Supply chain simulator: A scenario-based educational tool to enhance student learning

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Abstract

Simulation-based educational products are excellent set of illustrative tools that proffer features like visualization of the dynamic behavior of a real system, etc. Such products have great efficacy in education and are known to be one of the first-rate student centered learning methodologies. These products allow students to practice skills such as critical thinking and decision-making. In this paper, a case is presented where a scenario-based e-learning product namely ‘supply chain simulator’ is developed at KFUPM for an introductory technology course. The product simulates a supply chain – a network of facilities and distribution systems that carries out the task of procurement and transformation of materials from manufacturer to customer. The product was put to test during four semesters and results of the survey conducted by the instructors and the students are presented. The results clearly suggest the benefits of using such a tool in enhancing student learning.

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1. Introduction

Simulation-based educational products are excellent “illustrative tools”, used exceedingly in student centered learning methodologies. It is an active learning technique, which stimulates a player’s diverse cognitive skills and insight into a system by instantly staging the consequences of their actions and strategies. Such actions and strategies can be tested without the apprehension of failures or reprisal. Such products allow a player to increase his understanding of a system in a short span of time. As compared to real world experience, this accelerated learning is one of the unequaled advantages of such products.

These simulation-based educational products provide a unique way to reinforce the theory discussed in the classrooms. As a player/student becomes deeply involved in the scenario, simulation or gamming situation, a sense of competition and a desire to perform well is most likely to develop. Consequently, the teaching
effectiveness of these products is exceptionally high. These products render a great opportunity for the students to visualize and experience a practical scenario of what they learn in their coursework.

An elating facet of these products is the inherent concentration of a player on decision-making. It is this intensity that gives these simulation-based educational products its richness and effectiveness. Even though these interactive approaches are not considered to be a substitute of more formal approaches in teaching, it effectively complements these methods. Using Bloom’s taxonomy, the first three levels of knowledge, comprehension, and application, in most cases, are fully served. The fourth level of analysis could be present fully or partially depending upon the type of the tool or product and the use of it by the instructor.

The tool or product presented in this paper is developed in an academic project at King Fahd University of Petroleum and Minerals (KFUPM). The motivation behind this project came from a workshop on increasing teaching effectiveness (Ellington, 2002) and an undergraduate course that the authors are teaching. The course is an introductory technology course namely ‘introduction to technology’ which is a compulsory course taken by the undergraduate students in the College of Industrial Management at KFUPM. The objective of the course is to improve the understanding of the undergraduate management students in various areas of technology such as manufacturing, construction, communication, etc. To increase the effectiveness of the course, three simulation-based products were developed in this project. According to taxonomy presented in Randall (2002) these products can be categorized as a scenario-based e-learning products referred to as SBELP in this paper. One of these SBELP ‘supply chain simulator’ is presented in this paper. As the course is compulsory, average enrollment per semester is essentially high.

In Section 2, literature review is presented. Section 3 elaborates on the features of the SBELP. Feedbacks from the instructors, who have taught this course, are presented in Section 4. Section 5 shows the outcomes when the SBELP was tested with the students. Finally, conclusions are presented in Section 6.

2. Literature review

Simulation-based educational products in academics are becoming widespread and ample literature is available on this area. These products are categorized as scenario-, simulation-, and game-based e-learning (Randall, 2002). The realization of the efficacy of these products is growing (Albrecht, 1995; Carlson, 2003; Curland & Fawcett, 2001; Gilad & Sheizaf, 2000; Holweg & Bicheno, 2002; Shifrony & Ginat, 1997; Sparling, 2002; Walter, Coalter, & Rasheed, 1997). Literature on specific studies is presented below.

Santos (2002) developed an internet based interactive teaching aid that introduces students to the domestic and international consequences of monetary policies of different nations. This game was different from other simulators in that it allows students, who represent nations, to interact with each other rather than with a computer.

Hantsaridou, Theodorakakos, and Polatoglou (2005) presented a multimedia module for climate-simulation experiments. The application was based on the energy balance model. The proposed method was free from numerical or algebraic computations. To motivate the students into learning, the fundamental principles of the subject are taught in an active learning environment.

Chua (2005) bridged the gap between the gaming and simulation community and the knowledge management community. He provided a template for designing and implementing knowledge management simulation game. He also used this template to show the viability and the effectiveness of a simulation game.

In (Khaled, 2001), an equipment replacement game is presented to aid in teaching and explaining the different effects of the strategies of buying/selling of an equipment on the various economic performances of the construction companies. The probabilistic aspect of demand in the construction market is incorporated in the game. Alarcon and Ashley (1999) present a simulation game to test various lean production strategies and its impact on project’s cost and scheduling. In (Shifrony & Ginat, 1997), a simulation game is developed for teaching communication protocols. The students act as protocol components in this game. It is reported that this method has significantly improved the level of understanding and motivation among students. In (Avolio, 1988) a simulation game, conducted on transformational and transactional leadership, is presented. The game is used in a second year MBA class. The results show correlation between the game and the actual practice.

Ponce (2001) presented an educational tool for the analysis of some parameters in wireless communication. This tool is especially interesting for telecommunications students, since it provides an easy way to understand
the characterization of radio channels. The graphical visualization of the results allows students to identify the path followed by each ray from its origin at the transmitter antenna to the receiver after reflection, diffraction, etc. It also allows students to see its contribution to path loss, the power delay profile, and the direction of arrival.

A modified beer game is presented in Sparling (2002). Beer game is one of the most popular games in supply chain education that has introduced the problem. In Sparling (2002), the game is taken to the next step by helping students or managers plan to surmount those problems and manage an efficient supply chain. This paper suggests a strategy for taking that next step – helping move towards solutions of supply chain problems. Anderson and Morrice (2000) describe an implementation and development of java-based, multiplayer, multigroup, and distributed simulation game based on the classical beer game. In Anderson and Morrice (2000), a simulation game is proposed that is designed to teach service-oriented supply chain management principles and to test whether managers can use them effectively. Holweg and Bicheno (2002) describe how a participative simulation model is used to demonstrate supply chain dynamics and to model possible improvements to an entire supply chain.

Curland and Fawcett (2001) examine the perceived problems with numerical skills applied to subject area such as operations management and finance using simulation games. A financial accounting and investment simulation game is developed and studied in classroom environment in Albrecht (1995). The application of an industry simulation game in a business course is discussed in Margaret (1995). It is concluded that the industry simulation is a potentially useful tool for in-house training programs. It challenges managers to move outside their own particular functional expertise to create a holistic vision of the decision-making framework. The above survey suggests the value of these games in education and training.

Due to ever-increasing scope and scale of work in this area, formulating development standards are becoming important. Shareable content object reference model (SCORM) is “a collection of standards and specifications for web-based e-learning. It delineates communications between client side content and a host (generally part of a learning management system)” (ADL, 2007; Wikipedia-SCORM, 2007). SCORM is an e-learning standard in which the goal is to have learning objects reusable, accessible, interoperable and durable, abbreviated as ‘RAID’ (Li & Lin, 2005). Li and Lin (2005) proposed a hybrid scheme, for SCORM compliant courses, composed of an XML binding model and a WAP based directory service in which complex metadata could be dealt efficiently. Content object repository discovery and registration architecture (CORDRA) are another standard which is “open, standards-based model on how to design and implement software systems for the purposes of discovery, sharing and reuse of learning content through the establishment of interoperable federations of learning content repositories” (ADL², 2007; Cordra.net, 2007).

The next section depicts the objectives, highlighted features, interface and development of the SBELP in this work.

3. The SBELP: ‘supply chain simulator’

The SBELP is named as ‘supply chain simulator’ as it tries to emulate an international supply chain network. This supply chain is used to deliver goods such as electronic equipments or a machine. The performance of these supply chains is judged by parameters such as inventory holding cost, backorder cost, and transportation cost, etc. Some other important terminologies and parameters are expressed below for understanding:

1. Supply chain: a supply chain is a network of facilities and distribution systems that carries out the task of procurement and transformation of materials into intermediate and finished products, and the delivery of these products to customers. A supply chain is made up of several elements such as manufacturer, distributor, retailer, etc.
2. Inventory: a company’s merchandise, raw materials, finished and unfinished products which have not yet been sold.
3. Inventory holding cost: cost per item per day held in the inventory.
4. Backorders: back orders are defined as delayed orders.
5. Backorder cost: per day penalty per backorder.
6. Upstream and downstream: upstream and downstream are used to identify the direction of flow in a supply chain. Information flows upstream while material flow downstream. See Fig. 1.

7. The bullwhip effect: the increasing variability in information or orders upstream in a supply chain is known as “The Bullwhip effect”. This effect is due to the time delays in receiving orders and product shipment. This is one of the phenomena that a player must visualize while playing this SBELP. See Fig. 2.

Objective of the SBELP developed in this work is to take part in an international supply chain, in which the player acts as a manufacturer. As the decision by one of the elements, affects the over all supply chain, the player’s performance is judged based on the overall cost incurred by the supply chain during its operations. This can be done by minimizing two contradictory parameters – the inventory cost and the backorders cost.

A fundamental characteristic that affects the overall performance of the supply chain is the bull whip effect. One of the key objectives of this SBELP is to understand and visualize this bull whip effect that is caused by the delays in delivery of information upstream or materials downstream.

The highlighted SBELP features, including SBELP development and interface, text guides, varying scenarios, are presented below:

3.1. SBELP development and interface

The SBELP is developed in Macromedia Flash MX. The programming is done in actionscript. The suite was selected because of its excellent animation and graphical abilities along with the programming capabilities provided by scripting language known as actionscript. A screen shot of the playing screen is shown in Fig. 3.

3.2. Text guides

Simulation-based educational products are usually accompanied by help menus. A player, in general, tends to start the tool and experiment with the controls and concepts rather than reading the help menus at first. To shun this problem, concept of text guides is introduced. These text guides appear right after the starts instead of the scenario or task to accomplish itself. The interface is designed in such a manner that text the guide screens and the navigation system are more evident, initially, than the start button. The screen shot of the starting screen (opening text guide page) is shown in Fig. 4.
3.3. SBELP scenarios

One of the aspects, in which the SBELP varies with other similar supply chain products, is the changing scenarios during the course of the task. As stated earlier, bullwhip effect is one of the main causes of inefficiencies and the cost inflations in supply chain, caused by the time delays. In traditional supply chains, co-ordination among supply chain elements is minimal. Essentially, each one is working independently with its own policies. One strategy is to reduce this bullwhip effect, and accordingly the total supply chain and individual costs, is by not only sharing information, but also during the run time to reduce overall time lags. This enables each element in the supply chain to improve its decision-making, consequently reducing bullwhip effect resulting in improved efficiency and reduced costs.

To understand this whole phenomenon a player has to face three scenarios which changes as the game progress. The three scenarios are mention as follows:

3.4. 1st Scenario – “the traditional chain”

“The traditional chain” begins with the start of the task and lasts for initial few days. During this period a player must act alone and independently without any knowledge of the other components (no information from distributor or retailer is shared). This is the case where a company waits for an order to arrive and to react accordingly.
3.5. 2nd Scenario – “the value of information”

“The value of information” is the next phase. In this scenario, a player is exposed to all the information flowing in the supply chain – flow of material downstream and flow of order upstream. In this scenario, a player understands the value of information and the reduction of time delays in the information flow and can see the effects on his performance. The outside demand pattern remains either fixed or follows a ‘step change’ to keep the dynamics of the supply chain simple. Using the information seen at retailer and distributor the manufacturer can foresee and plan his production.

3.6. 3rd Scenario – “the true market”

Finally, uncovers the “the true market” scenario where a player is exposed to the more realistic situation. The demand in this case becomes stochastic (random) so that a player has to manage his/her supply chain with more realistic and complicated circumstances. The information sharing remains same as in the “the value of information” scenario.

4. Feedback from the instructors

As mentioned earlier, the course is compulsory. Accordingly, it is one of the highly populated courses. As a result, the number of instructors who have taught this course is sizeable. These instructors were asked by the authors to evaluate this game. A questionnaire is given to these instructors to give their feedback. The results of each question, in terms of percentage response, are shown in Table 1. The prime objective of this survey was to evaluate, in their opinion, the effectiveness of this game in the course.
5. Feedback from the students

The SBELP was put to test for about four semesters. The students’ response was judged based on change in motivation and overall learning on the topic. This response is evaluated mainly by student interviews and scores obtained during the tasks. During submissions of the results/scores obtained the students were cross-questioned about the core concepts and there was a clear correlation between the number of times a student has played and the learning and scoring. The students were informally asked about the nature of the assignment as compared to the conventional assignments and a considerable number of students showed their keen interest in receiving such type of assignments as compared to the others. Following are some of the elevating observations of the whole exercise:

Initially, the students were not highly enthusiastic with such an activity and considered it to be a regular assignment. However, their overall enthusiasm grew gradually. The response, in terms of number of times the game is played, was encouraging and is shown in Fig. 5.

The tasks for this SBELP were not explained in the classrooms. Students were asked to read, understand and play the SBELP on their own. Fig. 6 shows how many students did read the help guides before playing the SBELP.

About 25–30% of the students claimed that they understood the SBELP well. Students (5–10%) claimed that they did not understand the task at all or did not find it interesting. The rest of the students queried with the instructors over various clarifications in tasks, objectives and concepts. Figs. 7 and 8 show the response of the students on navigation system and the playing time of the SBELP.

Various informal questions during the assignment submission on the subject matter also suggested that the students not only gained and applied the knowledge but few were able to analyze the underlying reasons to their game performances.

<table>
<thead>
<tr>
<th>The game . . .</th>
<th>% Age response</th>
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<tr>
<td></td>
<td>Strongly agree</td>
</tr>
<tr>
<td>1  Is related to the course</td>
<td>32</td>
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<tr>
<td>2  Supplements the course</td>
<td>68</td>
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<tr>
<td>3  Enhances student’s learning</td>
<td>62</td>
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<td>4  Has clear objectives</td>
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<td>5  Increases effectiveness of the course</td>
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<tr>
<td>6  Has a suitable concept of help guides</td>
<td>–</td>
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<tr>
<td>7  Has appropriate language in text guides</td>
<td>68</td>
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<tr>
<td>8  Has a good quality of graphics</td>
<td>100</td>
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<tr>
<td>9  Has an easy navigation system</td>
<td>68</td>
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<tr>
<td>10 Has interesting animations and graphics</td>
<td>68</td>
</tr>
<tr>
<td>11 Has an appropriate playing time</td>
<td>100</td>
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Fig. 5. Number of times the SBELP has been played.

Table 1
Faculty response to the SBELP

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6. Conclusion

Simulation-based educational products have enormous potential as an active learning tool. Its use in management, engineering and sciences education is common. However, the realization of its potential is on the rise. As discussed earlier in Section 2, the literature on the use of such games suggests this trend. The authors still believe that the real momentum and focus to reap the benefits of this tool is yet to come, especially in engineering and sciences education.

A very distinctive and innate capacity these products posses is the ability to create a sense of competition amongst students. This ability was clearly observed during its test with the students. The results were very clear. The student’s motivation had a significant increase. Students used basic cognitive skills as in Bloom’s taxonomy – knowledge, comprehension and application, which at a level one course can be considered as a success. Even intermediate cognitive skills, such as analysis was evidently practiced by some students during the exercise.
The idea of text guides was also received well by the students. As the students were given this game with minimal information and they had to learn and play the game on their own. The results suggest it to be a successful strategy. The only complaint by some students was the length of the text guides. Also, during the student interview, almost 50–60% admitted that they have read almost 60–70% of the text before starting the game. There were very few students who tried the game without reading the text guides at all before starting the game.

Although the concept of simulation-based educational products is not new in education, there is a great room available to increase its application and incorporation in academics. This provides good opportunities for the research as well. For example, the concept of text guides needs a more in depth research in order to understand its effectiveness as compared to standard separate help files. The arrangement and amount of information in these text guides or help files is also an area to be dealt with. Another important area that can be explored is the time length of the game.

There can be few extensions to this SBELP also. Firstly, number of decision variables can be increased to make it more realistic. Such a product can be developed for an advanced level course in supply chain or production planning course. This SBELP is a single player product where student plays the role of a manufacturer while others are played by the computer itself. The game can also be furthered by making it a multiplayer product where each element is played by the students.

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