do as in the second TAM380 assignment.

Before the second LTG, students study some basic queuing theory and basic discrete event simulation with Excel, and then Arena. As part of a homework

assignment, I ask them to calculate the processing times of the machines (which are not explicitly given in the case studies), and I also have them create an Arena model of the manufacturing process in the LTG. By modifying this Arena model, they should be able to make informed decisions on choosing contracts and the amount of machine capacity necessary to sufficiently meet contract lead time deadlines.

The second assignment can be seen in Appendix D. I require them to write a paper, instead of just answering questions. All of the major types of decision need to be explained, including ones related to inventory, capacity, sequencing, lotsizes, borrowing money, and choosing contracts. They also must use queuing approximations and Arena simulation in helping them to make decisions. I want them to demonstrate to me that they can use these tools in making solid capacity decisions. Particularly for this second assignment, the TTM761 assignments do not have as defined structure for their grading as the TAM380 assignments, though inventory and capacity management decision as well as overall effort are a major factor.

2.1.3 Graduate Class - SCG

I had never previously used the SCG in a class. Therefore, I assigned the 1 week default scenario and did not modify any of the parameters, like I do in the LTG. I was surprised to find that the SCG was not a direct extension of the LTG as I had expected it to be. The learning objectives did not seem as clear to me as those in the LTG. Thus, I had to try to figure out how to make the SCG a meaningful experience in line with my desire to have students apply what they had learned in class to make better decisions than they could have before they took the class. Modeling the scenario in Arena would have been too complicated for the level of Arena taught in this class. By simplifying the scenario assuming that all events occurred in a specific order in a time bucket of one day, a spreadsheet simulation could be created to approximate the actual behavior of the system. Consequently, I required the students to create a spreadsheet simulation of the scenario. Then they had to use this simulation to test the effect of their decisions before making changes in the SCG. The assignment is in Appendix E. Questions about testing their decisions with the simulation are found in Part A, and Part B contains strategy questions similar to those found in the first LTG assignment. Unfortunately, the spreadsheet was much more complicated than the students had previously made, even with all the simplifications to the scenario. Therefore, they had a lot of problems. Perhaps if I had used the 2 week scenario, with its additional complications, the learning objectives would have been clearer to me. I know they have used the SCG in the NCSU College of Management and seemed happy with it, but I do not have specific details. The SCG did not seem a good fit for the TTM761 curriculum. Consequently, I did not use it again, and its effectiveness was not assessed.

2.2 Assessment

Since a significant portion of a student's grade in both the undergraduate and graduate class on the LTG assignments is based on effort, and for this study, I am most interested in whether students are better able to make good capacity and inventory decisions, I created a separate, more objective, method of assessing the student learning outcomes, rather than using the grades on their assignments.

2.2.1 Capacity Decisions

Ending up with a high cash balance in both the 1 week version and 2 week version of the LTG is largely a function of making solid capacity decisions about buying and selling machines with respect to meeting the chosen contract and having set the reorder point to the minimum amount necessary to meet demand during lead time. Having the optimal reorder point and order quantity does affect profitability but is largely outweighed by making solid capacity decisions in these cases. In addition, decisions about sequencing and lotsizes do not very significantly affect profitability for these scenarios. Therefore to measure whether students made solid capacity decisions, I looked at a function of their ending cash balance. The actual team rankings do not, by themselves, have a lot of meaning since teams that have very different rankings could actually have quite similar cash balances. In addition, doing better than the "Do Nothing" team does not have a consistent meaning from game to game, since the potential to improve upon the "Do Nothing" team's score is different from game to game.

However, comparing a team's ending cash balance to an estimate of the maximum cash balance attainable for that particular game is a direct measure of the team's performance in making capacity decisions. For each team, I computed the percentage of the maximum cash balance attainable that a team earned by simply dividing the team's ending cash balance by an estimate of the maximum cash balance attainable and multiplying the result by 100. Using the average of this percentage over all the teams that played a particular game enabled a consistent comparison of a classes' overall performance from game to game. This measure was used for both the undergraduate and graduate classes to determine if there was an improvement in their ability to make capacity decisions from the first game to the second game. An explanation of how the estimate of the maximum cash balance attainable for a particular game is provided in Appendix F.

2.2.2 Inventory Decisions

A different approach in the undergraduate and graduate classes had to be taken to evaluate whether playing the LTG had an affect on the students' ability to make inventory decisions. In the undergraduate class, data on calculating inventory order quantities and reorder points was available for both the Spring 2007 class that had previously completed both LTGs and for the Spring 2006 class which did not play the LTGs but were asked very similar test questions. Consequently, evaluating whether there was an improvement in the inventory question test scores from the Spring 2006 class to the Spring 2007 was the assessment method used.

In the graduate class, a similar comparison could not be made since the LTG had been played for several past semesters. But unlike the undergraduate class, students in the graduate class had been exposed to inventory calculations before the first LTG game. Therefore, evaluating whether there was an improvement in their ability to calculate estimates of the best order quantity and reorder point from the first to the second game was the assessment method selected. A rubric for this evaluation was created and is shown in Appendix G.

3. RESULTS

3.1 Effect on Student Learning

3.1.1 Capacity Decisions

3.1.1.1 Undergraduate Class

Table 1 shows the percentage earned of the maximum cash balance attainable for the undergraduate class. On average, the students earned 16.0% during the first game and 22.5% for the second. This slight increase indicates that there was some improvement in making capacity decisions, but the students were, on average, still no where near earning a high percentage of the maximum cash balance possible**.**

Table 1: Percentage Earned of Maximum Cash Balance Attainable in LTG

	Undergraduate Spring 2007		Graduate Spring 2006		Graduate Spring 2007	
	mean	standard deviation	mean	standard deviation	mean	standard deviation
Game 1	16.0%	29.8%	64.1%	32.9%	22.9%	28.3%
Game 2	22.5%	22.5%	81.6%	12.4%	79.8%	10.0%

Overall, I was not impressed by the undergraduate students' participation in the LTGs. During both games, 6 out of the 13 teams, did not receive a 100% in the "Changes" section. It was also obvious that very few teams had done many of the calculations asked in the second assignment before they played the game, as requested in the assignment. In general, they seemed perplexed by the LTG assignments, perhaps because they were probably very different than assignments they had had in other classes. The groups of 4 were also probably too big to facilitate active participation by all members. I did have some group members report to me that certain team members were not helping their group.

3.1.1.2 Graduate Class

Table 1 also shows the percentage earned of the maximum cash balance attainable for both graduate student classes. In Spring 2006, students earned 64.1% of the maximum in the first game and 81.6% in the second game. In Spring 2007, students earned 22.9% of the maximum in the first game and 79.8% in the second game. Thus, there was a significant improvement in performance from the first to the second game for both classes, and the percentage of the maximum amount earned was quite high, on average. Overall, I was satisfied with the effort of the graduate students. They seemed to handle these different types of assignments much better than the undergraduates.

3.1.2 Inventory Decisions

3.1.2.1 Undergraduate Class

The students were asked 9 multiple choice questions on inventory on their third test. Five of the questions related to calculating optimal order quantities and 4 questions related to reorder points. The test questions in Spring 2006 and Spring 2007 were very similar, with only the parameters of the problem changed. The classes were also similar in size (47 verses 49 students). As seen in Table 2, the mean performance of the inventory questions actually decreased from 6.11 in Spring 2006 to 5.84 in Spring 2007. There was a fairly large decrease in the mean score on the order quantity questions (3.13 to 2.47) and an increase in the reorder point questions (2.98 to 3.37).

Therefore, it seems the LTG helped them to better understand reorder points but confused them on calculating optimal order quantities. I believe that this confusion might be due to the fact there are two types of related order quantity calculations taught in this class, one if you are ordering the materials (EOQ) and another if you are manufacturing them (EMQ). Although there is manufacturing taking place in the LTG, the inventory decisions that need to be made are related to the acquisition of raw materials which are ordered. Hence the ordering quantity (EOQ) calculations are applicable for the LTG. Many students used the order quantity (EOQ) formulas on the test, even though the problem specifically stated that it was a manufacturing problem.

Table 2: Number of Correct Inventory Questions on Test

		Spring 2006		Spring 2007	
	number of questions	mean	standard deviation	mean	standard deviation
order quantity	5	3.13	1.56	2.47	1.49
reorder point	4	2.98	1.22	3.37	1.01
total	9	6.11	2.32	5.84	1.80

3.1.2.2 Graduate Class

Table 3 shows that there was a significant improvement in both reorder point and order quantity calculations from the first to the second game for both the Spring 2006 and Spring 2007 class. Both classes experienced greater than a 45% increase in their reorder point score. Even though the classes started with very different scores for their order quantity calculations, they both ended up with an average score near 87%.

Table 3: Percentage Correct on Inventory Evaluation Rubric

	Graduate Spring 2006		Graduate Spring 2007	
	mean	standard deviation	mean	standard deviation
first game reorder point	48.3%	43.1%	32.5%	22.2%
second game reorder point	97.9%	3.9%	78.8%	21.7%
first game order quantity	35.7%	33.8%	63.4%	42.5%
second game order quantity	86.7%	20.7%	86.6%	12.2%

3.2 Effect on Faculty/Pedagogy

Implementing the LTG and SCG require a lot of additional time when compared to preparing for a textbook-based lecture. Even though I had previously used the LTG, modifying the default parameters to make the scenarios different each semester and ensure that the experience is meaningful (requiring the students to make a lot of decisions and changes to perform well against their peers) is complicated. I often have to play the game in fast mode to make sure the scenario I created will accomplish these goals.

4. DISCUSSION

4.1 Summary of Important findings

Implementing the LTG in the graduate class improved performance in both making capacity and inventory decisions. Slight improvements in making capacity decisions occurred upon incorporating LTG in the undergraduate class, but an improvement was not seen in overall inventory decision-making skills.

4.2 Conclusions

Educational games can be important tools to enhance learning in some circumstances. In others, they may have little or no positive effect. It is important that one considers the type of student, group size (if any), how the educational game fits into the curriculum, and what you would like the students to get out of the experience before deciding on implementing one within a class.

4.3 Assessment of Technical Challenges

Since both the LTG and SCG are accessible through the Internet and do not require installation on campus computers, there were few technological challenges.

4.4 Potential Applications for Others on Campus

I have learned the following that may be applicable for other instructors interested in using educational games in their classes:

- Students are both excited and apprehensive about playing educational simulation games.

- Graduate students seem more receptive to educational simulations than undergraduates.
- Educational simulation games need to be modified each semester, and this can take a lot of time for the instructor.
- Using software in which you do not have access to the source code can be frustrating because you cannot modify the program when it does not do what you want it to do.
- Using software that is accessible through the Internet and does not have to be installed on computers on campus can be can be a time saver if the provider is reliable.

Appendix A

First Littlefield Assignment in Undergraduate Class

Team Name _____

TAM380
Littlefield Technologies Game 1 Questions
Due: Thursday, March 1, 2007 at 12:50pm

Authorized aid: This is a group assignment. The only people whom you can get help from are your group partners and Prof. Thoney.

	Actual	Possible
Changes		
Beginning	_____	4
Middle	_____	4
End	_____	4
Extra Credit	_____	
Questions 1-3	_____	12
Questions 4-6	_____	12
Total Points Earned	**_____**	**36**

Please have each team member sign the following:

I have neither given or received unauthorized help on this project.

_____

_____

_____

_____

The grading of this assignment is divided into 3 parts. The instructions for each part are given below.

Changes

To help ensure that you monitor your factory throughout the game, you will be given points based on whether you make *at least 2 changes at each of the following times during the game: beginning, middle, and end*. One change is defined as buying 1 machine, selling 1 machine, changing the reorder point, or changing the reorder quantity. The times periods are defined as follows:

beginning:	simulation days 50-105
middle:	simulation days 106-161
end:	simulation days 162-217

Extra Credit

To reward the teams who have the most money at the end of the game, I will give extra credit as follows:

teams with the 1st and 2nd highest cash balance:	5 points extra credit
teams with the 3rd and 4th highest cash balance:	4 points extra credit
teams with the 5th and 6th highest cash balance:	3 points extra credit
teams with the 7th and 8th highest cash balance:	2 points extra credit
teams with the 9th and 10th highest cash balance:	1 point extra credit

Questions

Type the answers to the following questions. Be sure to show analysis to justify your conclusions, *referring to graphs and/or calculations when appropriate.*

In addition, attach a printout of your "Transactions History" (Printouts should be made after the game is finished.)

1. Explain your strategy of buying machines. *(4 points)*

2. Explain your strategy of selling machines *(4 points)*

3. In retrospect, do you think your strategy of buying and selling machine worked well? Why or why not? *(4 points)*

4. Explain your reorder point strategy. *(4 points)*

5. Explain your reorder quantity strategy. *(4 points)*

6. In retrospect, do you think your inventory strategy (reorder point and reorder quantity) worked well? Why or why not? *(4 points)*

Appendix B

Second Littlefield Assignment in Undergraduate Class

Team Name _____

TAM380
Littlefield Technologies Game 2 Questions
Due: Thursday, April 26, 2007 at 12:50pm

Authorized aid: This is a group assignment. The only people whom you can get help from are your group partners and Prof. Thoney.

	Actual	Possible
Changes		
Beginning	_____	4
Middle	_____	4
End	_____	4
Extra Credit	_____	
Question 1	_____	5
Question 2	_____	8
Question 3	_____	8
Question 4	_____	8
Question 5	_____	12
Question 6	_____	12
Total Points Earned	**_____**	**65**

Please have each team member sign the following:
I have neither given or received unauthorized help on this project.

_____

_____

_____

_____

Please attach a printout of your "Transactions History" to your assignment. (Printouts should be made after the game is finished.)

The grading of this assignment is divided into 3 parts. The instructions for each part are given below.

Changes

To help ensure that you monitor your factory throughout the game, you will be given points based on whether you make *at least 2 changes at each of the following times during the game: beginning, middle, and end*. One change is defined as buying 1 machine, selling 1 machine, changing the reorder point, or changing the reorder quantity. The times periods are defined as follows:

beginning:	simulation days 50-105
middle:	simulation days 106-161
end:	simulation days 162-217

Extra Credit

To reward the teams who have the most money at the end of the game, I will give extra credit as shown below. Extra credit will be awarded ***only to teams that receive a score of 12 in the Changes section and end up with a cash balance that is higher than the Donothing Team***:

teams with the 1st and 2nd highest cash balance:	5 points extra credit
teams with the 3rd and 4th highest cash balance:	4 points extra credit
teams with the 5th and 6th highest cash balance:	3 points extra credit
teams with the 7th and 8th highest cash balance:	2 points extra credit
teams with the 9th and 10th highest cash balance:	1 point extra credit

Questions

Make sure you show all work. Be sure to show analysis to justify your conclusions, referring to graphs and/or calculations when appropriate.

The parts of the questions shown in bold should be answered before the game begins!! These parts can be handwritten (1a, 1b, 1c, 2a, 2b, 3a, 3b, 4a, 4b, 5a, 6a).

The parts of the questions not in bold (2c, 3c, 4c, 5b, 6b) must be typed.

Question 1

1a. Estimate the average demand in orders at day 25 by taking the average of the demand for days 16-25. Also estimate the average utilization for Stations 1, 2, and 3 at day 25 in the same manner.

1b. Using your answer in 1a, calculate the equation of the line representing the increase in demand from day 1 to day 150, and use it to approximate the demand at day 50 and day 150.

1c. Using the estimate of demand at day 180 calculated in 1b (demand day 180=demand day 150), calculate the equation of the line representing the decrease in demand from day 180 to day 267, and use it to approximate the demand at day 217.

Question 2

2a. Estimate the processing time for the machines at Station 1 by using the values calculated in 1a and the capacity equations discussed in class.

2b. Estimate the minimum number of machines you need at Station 1 to handle demand at day 50, day 150, and day 217 using the capacity equations discussed in class, your demand estimates from 1b and 1c, and your processing time estimate from 2a. (The minimum number of machines to handle demand is the minimum number for which the station utilization is less than 100%.)

2c. Explain your strategy for buying selling machines in Station 1 while you played Littlefield Game 2. Be sure to include how your answers to 2a and 2b affected your decisions. In retrospect, do you think your strategy for managing Station 1 worked well?

Question 3

3a. Estimate the processing time for the machines at Station 2 by using the values calculated in 1a and the capacity equations discussed in class.

3b. Estimate the minimum number of machines you need at Station 2 to handle demand at day 50, day 150, and day 217 using the capacity equations discussed in class, your demand estimates from 1b and 1c, and your processing time estimate from 3a. (The minimum number of machines to handle demand is the minimum number for which the station utilization is less than 100%.)

3c. Explain your strategy for buying selling machines in Station 2 while you played Littlefield Game 2. Be sure to include how your answers to 3a and 3b affected your decisions. In retrospect, do you think your strategy for managing Station 2 worked well?

Question 4

4a. Estimate the processing time for the machines at Station 3 by using the values calculated in 1a and the capacity equations discussed in class.

4b. Estimate the minimum number of machines you need at Station 3 to handle demand at day 50, day 150, and day 217 using the capacity equations discussed in class, your demand estimates from 1b and 1c, and your processing time estimate from 4a. (The minimum number of machines to handle demand is the minimum number for which the station utilization is less than 100%.)

4c. Explain your strategy for buying selling machines in Station 3 while you played Littlefield Game 2. Be sure to include how your answers to 4a and 4b affected your decisions. In retrospect, do you think your strategy for managing Station 3 worked well?

Question 5

5a. Estimate the minimum reorder point necessary in kits at day 50, day 150, and day 217 by using your demand estimates from 1b and 1c and inventory calculations discussed in your textbook. (The minimum reorder point does not include safety stock.)

5b. Explain your reorder point strategy while you played Littlefield Game 2. Be sure to include how your answers to 5a affected your decisions. In retrospect, do you think your reorder point strategy worked well?

Question 6

6a. Estimate the optimal reorder quantity in kits at day 50, day 150, and day 217 by using your demand estimates from 1b and 1c and inventory calculations discussed in your textbook.

6b. Explain your reorder quantity strategy while you played Littlefield Game 2. Be sure to include how your answers to 6a affected your decisions. In retrospect, do you think your reorder quantity strategy worked well?

Appendix C

First Littlefield Assignment in Graduate Class

TTM761
Littlefield Technologies Game 1 Strategy Evaluation
Due: Thursday, February 15, 2007
Percentage of Grade: 10%

Authorized aid: This is group assignment. The only person who you can get help from is your group partner and Prof. Thoney. Please write out and sign the honor code before you turn in the assignment: "I have neither given or received unauthorized help on this project."

Type the answers to the following questions on separate sheets of paper. Be sure to show analysis to justify your conclusions, referring to graphs and/or calculations when appropriate. In addition, attach a printout of your "Transactions History" as well as a printout of the "Sources and Uses of Cash". (Printouts should be made after the game is finished.)

1. Explain your strategy of buying and selling machines. In retrospect, do you think this strategy worked well? Why or why not?

2. Explain your inventory strategy. In retrospect, do you think this strategy worked well? Why or why not?

3. Explain your sequencing policy strategy. In retrospect, do you think this strategy worked well? Why or why not?

4. In retrospect, is there anything else you could have done to make more money? Explain your answer.

Appendix D

Second Littlefield Assignment in Graduate Class

TTM761
Littlefield Game 2 Assignment
Due: Tuesday, April 10, 2007
Percentage of Grade: 15%

Authorized aid: This is group assignment. The only people who you can get help from are your group partner(s) and Prof. Thoney. Please write out and sign the honor code before you turn in the assignment.

For this assignment, you must use queuing approximations and simulation with Arena as part of your justification for making some decisions!

This is a team report. It should discuss what actions you took during the weeks you had access to the factory and why you took those actions. The report should explain whether, in retrospect, you think you made good decisions in regards to additional machines you bought, machines you sold, your inventory policy (reorder point and quantity), your choice of contracts, your debt management strategy, and your lot sizing policy. It should also address what (if anything) you think you could have done to make more money. In addition, discuss the impact that the factory not being in optimal condition when you began managing it and the lack of available cash initially had on your strategy at the beginning of the game. Be sure to show analysis to justify your conclusions, referring to graphs and/or calculations when appropriate.

This paper is to be approximately 6 pages of text (not including graphs or tables), double-spaced with 12 point font. It should contain an introduction and conclusion. In addition, it must have a table that lists each transaction and provides a justification for each.

Content Checklist

_____ All your decisions in your "Transactions History" are explained

_____ You explain whether, in retrospect, you had a good strategy of buying and/or selling machines

_____ You explain whether, in retrospect, you had a good inventory strategy

_____ You explain whether, in retrospect, your choice of contracts was good

_____ You explain whether, in retrospect, you debt management strategy was good (Did you incur to much or too little? Did you pay it off in the best way?)

_____ You explain whether, in retrospect, you lot sizing policy was good

_____ You explain if there was anything else you could have done to make more money

_____ You explain how your decisions at the beginning were affected by the state of the factory when you began managing it

_____ You explain how your decisions at the beginning were affected by the initial lack of available cash

_____ You use the phrases “machine utilization”, “lead time”, “reorder point”, “reorder quantity”, and “queuing time” at least once each and not all in one sentence

_____ There are graphs included to support your decisions and conclusions

_____ There are calculations included to support your decisions and conclusions

_____ You describe at least one instance in which you used a queuing approximation to help make a decision

_____ You describe at least one instance in which you used simulation modeling with Arena to help make a decision

_____ You do not repeat any of the items mentioned previously as a question in your report. For example, do not have a section entitled “Explain whether, in retrospect, you had a good strategy of buying and/or selling machines?” If you would like to have section titles, something like “Machine Purchase Strategy” would be fine

_____ Your paper has an introduction

_____ Your paper has a conclusion

Appendix E

Supply Chain Assignment in Graduate Class

TTM761
Internet Supply Chain Game Assignment
Due: Thursday, April 20, 2006
Percentage of Grade: 10%

Authorized aid: This is a group assignment. The only person who you can get help from is your group partner(s) and Prof. Thoney. Please write out and sign the honor code before you turn in the assignment: "I have neither given or received unauthorized help on this project."

Part A (50%)

Create an Excel spreadsheet to approximately simulate the Internet Supply Chain Scenario, using time buckets of 1 day. In other words, just approximate the expected number of orders per day. There is no need to generate the interarrival times of each customer as we did in the Queuing/Simulation 1 Homework. Please model the different costs listed in the "Sources and Uses of Cash" as well as the capacity addition costs.

You should use this spreadsheet to test your strategies before and during the game.

1. Demonstrate to me how closely your spreadsheet costs approximated those in the simulation and explain to me how you used the spreadsheet to test your strategies. In your spreadsheet workbook, please include an example of each of the following that you refer to when answering this question:

    a. spreadsheet simulation of the game when you first accessed it at time 730

    b. spreadsheet simulation of the game when you finished at time 1460 (should include the decisions you actually made)

    c. spreadsheet simulation that shows me how you tested a strategy

    d. spreadsheet simulation that shows me how you could have improved a strategy

Part B (50%)

2. Explain your strategy of adding capacity. In retrospect, do you think this strategy worked well? Why or why not? What could you have done to improve it?

3. Explain your batch size (quantity) strategy. In retrospect, do you think this strategy worked well? Why or why not? What could you have done to improve it?

4. Explain your order point strategy. In retrospect, do you think this strategy worked well? Why or why not? What could you have done to improve it?

5. Explain your transportation selection strategy (truck or mail)? In retrospect, do you think this strategy worked well? Why or why not? What could you have done to improve it?

Type the answers to the above 5 questions on separate sheets of paper. Each answer should only be about 1 page long. Be sure to show analysis to justify your conclusions, referring to the spreadsheet you created, graphs and/or calculations when appropriate.

In addition, attach a printout of your "Transactions History" as well as a printout of the "Sources and Uses of Cash". (Printouts should be made after the game is finished.) You do not need to explain each transactions, but I should be able to understand your transaction history based on your strategy descriptions to questions 2-5.

Checklist for What to Send/Hand in

_____ Excel spreadsheet (electronic copy) with the 4 examples requested

_____Answers to each of the 5 questions

_____Printout of "Transactions History"

_____Printout of "Sources and Uses of Cash"

_____ Write out and sign Honor Code

Appendix F

Estimate of Maximum Cash Balance Attainable

To determine a precise estimate of the maximum cash balance attainable in the LTGs, a very detailed simulation would have to be created, and then a simulation optimization study would need to be performed. However, it is possible to more easily determine a close estimate. That is the method that was selected and will be explained here. The estimate is set up so that it may be a little higher than can actually be attained (biased high).

$$M = D*(P-C) – B + S$$

where
M: maximum cash balance attainable
D: total expected demand throughout the lifecycle of the product
P: price the customer pays for one final product if it is completed within the specified lead time
C: cost of the raw materials to make one final product
B: cost of buying additional machines to satisfy demand
S: money earned from selling machines

Note: Part of the reason that the estimate may be higher than is possible to achieve comes from the fact that inventory carrying costs are not taken into account (opportunity cost of capital in this case) and that all products may not be completed within their contracted lead time.

1 week LTGs

The number of additional machines and number that could be sold right away were found by first using M/M/c queuing theory approximations to calculate the minimum number of machines for each station within the factory so that peak demand could be satisfied with an expected utilization of no more than 90%. 90% was chosen since this usually allowed lead times to be met. Then this number was compared to the number of machines actually within the factory to determine the number of additional machines to buy and to initially sell. Since there was a decrease in demand near the end of the game, machines usually could be sold then also. The same type of computation was used to determine minimum number of machines for each station so that the demand rate at the point in time at which the player loses control of the game could be satisfied with an expected utilization of no more than 90%. Then this number was compared to the number of machines that were needed to meet peak demand to determine the number of machines that could be sold near the end of the game.

2 week LTGs

The procedure for determining how many machines could be bought and sold was similar to that for the 1 week LTGs. The procedure for determining the number of machines that could be sold near the end of the game was identical. However since there was the additional complication of contracts to choose from in the 2 week LTGs, the procedure for determining how many machines needed to be bought and how many could be sold initially was somewhat different. The minimum number of machines for each station so that peak demand could be satisfied with an expected utilization of no more than 90%

represents the number that needed to be purchased to meet contract 1 deadlines, the default contract. To meet contract 2 or 3, which have increasingly shorter lead times but increasingly higher prices (P), purchasing more machines is often necessary. I determined the minimum number of machines necessary for each of the contracts by using the simplified simulation of the machine operations that was created in TTM761 to find the cheapest combination of machines that would need to be purchased to satisfy the lead time promised by that contract at least 90% of the time. If there were not enough machines to satisfy at least 90%, then it would usually be better to select a longer lead time contract. Then I used that information to compute the maximum cash balance attainable, M, for each of the 3 contracts and selected the most lucrative as my actual M value used in the assessment. This method of selecting contacts and determining the number of machines necessary also tends to bias the M value high, as it assumes that all products meet the lead time of the selected contract.

To demonstrate that the estimate, M, of the maximum cash balance attainable is not excessively large, the maximum percentage earned over all teams for each game is shown in Table 4. It demonstrates that for each game played except game 1 for the graduate class in Spring 2007, it is indeed possible to earn a high percentage of M. I played the game 1 that the graduate class in Spring 2007 played in fast mode and was easily able to obtain 98% of M. This demonstrates that it was indeed possible to obtain a high percentage of M in that case also.

Table 4: Maximum Percentage Earned of Maximum Cash Balance Attainable in LTG

	Undergraduate Spring 2007	Graduate Spring 2006	Graduate Spring 2007
Game 1	94.4%	99.5%	64.2%
Game 2	87.0%	93.9%	92.4%

Appendix G

Graduate Class Inventory Evaluation Rubric

Reorder Point

dL + ss, where

d: daily demand
L: lead time in days
ss: safety stock

formula used (1 point) _____

d value used correct (1 point) _____

L value used correct (1 points) _____

ss stock is reasonable (2 points) _____

Total _____

Order Quantity

$\sqrt{\frac{2DA}{iC}}$, where

D: yearly demand
A: fixed order cost
i: inventory carrying rate
C: unit cost of item

formula used (1 point) _____

D value used correct (1 point) _____

A value used correct (1 point) _____

i value used correct (1 point) _____

C value used correct (1 point) _____

consistent units (orders or kits) (1 point) _____

consistent time frame (1 point) _____

Total _____