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An Integrated Study Methodology for Learning Strategic Inventory Management*

W. B. LEE, H. C. W. LAU and A. NING
Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hunghom, Hong Kong. E-mail: mfandrew@inet.polyu.edu.hk

The pivotal idea central to engineering education is the cultivation of a motivation-based environment. There is little doubt that students learn better, particularly with regard to 'deep learning' if they are allowed to focus on areas of a curriculum in which they are strongly motivated. On the other hand, engineering education can also be regarded as an integrated study for students, which foster the cultivation of basic skills and the talent to follow well-defined patterns of procedures in order to solve problems. This paper presents the design and implementation of an educational simulation which mimics a microworld of business activities. The objective of such educational simulation is to present an integrated environment for students to undergo a motivation-based learning experience based on an integrated study methodology. The design and implementation of the educational simulation is intended to motivate students to accept personal responsibility for behavior in a simulated environment by recognizing and taking pride with a sense of self achievement.

Keywords: integrated study methodology; motivation-based learning; educational simulator; logistics workflow inventory management.

INTRODUCTION

HISTORICALLY, an engineering education curriculum is designed in such a way that it tends to be over-specialized and over-crowded. Recent international surveys of engineering education conducted in other parts of the world show that it is not uncommon to find that most engineering graduates work in jobs and careers that are very different from that of their undergraduate discipline [1]. The principles of learning methodologies, such as problem-based and action-based learning, are well accepted and recognized by those who work in higher education. These methodologies allow students to reinforce what they learn by exposing them to real life problems (either before or after they are taught the theoretical background) and by giving them the opportunity to have an exposure to the decision making process. A learner's motivation is central to the learning process as it facilitates the process of acquiring skills and knowledge [2–3]. There is little doubt that students learn better, particularly with regard to 'deep learning' if they are motivated in what they are taught.

On the other hand, there is a growing support in recent years for a motivating environment which is conducive to creative learning. Such an environment is particularly concerned with the provision of appropriate settings for students to be exposed to the complexities of the real world, which could not be taught in a conventional text-based learning manner. The increase of such support is caused by three main factors. Firstly, there is a growing awareness, fuelled by criticisms from employers that students need to be better equipped to cope with real problems and be able to collaborate and communicate with people to explore opportunities and meet challenges. Secondly, there is pressure on academics to reform their teaching and learning methodologies. This pressure is encouraging academics to explore ways in which students can work effectively both alone, as individuals and also in groups, perhaps without supervision, which is similar to the situation they will face in the workplace. Thirdly, academics and employers are becoming increasingly aware that creative learning can raise the quality of the learning experience by developing a range of personal skills and qualities, enhancing understanding of key concepts and giving exposure to a greater variety of perspectives and materials. An atmosphere of joy and fun provides the conditions for such an environment.

The theoretical basis for an 'integrated study methodology' is made up of two parts:

- social-cognitive learning environment design [4];
- the psychology of motivation [5–8].

Despite the common understanding of the usefulness and role of learners' motivation in education, surprisingly little has been practiced or publicized with regard to its serious implementation in educational institutions as a formal part of the curriculum. Difficulties have arisen from the possible conflict between the motivation of the learners and the concerns of teachers or other appropriate authorities who believe or dictate what his/her students should learn.

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In this paper, the design and implementation of an educational simulation to facilitate an integrated study methodology is described. The developed educational simulation is based on a 'microworld' concept, which allows students to address the challenges of the 'real world' in an enjoyable and motivating way, through a number of activities which simulate the reality of the working environment. According to the degree of interaction with students involved, learning can take place in many forms such as independent learning and collaborative learning. The use of such simulation is one of the most effective methods since it contains the full context of events and stories to be unfolded and explored by the learners. Students have to comprehend the rules, think of the strategies and action to be taken, receive feedback on the outcome of their action and then decide what to do next.

Eventually, the student's learning process is monitored and assessed largely by the feedback from the students themselves through their reflective journals as well as through group interviews. In particular, the way in which they score points throughout the course of the simulation is recorded and analyzed in detail in order to evaluate their learning progress.

LITERATURE REVIEW

'In the past, the focus of traditional learning approach is usually teacher-centered. However, in today's educational environment, such focus has shifted to student-centered [9]. Traditional learning is usually based on the lecture and tutorials, which can be regarded as a 'push' system. According to push and pull dichotomy, students are pulled into the learning process and encouraged to participate through an integrative environment [10–11]. The elements present in such integrative environment have been discussed by Atif [12], Snell-Siddle & Toki [13] and Thomas [14]. Generally speaking, there are three learning elements that have been mentioned, namely,

- self-achievement
- self-paced
- peer-to-peer interaction,

all of which aim to motivate students to acquire the knowledge and skills.

Self-achievement

At times engineering education can be regarded as a learning process that epitomizes self-achievement and students usually experience this through game participation. The effectiveness of using simulation games has been noted by Ravenscroft [15]. Randel, at el. [16], Johnston & de Felix [17] and Druckman [18] who reported that business simulation games were most effective for educational purposes. In order to enhance motivation-based learning, Soloway, at el. [19] conceptualized the games as student-centered learning environments. By the late 1990s, the use of games in business schools appeared to have become very common. Soloway & Bielaczyz [20] found that educational games needed to broaden, integrate and look at issues of communication, inquiry, reasoning and cognitive skills. Moreover, Roger [21] examined the effectiveness of simulation games to enhance the problem-solving ability of the students. Butterfield & Pendegraft [22] suggested that team performance management could be improved through such games. McGrenere [23] and Azar [24] suggested that the goal of motivation-based learning was to teach specific knowledge, decision making and other skills through games.

The adoption of a game-based learning approach could help students to enhance their knowledge more effectively than can a traditional learning approach [25–26]. Snell-Siddle & Toki [13] and Burn [27] concluded that games could help to motivate students in schools including colleges and universities. Nassar [28] suggested that the game could be a part of that course and that it provided a motivation medium to enhance standard formal teaching methods. Klassen & Willoughby [29] stated that an effective game would help students to understand concepts more quickly and to remember them better than would a formal lecture.

Self-paced

In general, self-paced learning format is commonly used in distance education. Candy [30] argued that the term self-paced learning acts as:

- a personal attribute (personal autonomy);
- the willingness and capacity to conduct one's own education (self-management);
- a mode of organizing instruction in formal settings (learner-control);
- the individual, non-institutional pursuit of learning opportunities in the 'natural societal setting.

According to Young [31], comparing with traditional learning, self-paced learning could provide an opportunity for the development of new educational tools that aim to motivate students. Moreover, Yin [32] concluded that self-paced learners with appropriate guidance should facilitate to meet the learners' needs, personal characteristics, and develop their potentials particularly in an optimal way. Furthermore, Atif [12] studied that self-paced learning is a more effective way to learn because the learners can set the pace of learning themselves.

Peer-to-peer interaction

In most cases, peer-to-peer interaction can be defined as group project and small group discussion. According to Liu & Hsiao [33], peer-to-peer interaction could be regarded as a technique to engage students actively in learning. Moreover, Schmidt [34] claimed that peer-to-peer interaction is a learning exploratory process, where the objective is to enable the students to pursue their personal choices. According to Thomas [14], the

utilization of peer-to-peer interaction technique could provide a real-world situation and teamwork environment for students to demonstrate their knowledge and understanding in a social context. Other researchers had proposed training models that focused on the creation of peer-to-peer interactive environment to motivate students to develop their interpersonal skills [35–37].

Based on the literature review, there is limited research in the issue of integrating different learning approaches. As academicians, it is necessary that integrated studies should be widely developed in the new educational environment. Through these integrated studies, tutors are more than a repository of the information importing their knowledge or experience to the relatively passive students compared with the traditional education. Moreover, there is limited research in using simulation as a tool for assessing the progress of students' learning. Therefore, to fill this gap in the research, an educational simulation based on an integrated study methodology (called SimEnterprise) is proposed. The simulation aims to provide an integrated study environment for students to learn how modern business is conducted, while at the same time suggesting enough information for tutors to evaluate the progress of students' learning. Figure 1 depicts the learning elements in the proposed educational simulation.

DESCRIPTION OF EDUCATIONAL SIMULATION (SIMENTERPRISE)

Educational simulation (SimEnterprise) environment

The educational simulation (called SimEnterprise) is developed by the Industrial and Systems Engineering Department at The Hong Kong Polytechnic University. Apart from teaching, SimEnterprise can also be used to support operational training for Small and Medium Enterprise (SME) company staff. The objective of this simulation is to present an integrated study environment for students to undergo a motivation-based learning experience. The design of this simulation attempts to motivate students to accept their personal responsibility for behavior in the simulation environment by recognizing and taking pride in self achievement. In addition, this simulation is equipped with self-paced learning features to provide students with the ability to learn anywhere, anytime, and at a pace that suits their existing skills, knowledge and aptitudes. Furthermore, this simulation facilitates the establishment of a peer-to-peer learning environment, thus assisting tutors to leverage students' attention in the simulation to create activities tied to their learning.

SimEnterprise mimics a microworld of business activities in trading and production planning. It focuses on the trading activities, such as the bidding of customer orders and the sourcing of material components. Each student can regard themselves as account executives in a small and medium enterprise. They need to oversee the business activities by themselves as well as to compete with ghost players for customer demand and material supply. On the other hand, students are asked to prepare their own business strategies and their adaptability will be tested towards the dynamic changes of market situation. Students' learning experience will be continuously adapted to their behavior, such as their choice of product dealings as well as their reputations in transaction history.

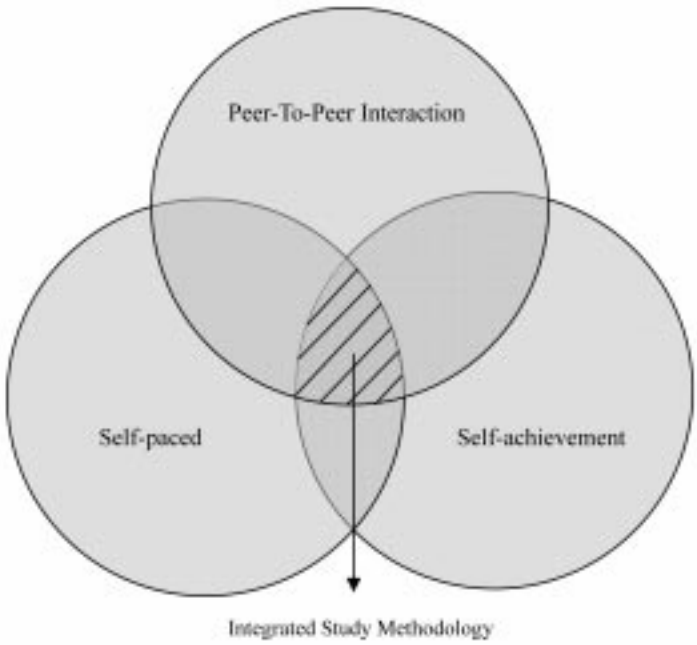

Fig. 1. The learning elements in the proposed integrated study methodology.

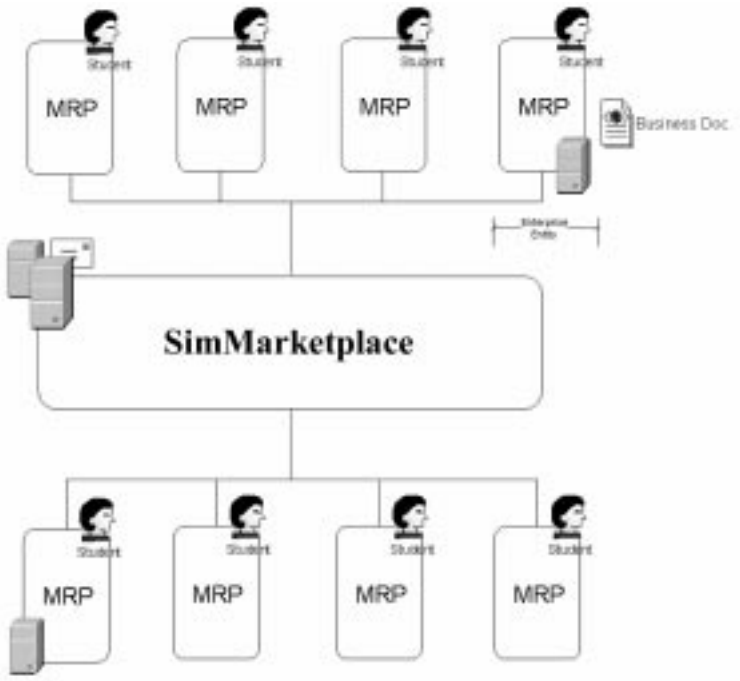

Fig. 2 The system environment of SimEnterprise.

Participation in SimEnterprise

As mentioned, SimEnterprise aims to provide a simulated and interactive business environment through which the students can gain practical experience in how a commercial company operates. Figure 2 depicts the system environment of SimEnterprise. Tutors and students can be regarded as an enterprise entity, just like a business company in the commercial world. They conduct business transactions (such as submitting finished goods quotations and placing component purchase orders) via the SimMarketplace, where all transactions will be recorded. Apart from the recording function, the SimMarketplace is responsible for the customer order bidding process, i.e. the evaluation on whether a particular customer order should be granted to a particular student.

Figure 3 shows the main page of SimEnterprise and it can be divided into three sections. The core workflow of the action taken is presented in a flowchart format. In the lower section of the right hand side of Fig. 3, there are three buttons namely: Demand Pool, Supply Pool and Score Board. When the Demand Pool button is pressed,

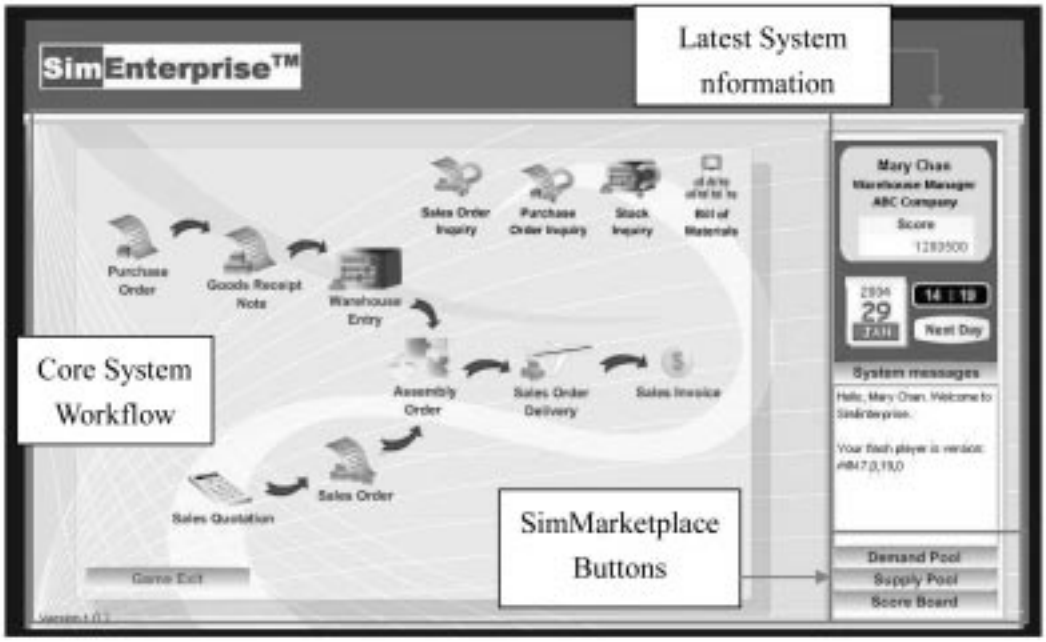

Fig. 3. The main page of SimEnterprise.

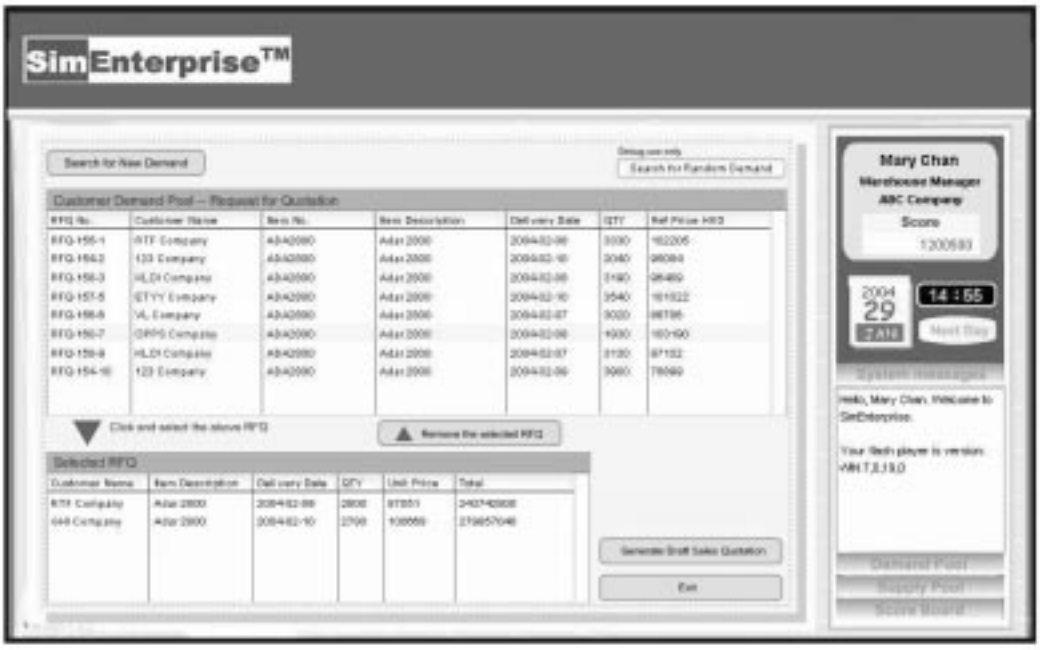

Fig. 4. The display of customer enquiries (Request For Quotation, RFQ) after the Demand Pool button is pressed.

the latest customer enquiries (Request For Quotation, RFQ) will be delivered to students from SimMarketplace, as shown in Fig. 4. Similarly, when the Supply Pool button is pressed, the latest material quotations from suppliers will be shown to students, as shown in Fig. 5. When the Score Board button is pressed, a simple profit and loss statement and students' performance statuses will be shown (Fig. 6). The upper section of the right side of Fig. 3 states the latest SimMarketplace information.

Students are expected to perform the role as trading firms and they need to do businesses with partners (suppliers and customers, both virtual) in order to acquire trading profits. Their working tasks include inventory management, stocks procurement and replenishment, etc. On the completion of this educational simulation, students will be able to:

- understand the interaction between purchasing, production and sales marketing;
- gain practical knowledge or experience of basic operation management, planning and control;
- understand the workflow in supply chain management (SCM);
- learn how to work out a suitable business strategy in a real business situation.

Fig. 5. The display of component quotations from suppliers after Supply Pool button is pressed.

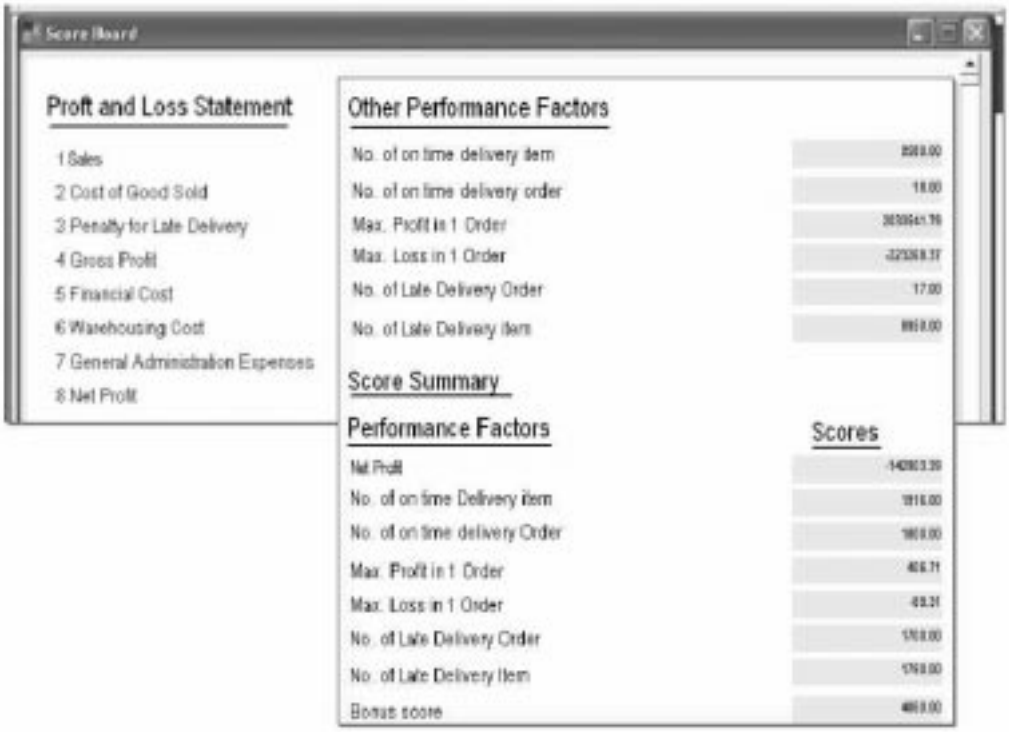

Fig. 6. The display of the profit and loss statement and students' performance statuses after the Score Board button is pressed.

A sample run

In this section a typical run of the simulation will be described. Usually it takes an hour and a half to complete the simulation. Alternatively, this simulation can be played over an extended period according to student's desires. In this case, students can conduct a more detailed analysis of market information.

The scenario to be simulated is a trading company selling personal computers. Figure 7 describes the basic workflow (in business transaction) of SimEnterprise. Students need to do the sourcing of material components, such as CPU, Monitor, etc. In addition, they need to assemble the material components into Computer Sets and resell the finished goods to their customers. (A sample finished good and its BOM structure is listed in Fig. 8.) The goal for students is to maintain a positive cash flow and to achieve a decent trading profit. For example, students have to make decisions on the quantities to be bought at a price that they think is reasonable to meet customer demand. The provided trading platform can allow students to create and consolidate their

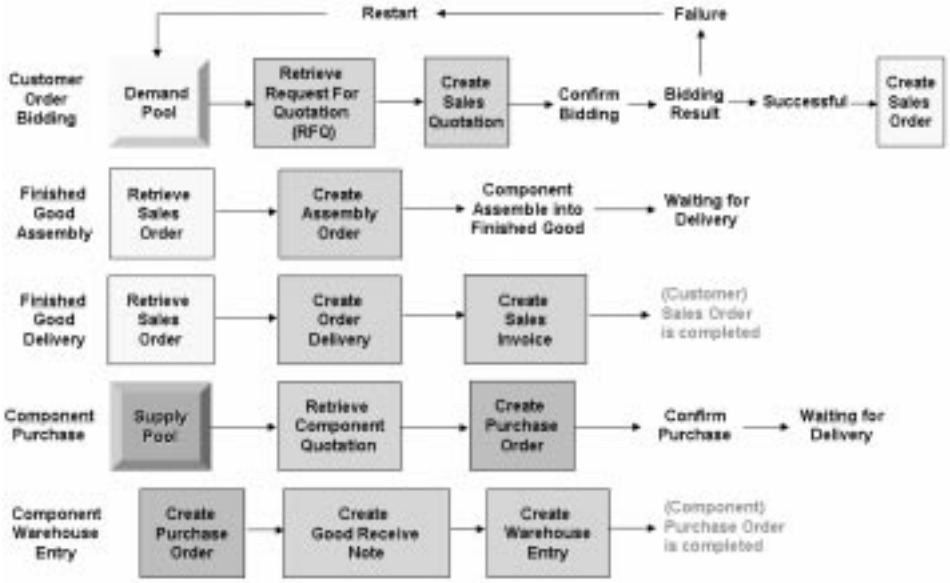

Fig. 7. The basic workflow (in business transaction) of SimEnterprise.

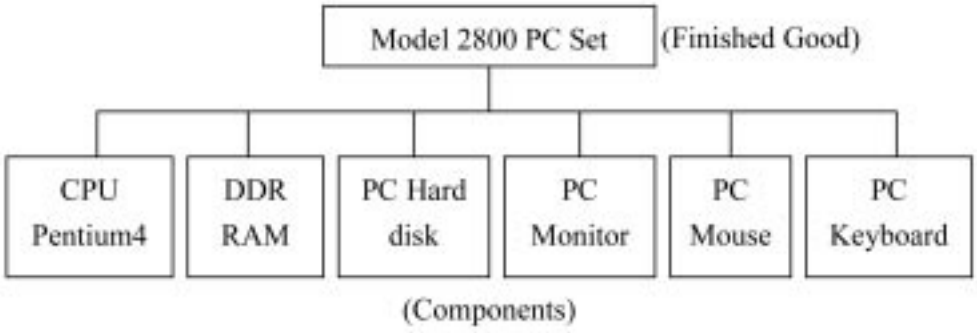

Fig. 8. A sample finished good and its BOM structure.

wealth. There are a lot of different strategies the students can try out. However, students must ensure that the workflow transactions are valid (the left hand side of Fig. 3).

Throughout the simulation, students are expected to encounter a fluctuation in customer demand as well as component supplies (both in price and quantity). Such fluctuations (e.g. upward-trend, downward-trend, etc.) can be manipulated through different combinations of business logics in SimMarketplace.

Different price pattern for each student

An example of the price pattern for a component (CPU) is listed in Fig. 9. Suppose a downward price trend for component CPU is set for all students (see the dotted line in Fig. 9) and Student A is on Day 18 while Student B is only on Day 3. Because of the time difference, Student B may gain an advantage over Student A by knowing the events that have already happened. However, as illustrated by the resulting price pattern for Student A and Student B, an increase in price uncertainty (in the short term) can be employed to reduce the possible advantage. The amount of deviation from the default price pattern has taken into account students' trading histories and is calculated using an in-house developed algorithm. It should be noted that although both price patterns can be different in the short term, they remain analogous to the default price pattern in the long term. With simulation setting it is hoped to ensure a certain level of fair play.

Score calculation

Students' scores are calculated based on the behavior throughout their participation in SimEnterprise. Scores are influenced by two scores (Financial Score and Performance Score) and their meanings are described as follows. Fig. 10 describes how students' scores are calculated.

The meaning of each factor affecting the Financial Score is described as follows:

- *Sales.* This value is calculated according to the amount of money received through completion of customer orders.

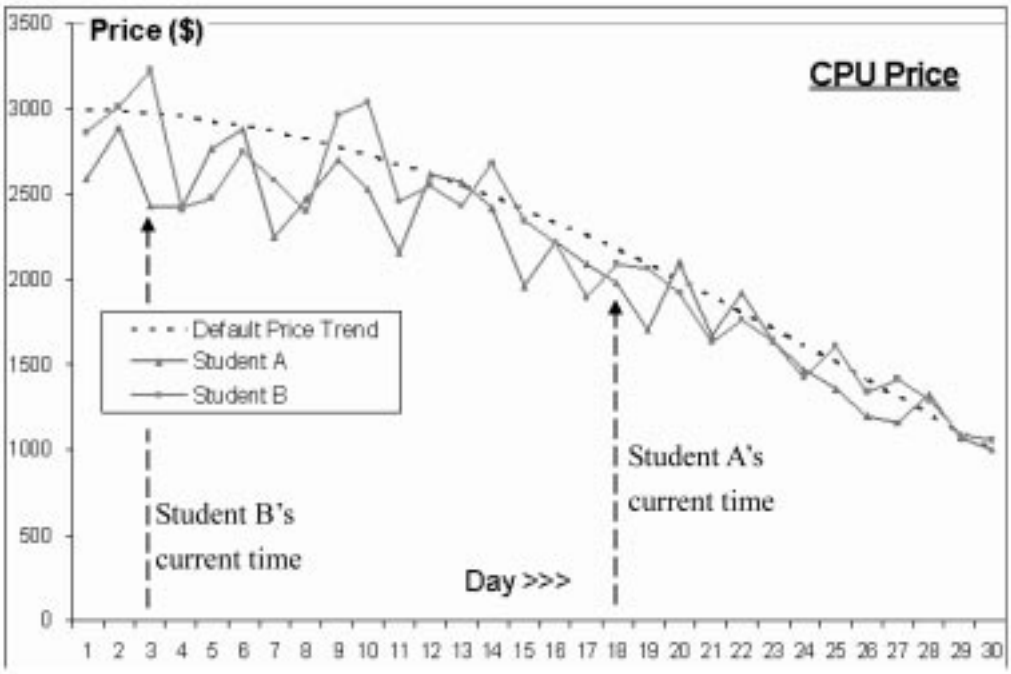

Fig. 9. Different Price pattern for each student.

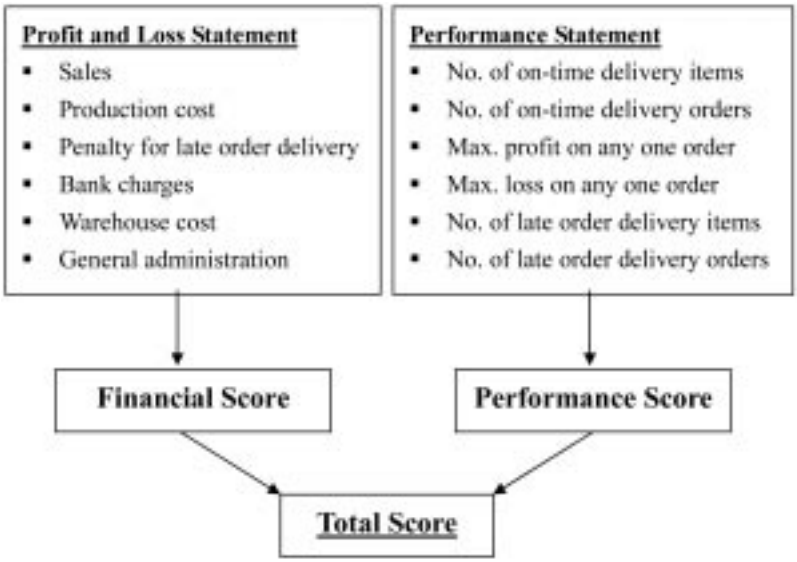

Fig. 10. Total score calculation details.

- Pro*duction cost.* This value is calculated according to the amount of money spent on the purchase of the necessary material components.
- *Penalty of late order delivery.* This value shows the sum of penalty charges. If a customer order has not been completed on-time, a late penalty would be charged.
- *Bank charges.* This value shows the sum of bank charges. Students should try to maintain a Positive Cash-Flow; otherwise bank charges (e.g. bank overdraft) would apply.
- *Warehouse cost.* The calculation of this value is based on how much stock students have put in the warehouse. Obviously, the larger amount of stock and the longer the residual time, the higher the cost.
- *General administration expenses.* This value shows a lump sum of money that has been used to run the company, including electricity charges, management fee, etc.

Apart from the consideration of the financial status of students' trading behavior, a number of performance factors are required to be measured as well. The meaning of each factor affecting the Performance Score is described as follows:

- *No. of on-time delivery items.* This value shows the sum of PC Sets based on the customer orders that have been completed on-time.
- *No. of on-time delivery orders.* This value shows the number of orders that have been completed on-time.
- *Max. profit in any one order.* This value shows the maximum PROFIT on one particular customer order from students' trading history.
- *Max. loss in any one order.* This value shows the maximum LOSS on one particular customer order from students' trading history.
- *No. of late order delivery items.* This value shows the sum of PC Sets based on the customer orders that have NOT been completed on-time.
- *No. of late order delivery orders.* This value shows the number of orders that have NOT been completed on-time.

Table 1 shows the position of Student A after two sessions of participation. According to the information, the score calculation is illustrated as follows:

$$\begin{aligned}\text{Financial Score} &= \text{k factor} \\ &\quad \times (\text{Total income} - \text{Total expenditure}) \\ &= \text{k factor} \\ &\quad \times (\text{Sales} - \text{Production cost} - \text{Penalty} \\ &\quad - \text{Bank charges} - \text{Warehouse cost} \\ &\quad - \text{General expenses}) \\ &= 0.001 \times (91{,}952{,}646 - 234{,}856{,}040) \\ &\quad - 142{,}903\end{aligned}$$

Table 1. The position of Student A after two sessions of participation

Profit & loss statement		Performance statement	
Sales	91,952,646.00	No. of on-time delivery items	9,580.00
Production cost	167,682,056.60	No. of on-time delivery orders	18
Penalty for late order delivery	65,958,230.00	Maximum profit in any one order	2,033,541.79
Bank charges	57,302.19	Maximum loss in any one order	−223,268.37
Warehouse cost	1,048,451.40	No. of late delivery items	8,950.00
General administration expenses	110,000.00	No. of late delivery orders	17
Net profit	**−142,903,394.19**		

Table 2. The conversion of Student A's performance after two sessions of participation

Performance statement		Converted score
No. of on-time delivery items	9,580.00	479
No. of on-time delivery orders	18	360
Maximum profit in any one order	2,033,541.79	102
Maximum loss in any one order	−223,268.37	−45
No. of late delivery items	8,950.00	−448
No. of late delivery orders	17	−340
Performance Score		108

For the calculation of performance score, the conversion for Student A's performance is described in Table 2.

As the Total Score is the sum of Financial Score and Performance Score, in this case:

$$\begin{aligned}\text{Total Score} &= \text{Financial Score} \\ &\quad + \text{Performance Score} \\ &= -142{,}903 + 108 = -142{,}795\end{aligned}$$

It should be noted that this score value is calculated in a real-time basis and it will change according to Student A's performance later in the simulation. Nevertheless, the pattern of each student's score is recorded in SimMarketplace to allow future analysis of students' learning outcome and development of predictive models how students behave within this peer-to-peer learning environment.

ASSESSMENT ON LEARNING OUTCOMES

The design of the assessment is the most important part of the SimEnterprise project as the assessment measures students' satisfaction and their learning outcome. Assessment is based on the feedback from students from questionnaires, reflective learning journals and their simulation score trends which reflect students' understanding of the activities. There are two different assessment methods: qualitative and quantitative.

Quantitative assessment based on feedback from questionnaires

As shown in Table 3, Questions 1–5 provide feedback regarding the SimEnterprise project.

In the academic year 2004/2005, 68 degree students, who were in their final year in the Department of Industrial and Systems Engineering of the Hong Kong Polytechnic University, participated in SimEnterprise. The feedback questionnaires were analyzed and the results are shown in Figs 11 to 16. Feedback ratings were divided into 5 levels, namely: Strongly agree, Agree, Neutral, Disagree, and Strongly disagree.

Question 1 asks students whether their motivation to learn more about strategic inventory management have increased as a result of participation in SimEnterprise. There are 31 students strongly agree with the statement and another 31 students agree with the statement. As shown in Fig. 11, with more than 90% of students express their approval, (preliminary speaking) the implementation of SimEnterprise can be regarded as a success to motivate students to learn the suggested topic.

Question 2 asks students whether they have searched and read additional material to achieve better result in SimEnterprise. There are 36 students strongly agree with the statement and another 28 students agree with the statement. As shown in Figure 12, again with more than 90% of students express their approval, they regard the experience acquired in SimEnterprise epitomizes self-achievement.

Question 3 asks students if they have achieved their desirable learning target at their own pace. As shown in Fig. 13, although the majority of students show favorable responses, the total percentage of such response is the least out of those five questions. An initial conclusion may be either students have set up an easy learning target or they do not know how to control their learning pace.

Question 4 asks students if they have learnt how to be more cooperative and competitive via the simulated real-world situation provided by SimEnterprise. As shown in Fig. 14, since the majority of students show favorable responses, they seem to enjoy the interaction with others in the generated peer-to-peer environment.

Question 5 asks students if they think SimEnterprise is a successful example to show an integrated methodology to illustrate different learning elements at the same time. As shown in Fig. 15, the majority of students agree with the statement, thus offering a convincing case to support the proposed integrated study methodology. It seemed that the implementation of SimEnterprise

Table 3. Evaluative questions listed in questionnaires

Question 1	Your motivation to learn more about strategic inventory management has increased as a result of participation in SimEnterprise.
Question 2	You have searched and read additional material to achieve better result in SimEnterprise.
Question 3	You have achieved your desirable learning target at your own pace.
Question 4	You have learnt how to be more cooperative and competitive via the simulated real-world situation provided by SimEnterprise.
Question 5	You think that SimEnterprise is a successful example to show an integrated methodology to illustrate different learning elements at the same time.

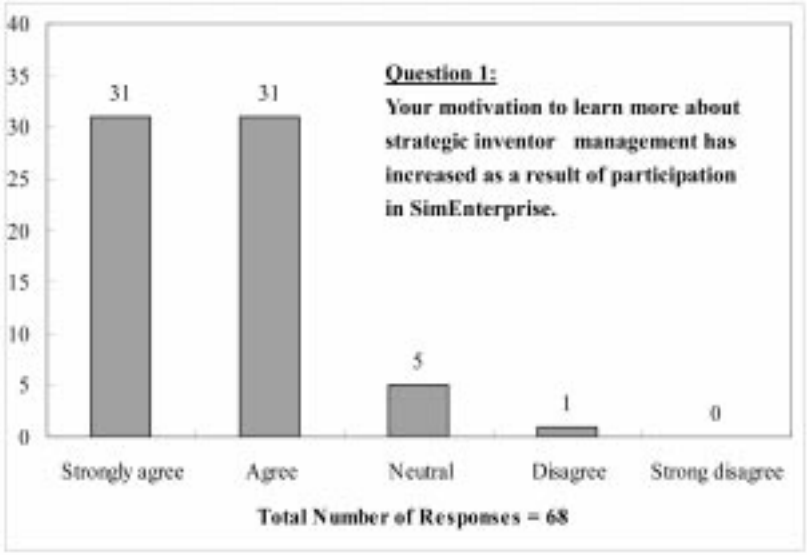

Fig. 11. Responses to Question 1.

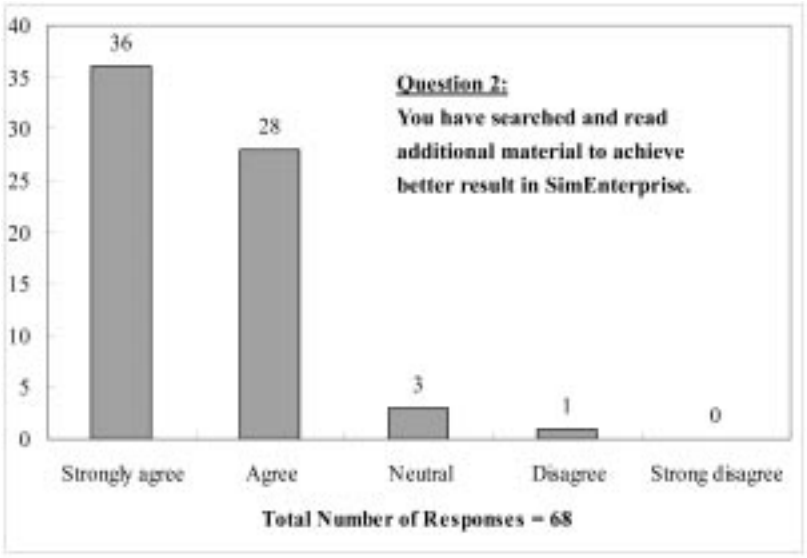

Fig. 12. Responses to Question 2.

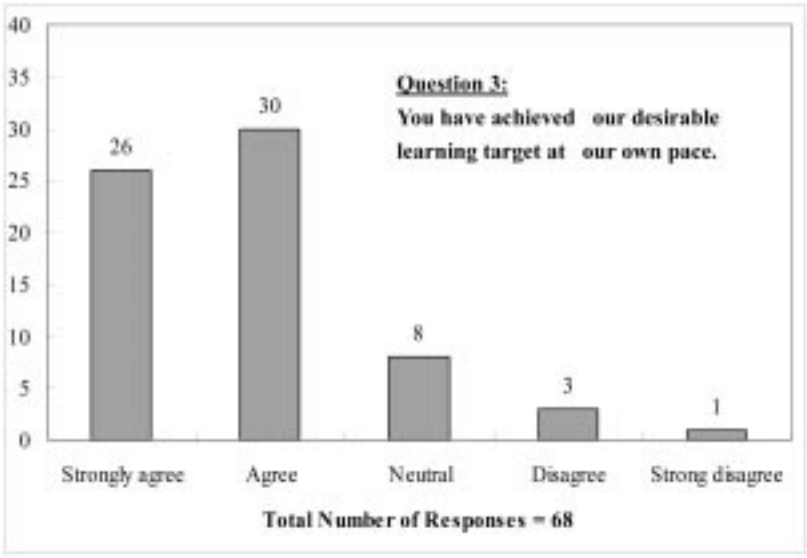

Fig. 13. Responses to Question 3.

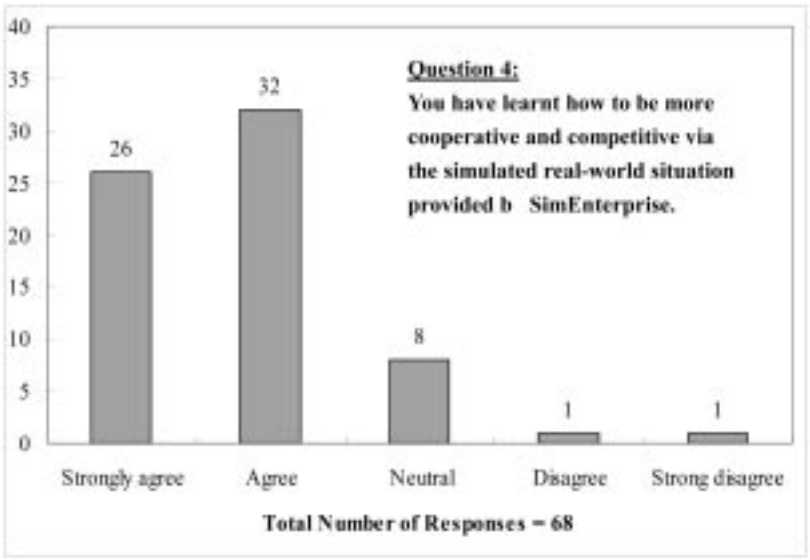

Fig. 14. Responses to Question 4.

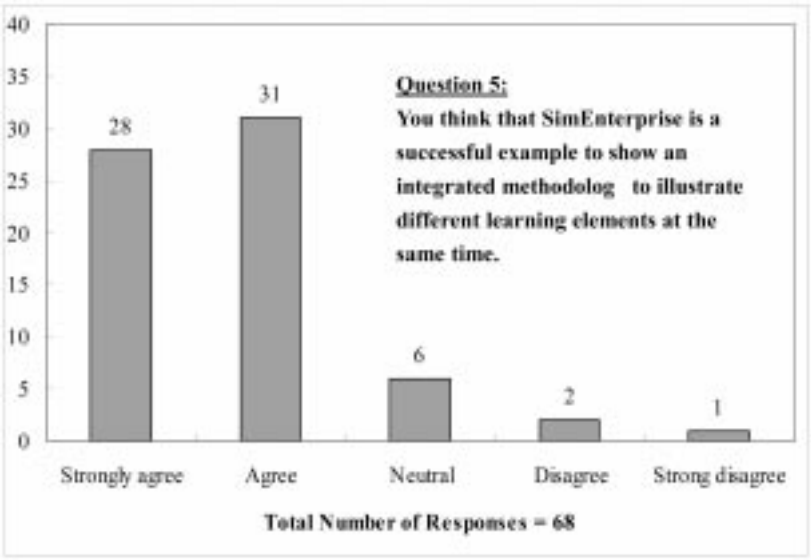

Fig. 15. Responses to Question 5.

Table 4. The observed three categories

	No of products traded	Types of strategies	Implications—students have learned:
Category 1	1 product	Make-to-stock & make-to-order	To use two different business strategies
Category 2	3 products	Make-to-stock & make-to-order	To find out the most tradable product
Category 3	More than 3 products	Risk diversification	To diversify the risk by trading more products

successfully fulfilled the requirements to motivate students to learn the suggested topic as well as letting students experience different kinds of learning elements at the same time.

Qualitative assessment based on students' reflective learning journal

At the end of their participation, students are asked to write down their thoughts in the form of a reflective learning journal. Table 4 shows the three categories that have been observed in terms of the number of traded products and the types of business strategies.

One product is traded using two business strategies (Category 1)

- *Observation.* As shown in Fig. 16, initially the student spends some time to develop the business strategy. After the learning period, the student uses a make-to-stock strategy and scores points. When the strategy was changed from make-to-stock to make-to-order, score

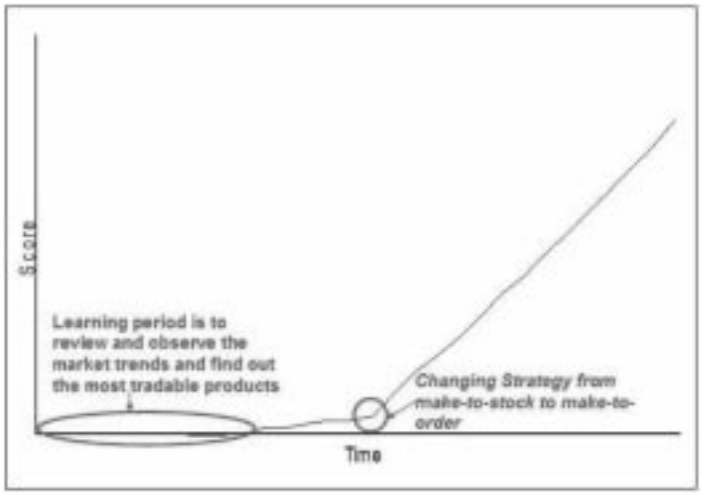

Fig. 16. One product is traded using two business strategies.

points would increase rapidly. This indicates that students come to realize that the lowest warehouse cost is achieved when using 'make-to-order' strategy; which is thus more profitable.

- *Implications.* Throughout the simulation, students learn how to make more profit using the 'make-to-order' strategy. Students also learn the differences between the make-to-stock approach and the make-to-order approach in the business environment (through trial and error in operating these business strategies in different situations).

Three products are traded at the beginning then focusing on one product eventually (Category 2)

- *Observation.* By comparison, the learning time in Fig. 17 seems relatively shorter than the one in Fig. 16. The student trades three products at the beginning and then focuses on one product eventually. After the change in trading strategy, the score increases rapidly.
- *Implications.* Figure 17 reveals that students can achieve a higher score because of the change in trading strategy (from three products to one product). At the beginning, most resources are held as inventory. This leads to an increase in warehouse costs. After realizing which one is the most profitable product, students can decide to focus on trading one product, thus obtaining a substantial increase in their scores.

More than three products are traded (Category 3)

- *Observation.* According to Fig. 18, the number of points scored increases steadily throughout students' participation. Students focus on more than three products and employ the make-to-order strategy. This indicates that the risk can be diversified and because of this, students prefer not to change their trading parameters frequently.
- *Implications.* The students have learnt how to diversify the risks by not focusing on trading one product. They have also learnt how to use this strategy with good effect.

In brief, apart from letting students experience different kind of learning elements at the same time, SimEnterprise can also be regarded as a

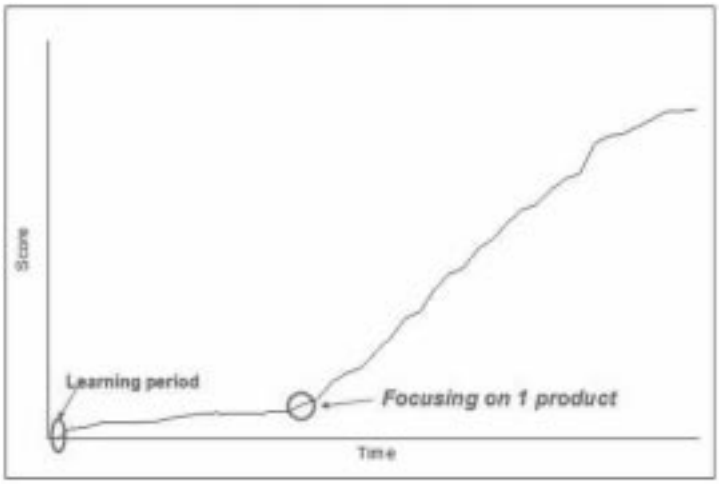

Fig. 17. Three products are traded at the beginning, then focusing on one product eventually.

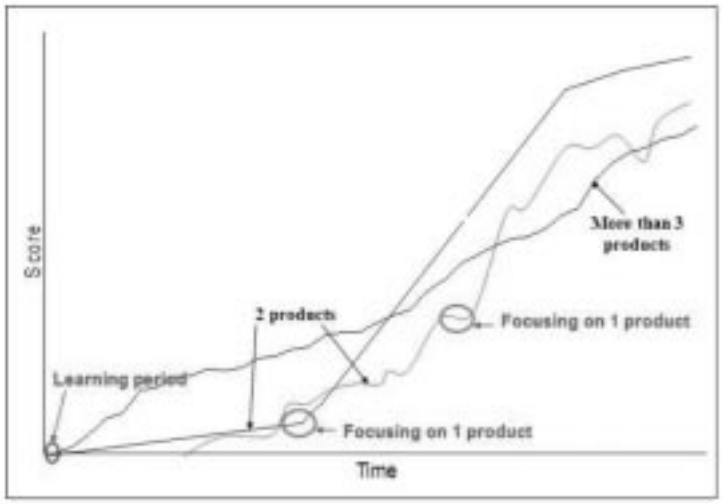

Fig. 18. More than three products are traded.

tool to reveal students' behavior. Their learning progresses can be identified through the analysis of their score pattern as well as the adoption of a reflective learning journal.

CONCLUSION

The educational simulation (SimEnterprise) uses an integrated study methodology to introduce different kind of learning elements at the same time in order to motivate students for learning. This paper explains the design and implementation of the proposed integrated study methodology to promote motivation-based learning. The results of the survey seem to provide a persuasive case that the adoption of the proposed methodology may help to explain how useful an integrated study environment can assist students to achieve their desirable learning target. In conclusion, this study paves the way for further exploration in the area of motivation-based learning using the 'microworld' concept, thereby contributing to educational research by promoting a more open, self-paced and self-learning approach in tertiary education.

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W. B. Lee is currently the Cheng Yick-chi Chair Professor of Manufacturing Engineering and Head of the Department of Industrial and Systems Engineering and the Director of The Hong Kong Polytechnic University Microsoft Enterprise Systems Center, Ultra-precision Machining Center and Advanced Technology Manufacturing Research Center. His current research areas include manufacturing technology, dispersed network manufacturing system, manufacturing strategy, and knowledge management. He has published two research monograms, co-edited two books, and has more than 200 papers published in referred journals and conferences.

H. C. W. Lau is currently an Associate Professor in the Department of Industrial and Systems Engineering at the Hong Kong Polytechnic University, involved in research and teaching activities. He received his Master degree at Aston University in Birmingham in 1981 and his Doctorate at the University of Adelaide in 1995. His current research areas cover manufacturing information systems and artificial intelligence applications, and he has authored and co-authored over 100 international research papers covering multi-agent modeling, object technology, global manufacturing and computational intelligence applications.

A. Ning is currently an Instructor in the Department of Industrial and Systems Engineering at the Hong Kong Polytechnic University. His current research areas encompass artificial intelligence applications, multi-agent modeling, Logistics and Supply Chain Management and global manufacturing.