Serious Games Integrated Framework: Keep Them in the Flow

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Serious Games Integrated Framework: Keep Them In The Flow

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Abstract

Serious games aim to improve the learner experience, allowing them to build knowledge and skills using untraditional learning tools. Supply chain management (SCM) and similar complex fields are promising areas for the adoption of such technology. Complex interrelated concepts and the difficulties faced by the student in understanding and managing the complete image of the field prompts teachers to search for alternative learning tools. This paper proposes an integrated simulation-based serious games framework and describes an implemented serious game called AuSuM (AUtomobile SUpply chain Management). The framework explains the required components and the relationships between them in order to improve engagement and motivation for students in the classroom. This framework was tested through the implemented game, and piloted in real classrooms where it demonstrated improvement in students' engagement, motivation and knowledge development.

Keywords: Serious games; Simulation games; Supply chain management, Optimisation.

Introduction

Successful supply-chain operations depend essentially on effective integration between business processes and network members. In order to realise overall system objectives, a synchronisation between all processes should be achieved. This synchronisation is exposed to dynamism, uncertainty, large-scale processes and flows, and multi-functional challenges which together lead to high supply chain complexity. This complexity affects the number and diversity of the supply-chain elements. Adopting a suitable business model in a highly complex supply chain is a challenging process, due to the boundless data, performance trade-offs, constraints and decision variables that must be taken into account.

Lack of understanding of supply-chain performance variables and drivers, along with poorly designed and ineffective management strategies, make it difficult to identify the real causes of supply-chain complexity. Lectures and traditional ways of learning can provide students with theoretical knowledge but is likely to fail to develop the practical skills they need for their future careers (Abykanova, Nugumanova, Yelezhanova, Kabylkhamit, & Sabirova, 2016). This leads to students struggling to appreciate the links between supply-chain concepts and their application. To overcome this situation, learning organisations need to create and employ novel approaches to teaching and learning. The current generation's learning style differs from those of previous generations in being much more interactive, visual and problem-based (Pasin & Giroux, 2011).

Universities are increasingly embracing simulation as an important contributor to improving students' learning abilities in operations-management-related courses. Simulation tools' strengths follow from their employing time dimensions and modelling the real world using building blocks, system variables and scenario application. However, their weaknesses follow

from the fact that analysis characteristics can overshadow current applications of discrete event simulations, from a lack of pedagogical perspectives and their inability to include interactive player roles in the system.

The trend toward accepting games in education started slowly (Eck, 2006), but has increased in the past decade to the extent of creating a virtual world for each player. In this virtual world, learners can practise at their own individual rate, and exploit the freedom to examine various scenarios and make errors without painful failure (Fleming, Bavin & Stasiak, 2017). Research and studies have covered several aspects of learning in games, such as the learners' ability to combine information from different areas to come up with solutions, or to make decisions and examine their impacts on the game flows (Bu & Mitchell, 2009). Communication between students during playing sessions improves their social skills, which can be achieved by encouraging them to contact each other to discuss, negotiate and decide their playing strategies collaboratively, dealing with conflict solutions and planning next steps in the game journey (Pivec & Dziabenko, 2004). Teachers also have to ensure that they incorporate fair and robust assessment techniques when gaming is used in learning (Cruz, Cruz, Ruiz, Hernández, 2015).

This study develops a novel framework for simulation-based serious games, integrating optimisation techniques to aide student learning in complex fields such as supply-chain management. Various decision-making points were handled, and different scenarios applied and controlled by the instructor, to preserve the instructor role in the classroom.

Simulation-based serious games

Over the past decade, simulation-based serious games have increasingly been adopted as a learning and training tool, employed widely in such learning environments as classroom education, healthcare and hospitals training, as well as government and military departments. The term 'Serious Games' is still not well defined in the literature, and various terms are used to represent them, including game-based learning, educational games, edutainment, and simulation game (Pourabdollahian, Taisch & Kerga, 2012). Generally, Serious Games are the tools integrating educational and entertaining factors (Wouters, van Nimwegen, van Oostendorp & van der Spek, 2013). Some authors define serious games as a learning of serious context in a playing environment (Charsky, 2010). In order to achieve the learning and entertaining factors in one activity, to engage and motivate learners, learning theories, psychology and computer technologies need to be integrated into the serious game activity (Yusoff, Crowder & Gilbert, 2010).

Research studies have reported several aspects of learning in games, including the learners' ability to combine information from different areas and develop a solution or make a decision and examine its impact on the game flow (Ranchhod, Gurău, Loukis, & Trivedi, 2014). There is a wide scope for the use of simulation as an aid to these learning techniques. Successful adoption of simulation is highlighted in medical, engineering, and science schools (Khalaila, 2014; Koltai, Lozano, Uzonyi-Kecskés & Moreno, 2017). Individual attempts have adopted simulation games in subjects such as economics (van Wyk, 2013), health (Wattanasoontorn, Boada, García, Sbert, 2013), and engineering (Ross, Fitzgerald & Rhodes, 2014). Business modules, including supply-chain management, provide one area where successful implementation can be most effectively achieved. Simulation games are popular in the field

of operations management (OM) due to their capacity to provide virtual experiential environments in which learners can practise and examine the challenging issues of complex production systems (Tobail & Arisha, 2013). Similarly, they can build concrete and memorable experiences as well as allowing students to be exposed to both practical and theoretical understandings (Haapasalo, Hyvo & Hyvönen, 2001). They can also be considered as potential bridges to overcome the barriers of transferring knowledge from academia to practitioners (Tobail, Crowe & Arisha, 2012).

Optimisation techniques are integrated into simulation systems to enhance their capacity to find the best solutions to complex problems, especially when the objectives involved are conflicting and the problems have enormous numbers of variables. In production and planning, Gansterer, Almeder & Hartl (2014) developed a framework using simulation-based optimisation to detect the production parameters. A hybrid simulation optimisation approach, integrating simulation and optimisation techniques to resolve multi-objective problems, has been shown to be effective when applied to the design and control of supply-chain networks. This involves various controlling factors, such as demand and supply uncertainty and performance indicators that represent cost and responsiveness (Haijema & Bloemhof-ruwaard, 2012). In supply-chain management, stock level problems were targeted by Taleizadeh, Niaki, Aryanezhad and Shafii (2013) through a simulation-based optimisation model in order to find the optimum stock level. In flow shop scheduling (Lin & Chen, 2015) a hybrid simulation optimisation approach is used to overcome the complex and stochastic nature of the problem. In production and planning, Gansterer, Almeder and Hartl (2014) developed a framework using simulation-based optimisation to detect the production parameters. That makes tools based on the integration between simulation and optimisation promising for achieving valuable solutions to complex problems. However, the fundamental

problem was, and remains, that no formal guidelines and steps exist on how to integrate an optimiser in a serious-game framework, and how to get the benefits of that integration. Van der Zee, Holkenborg and Robinson (2012) were the first to propose a formal conceptual model of simulation-based serious games to integrate discrete event simulation within gaming environments, which was successfully used in supporting serious games (Costantino & Pellegrino, 2010; Katsaliaki, Mustafee & Kumar, 2014; Lancaster, 2014). There have been a few attempts to build roles similar to the optimisation role to provide players with solutions for situations they faced, but these trials have lacked formal frameworks and did not focus on measuring the optimiser's effect on leveraging knowledge, focusing instead on measuring the effect of the whole game on achieving learning (Costantino, Di Gravio, Shaban & Tronci, 2012).

Simulation can be defined as the process of running a computer model of a real system to conduct an experiment for purposes of understanding the behavior, or evaluating the operational strategy, of the system with minimum painful loss – or both (Tobail, Crowe & Arisha, 2010). Integrating optimisation into discrete event-simulation models improves players' decision-making processes by guiding them towards the optimum decisions, and – if a further feature is added – allowing them to compare the decisions taken with optimum decisions, so they can learn from the history of their attempts. Empirical evidence indicates that integrating discrete-event simulation and gaming environments can result in improvements to system understanding, motivation and learning capabilities. This paper develops a framework to identify integration guidelines and the ideal functionality of the optimiser (the basic role of the optimiser and how it is linked to the other components) within a simulation-based serious games framework. It hereby aims to fill the gap in the literature regarding integrating optimisation into simulation-based serious games.

Games in higher education

Since its emergence in the late 1960s, experiential learning has been exploited to overcome the drawbacks of traditional teaching by encouraging interactivity, collaboration, peer and active learning (Ruben, 1999). Adopting computer games in higher education has been shown to improve the process of skills and knowledge-development by students. This enables them to be immersed, engaged and motivated in a fantasy world, equipped with interactive facilities and immediate feedback for their actions (Seng & Yatim, 2014). Several attempts have adopted simulation games in subjects such as economics (van Wyk, 2013), health (Wattanasoontorn et al., 2013), engineering (Ross, Fitzgerald & Rhodes, 2014), nursing (Stanley & Latimer, 2011), chemistry (Stieff & Wilensky, 2003), physics (Chang, Chen, Lin & Sung, 2008), and management (Gold & Gold, 2010).

The focus in games development for teaching is on improving student understanding of certain areas of the subject, and in some cases on improving soft skills such as communication, leadership and collaboration. In the area of supply-chain management, Pasin and Giroux (2011) developed a serious game to simulate a manufacturer of two products, where participants play as teams. Each team receives historical data and tries to manage the inventory and forecast future demand for the next ten coming periods. Vanhoucke showed the impact of games on learner engagement through using a project-management game (Vanhoucke, Vereecke & Gemmel, 2005). Risk-management topics were explained to learners using a risk-management game in teaching (Barrese, Scordis & Schelhorn, 2003). Using such serious games in higher education has helped the instructors to improve student engagement, clarify complex concepts in fields such as supply-chain management, and build an interactive learning environment. But most of the proposed frameworks lack instructor engagement in the learning process within the game environment, making them completely

student-centered as learning tools and thereby weakening the guarantee of knowledge construction and integration during the game-playing sessions.

Framework for the design and integration of AuSuM game in classroom design concepts

The first formal simulation-based serious game framework proposed by van der Zee, Holkenborg and Robinson (2012) focused only on the integration between simulation and games, but there was no consideration of students' supervisory or guideline dimension and assessment. The framework for any learning game must integrate both their educational and entertainment characteristics and dimensions (Aleven, Myers, Easterday & Ogan 2010). The educational component defines how the game is employed as a learning tool, specifying how it is used in the classroom and outlining the learning objectives (Dillenbourg & Jermann, 2010). The entertainment component determines how it involves engaging and fun elements (Schell, 2011). Both components together build a challenging, engaging experience for students to fulfill certain learning goals set by pedagogical objectives. In addition to these two components, the framework proposed here integrates a third component, representing the game's practices for supervising and guiding students (see Figure 1).
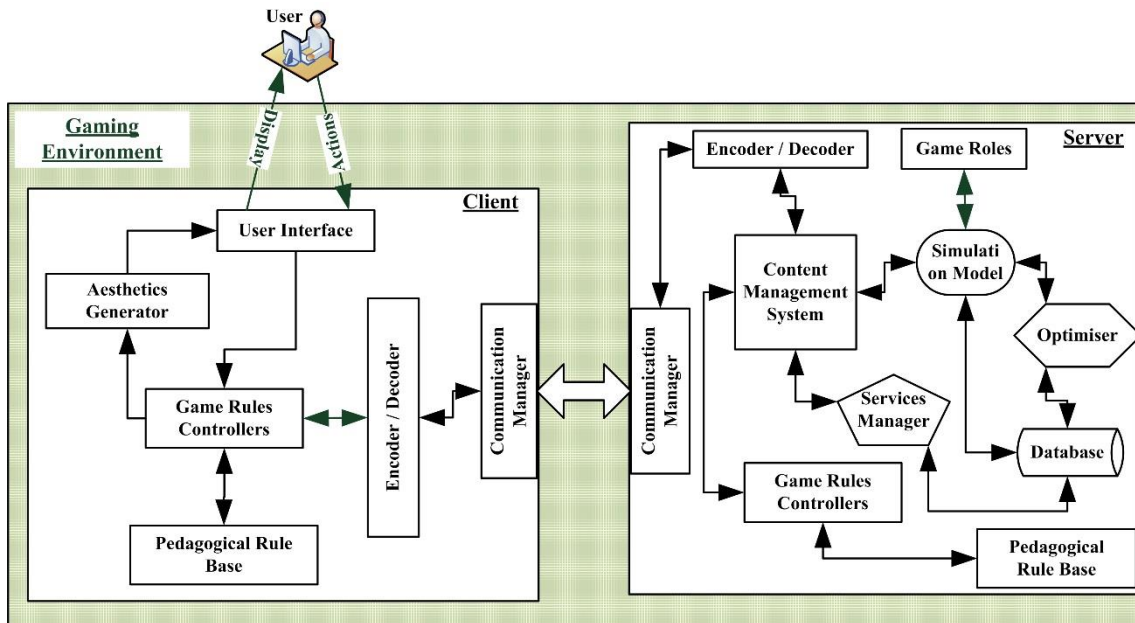
Figure 1: The AuSuM client-server framework structure

The AuSuM (Automobile Supply Chain Management) game was designed to simulate an automobile supply-chain network. Pedagogical, entertainment and optimisation components were taken into consideration in the design process of the framework. Students can choose to play any of three roles, as a manufacturer, distribution centre or retailer, and enacts that role via a comprehensive graphical user interface, which includes a playground section, control panel, monitor and statistical charts section, updates window, as well as indicators for rank, performance and pedigree. The 'playground' section displays the role's basic components and animation. The control panel receives the player's actions and transfers them to the client software. Graphical statistical indicators and charts give the player feedback on their performance, so helping them to improve.

Players/learners proceed to play (i.e. manage) their chosen roles by applying orders for goods to their upstream suppliers to replenishment the warehouse. Players receive sales orders from their downstream partners, which they must fulfill from the warehouse stock (see Figure 2).

Players must manage their inventory to minimise costs and maximise profits. Manufacturer players assemble cars using materials from different suppliers, such as metal sheets, tyres, engines, etc. Retailers receive orders from customers at a rate that is preset by the game's administrator. Both administrator and instructor roles could be handled by the instructor. For all players, deciding the order quantity and time to make the orders for warehouse replenishment is considered as a challenging decision point.
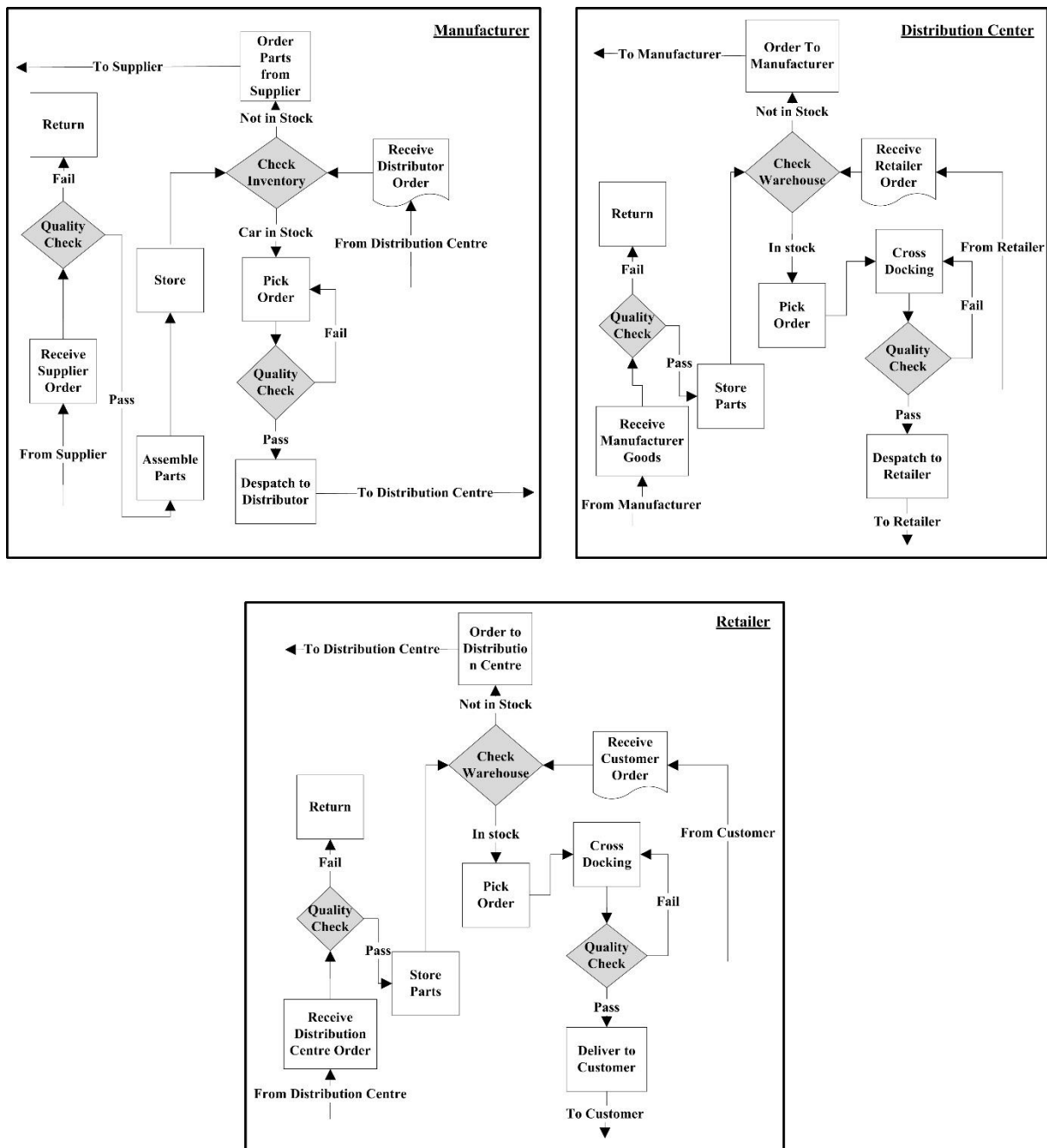

Figure 2: Player roles – conceptual models

Essentially, AuSuM was developed to provide a flexible and configurable teaching aid in a gaming environment to help instructors in major supply-chain management courses; to help students develop knowledge and practical skills by examining various supply chain-scenarios that would enhance collaboration and interaction between players; and to deliver a test-bed environment for supply-chain management theories while helping researchers evaluate students' decision-making behaviors and analyse the results to identify teaching preferences, or for other research purposes. Based on comprehensive conceptual models, each role was designed and implemented a shown in Figure 2, which describes the game story, rules, and available operations for each player.

Extensive supply chain management field investigation and interviews with experts and instructors were undertaken to identify what the game's learning objectives should be. The mechanics of the game were structured to reflect these learning objectives so that players should understand concepts by enacting them, including making orders, receiving goods, warehousing, manufacturing, shipping, and maintenance. Regarding the pedagogical and supporting technology elements, a number of computers were connected to a server so that students could work as groups. Each group plays a specific role, interacting with the server via their player interface. To simulate the game story, the server runs a simulation model of a supply chain, which is integrated with an optimiser element. Multiple learning styles were used represented in macro and micro processing. Macro processing involves players grasping a complete picture of the activities of the whole supply chain network (and its interconnected entities), whereas micro processing is involved in the players managing every individual process in their role.

Entertaining features were embedded in the game environment to ensure the players' engagement and entertainment, together with the fulfilment of the learning objectives. Aesthetics were represented in the visual graphics and sound effects to enable the player to deal with various elements of the game according to the storyline rules. Colour-coding, counters, visual messages, and timers are used to increase the level of immersion. The game storyline was designed to realise the learning objectives and help players practise the main supply-chain management concepts such as deciding order quantities (according to demand forecasting), receiving goods and storing them (to practise and respond to warehousing issues), and responding to sales orders (by accepting or rejecting them). AuSuM was designed to provide a comprehensive simulation of the different supply-chain network roles (manufacturer, distribution center, and retailer). Three main flows were modelled – cash, materials and information (see Figure 3). Players compete with each other in the level of points scored, by ranking, and by decision accuracy.

Each player represents a node in the whole supply-chain network. Maximising profits, keeping costs to a minimum and fulfiling orders on time are the main goals, and are also the crucial factors in deciding rankings among the group of players. Decisions on the scope of the game include inventory management, capacity planning, partner selection and shipping decisions. Every player manages their 'playground' using a comprehensive control panel to apply for orders, recruit partners, and run good operations. Accepting orders requires manufacturer players to check the stock before making that decision and then start goods dispatching if they have enough stock – or make purchase orders to their suppliers if not – so they can proceed with the car-assembly process to satisfy the outstanding orders. Distribution centre players can ship directly to their retailers from the warehouse if they have enough stock, or get more cars by generating purchase orders to their suppliers. Retailer players deal

with customers as downstream demand generators at a rate determined by the instructor: they must decide to accept or reject sales orders according to their warehouse stocks and demand forecasting. When sending purchase orders to their distribution centres, quantities are a challenging decision.

The instructor can adjust the logistics controlling the game's parameters to generate different rates of accidents and delays in the shipping process, which introduce levels of uncertainty into the supply chain network that require players to examine whether they need to insure against uncertainty. Players' assets and resources deteriorate over the time, and graphical indicators monitor and display deterioration levels so players can judge whether to take maintenance actions (which will increase their costs) or postpone them until later. Such multiple and complex decision points embedded in the game give it a complex storyline.
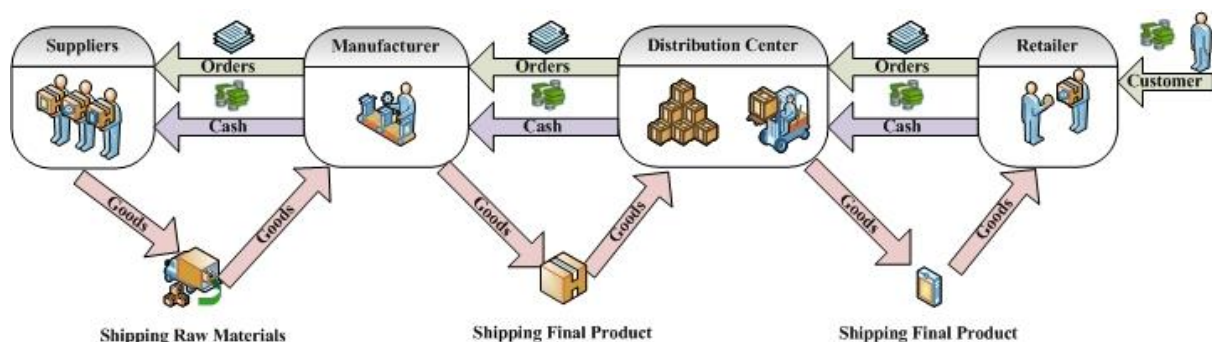

Figure 3: Supply chain flows

AuSuM architecture

The AuSuM game is designed on a client-server model where the server hosts scripts and the database, and the client runs the player application: they communicate over the Internet using Hyper-Text Transfer Protocol (HTTP). Encoder/decoder modules are added to both sides to

handle interactions between client actions and server responses via the HTTP protocol.

Figure 1 shows the AuSuM architecture (Simulation-Optimisation Integration).

Communication manager

The Communication Manager listens to the messages over the client/server communication channels, each message consisting of various fields to identify the client identity, the required operation, and its parameters. Message structures are designed to handle flexibility, and so can enable extending the game's features, interface, and operations, which can increase their applicability to different knowledge fields other than supply-chain management. All messages received by the server are decoded to extract the output parameters and pass them on to related components such as the content management system, services manager, and database management system.

Content-management system

This system guarantees the game's security policy and handles users' access permissions according to their user type – student, instructor, or administrator. The game administrator is responsible for configuring the database and creating the basic infrastructure for the game runs. The instructor sets up the supply-chain network parameters, such as demand and supply patterns, delays, accident generators, preview performance reports and statistical charts, records players' ranks and pedigree, intervenes in real-time during game runs to adjust game parameters, and controls the optimiser modes (present or hidden). Player users manage one supply-chain role (manufacturer, DC, retailer), and can preview performance indicators and results in form of reports and statistical charts transmitted by the server.

Database

The comprehensive relational database system was designed according to an ER (Entity-Relationship) structure and developed using SQL language and server script pages to handle users' information, game rules, simulation model variables, historical data, and meta-data and

reports. All users are connected to the database through the related client application. Storing and retrieving data to/from the database is implemented via a set of services to guarantee data validation and to support the system's security policy. Simulation parameters and game variables are stored in the database and read from it by the players' client applications. The same approach is adopted for various database related components and tables.

Services manager

The server hosts several categories of services. Database services are handled by the database management operations, and communication services handle communications between the server and player-clients. The services manager manages synchronisation and activating of the service required. It activates the service, traces its execution and stores the result to be sent to the client who requested the service. The content-management system controls permissions for requesting the service. Players' purchase-order decisions, for example, activate the new purchase-order service, which manages the related parts of the database and communication variables to achieve the task.

Simulation model

A discrete event-simulation model was developed on the server to imitate goods, information and cash flows between the entities represented in players' client applications. Actions taken by players on the client side are transferred to the server side, thus modifying the simulation model variables' settings. The impacts on the simulation model influenced by the variables' settings are sent back to the client side application, where they are represented via its graphical interface. The model was built on an optimum conceptual framework to facilitate real-time responses to players' actions. The instructor can adjust the model's scenario designs and parameters, along with exploration reports, via their client applications. The optimiser engine is connected to the simulation model so as to generate the optimum solutions for

certain situations for each player and store them in the database, to be retrieved by player requests.

Optimiser

The optimiser module comprises main three components: the interface, the mode controller, and the optimiser core (see Figure 4). The optimiser input parameters are received from the simulation model and database via the optimiser interface where they are validated and prepared for the optimiser core, which uses an optimisation algorithm to receive inputs and search for solutions to current problems in the solution space, taking the defined constraints into consideration. The optimum solution for the current simulation problem is stored in the database to be retrieved via the players or instructor client applications. The instructor can apply various optimiser operational modes to set up its response behavior. In passive mode, the optimiser generates optimum solutions to be saved in the database to allow the instructor to track a player's performance, but the optimiser is hidden in the player's client application (passive). In the active mode, players are given historical charts, which compare their decisions and the optimiser decisions. Historical data can be loaded from the database to the optimiser core to execute required operations. The optimiser modular structure enables working algorithms to be adapted according to the problem or game area of interest.
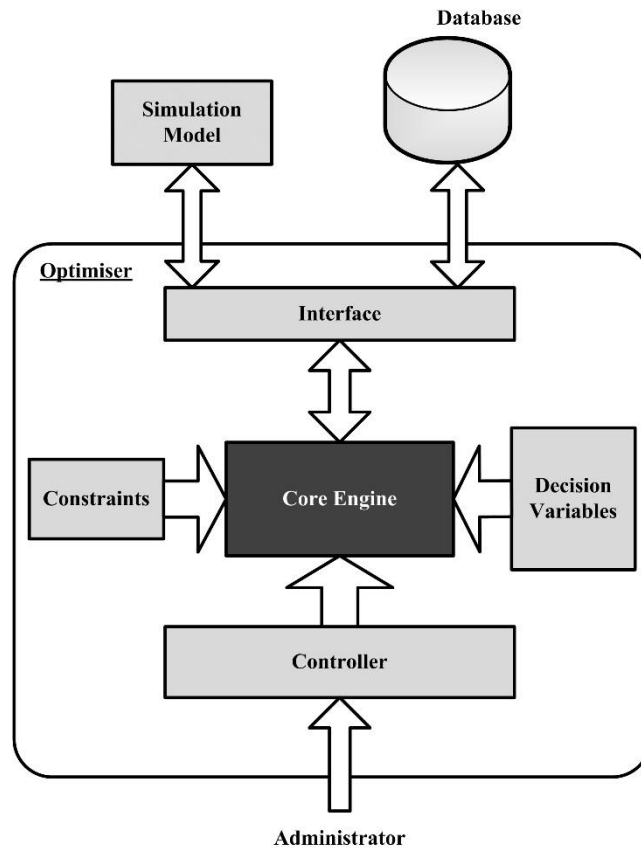
Figure 4: The optimiser structure

The game's optimiser core was built and integrated into the AuSuM framework as part of its design specifications. Setting the optimiser's operating parameters is the responsibility of the instructor. The main key aspects of the optimiser learning facility are:

- Historical graphical charts to represent both the player's and the optimum decisions in every situation, enabling learning by comparison.

- Visual aids and animations to aid learning by understanding and remembering.

- Emotional support that helps players retain knowledge longer when players make decisions that the optimiser approves so the player feels happier and awaits the results with more confidence.

In the category of games designed for fields of low complexity, it is a straightforward process to design and embed a module or agent to provide players with solutions or directions for the

optimum path of their playing journeys. But in games designed for high complexity fields – such as operations management and supply-chain management – which can feature enormous numbers of decision variables, a more complex and intelligent engine is needed to provide solutions and directions for the multi-objective, multi-variable problems involved. This study was developed to fill the gap in the solid formal framework literature to integrate optimisation techniques into the simulation-based serious game for complex fields such as supply chain management.

A common view among experts and instructors is that serious games might replace the role of the instructor, which may be due to classroom game integration models, which may employ one of three techniques. The first approach is to set the game up for students to play on their own without an instructor intervening: such models obviously lack guidance and supervisory features. The second approach resembles the first, but with the addition of guidance and directions from an instructor. However, this approach presents disadvantages in terms of distraction and lack of engagement on the students' behalf, which could lower the game's entertainment level. The third approach, adopted in this study, is to mix the previous two approaches: the students play the game themselves, but the instructor intervenes by running the game 'behind the scenes', thus preserving students' engagement levels. The instructor is given the facility to trace players' performance via statistical charts, and the ability to make instant changes in the game and simulation model parameters. They can control the model by increasing or decreasing demand, varying logistics parameters, or managing suppliers' lead times and orders' acceptance, and can apply those changed parameters either to individual players or to the whole class. In the framework implemented in this study, the instructor's role is not limited to the options available in other previous games: they can control the

optimiser mode to supervise and guide players towards developing and improving their learning abilities by using both the optimiser's visual and directive features.

AuSuM configuration

At the start of each experimental session, the administrator/instructor configures the game via an efficient, user-friendly interface for the unlimited number of players, and sets the demand and supply patterns to fulfil the learning objective to be delivered to players/learners (see Figure 5). Supplier delays and accident rates can be adjusted to be generated randomly to embed uncertainty into the whole network, which forces players to think about insuring goods before shipping. At the end of each experimental session, all results are saved so the instructive can review statistical reports.

AuSuM playing and interfaces

The AuSuM game can be played in single or multiplayer modes. For single players, the instructor allocates certain roles to the students (manufacturer, distribution center, or retailer) and controls the whole network and all parameters involved. In the multi-player mode, each player performs as a part of the whole supply-chain network.

Each player's PC has a user-friendly interface to facilitate controlling the various processes and to follow the results and performance indicators (see Figure 6). Its main component is a 'playground', which shows animations of goods and trucks etc., and visual indicators of player's actions and server responses, as well as special icons such as cars and personal characteristics to make it more attractive and engaging to the players. There is also a control panel with assigned buttons for managing functions (e.g. making orders, linking to partners, starting manufacturing cars, shipping, and applying maintenance efforts). The ranking, player's pedigree degree, and score-point windows advise players as to their current rank among other players and pedigree degree status. Another button is assigned to show players'

network connections with other upstream and downstream partners. An optimiser window showing a detailed chart comparing the player's and the optimiser's actions can be opened from the control panel, and performance indicators and statistics are displayed in order-statistics windows and warehouse monitors.
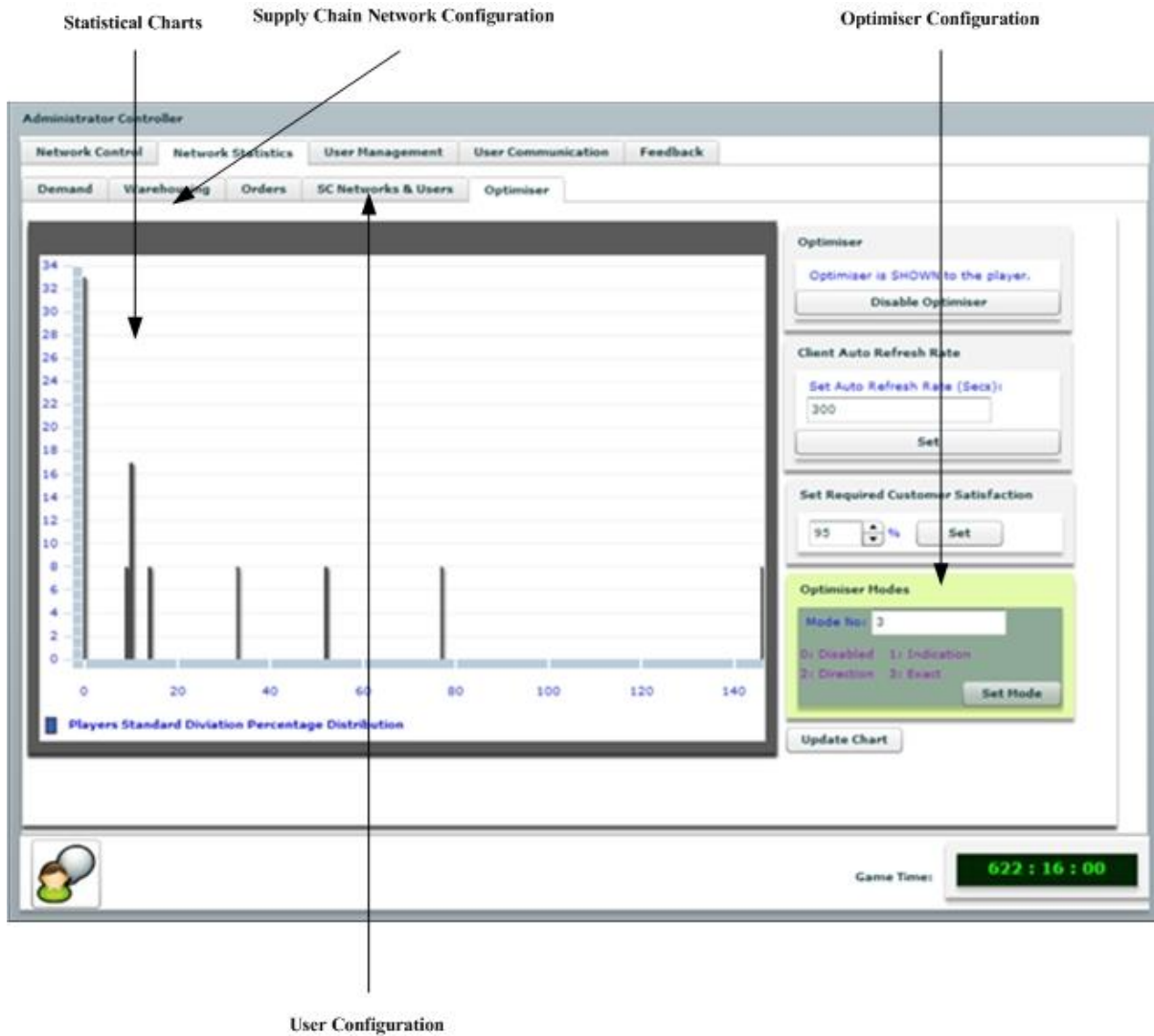

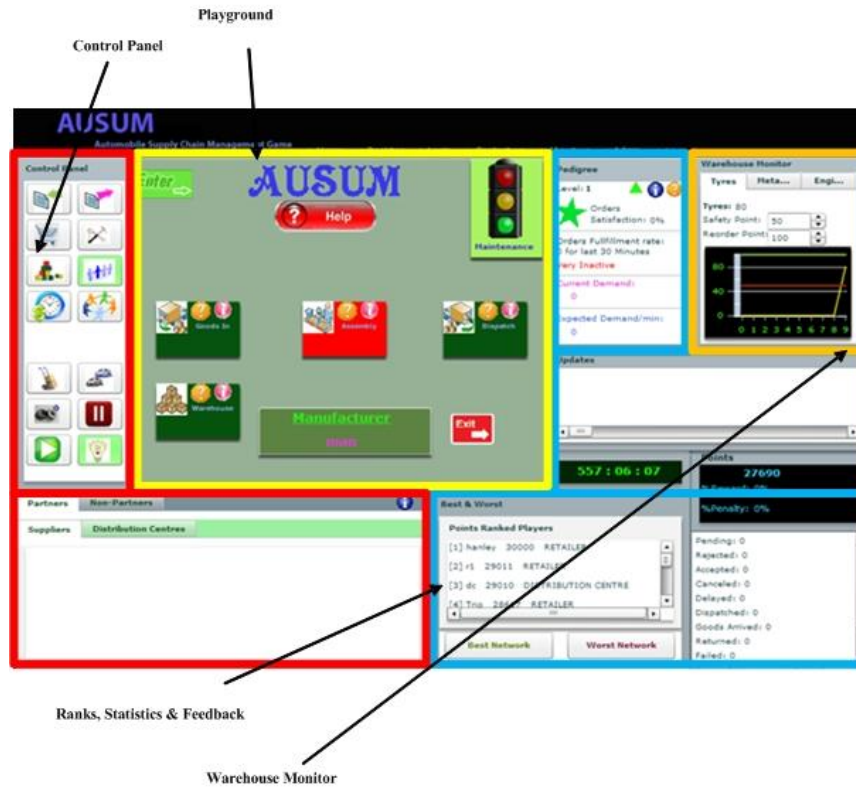**Figure 5: The administrator's interface**

Figure 6: The player interface

The instructor interface was designed to provide the instructor with initialising, tracing and monitoring facilities, the ability to make a real-time intervention, and receive results and reports about players' performances. After initialising the game, the instructors watch and trace players' performance and checks reports so they can intervene at any time to change game parameters as needed.

Information about each player, including ranks, current playing levels, lead times, and penalties or rewards gained, are provided by the server to be displayed in each player's window, and those of their partners, which helps players trying to make a decision about choosing suitable network partners. Players send purchase orders to their upstream partners to receive goods within certain lead times (if the order is accepted): the same applies to sales orders (but with the stream in the opposite direction). Lead times, warehouse monitoring, and

expected demand information are displayed; as they are crucial elements in helping players decide order quantities. An optional insurance facility is provided for each order to cope with uncertain accidents that could happen according to a rate configured by the instructor.

AuSuM results

Game results are displayed for all player types (administrator, instructor, and student) in the form of reports and statistical charts, which can be previewed during the playing session and at end of the game (see Figure 7). Instructors can preview real-time reports about player performance, order satisfaction and warehouse capacity, and can decide to change some parameters instantly to trigger new learning challenges. The player in turn can see performance reports (updated in real time) and charts comparing their decisions with optimum decisions while playing, enabling learning by comparison. Player rankings are updated and displayed during playing sessions to encourage competition. When the game is over, both the instructor and the players can receive final performance reports.

Figure 7: Players' results and statistical charts

Methodology

Experiments

The AuSuM game was tested in real classroom settings to study its impact on students and analyse its success as a learning tool. The primary goal was to evaluate the effectiveness of the proposed framework in achieving its pedagogical goals and its engaging and entertainment aspects, and to evaluate the influences of integrating the optimiser agent into serious-games frameworks.

This experiment was undertaken in the setting of a college of business with fifty-seven students attending supply chain management course. They were first given an introduction to the game and then asked to play the game during a lecture session. The instructor controlled the game by setting its control variables and scenarios and enabling various optimiser modes. Students were asked to form groups of three to four, and instructed to play one of the roles (manufacturer, distribution centre or retailer). Comments and observations were collected during the playing session to reflect student interest, and an open discussion was held afterward during which they were invited to comment on and evaluate the game. To assess the experiment's outcome, a five-point Likert scale ranging from "strongly disagree" to "strongly agree" was adopted in a questionnaire approach. This questionnaire was divided into three sections: in the first, a usability survey was employed to measure the game's usability and engagement; the second section concerned its pedagogical achievement (learning and teaching); and the third evaluated the integration of the optimiser (see Table 1).

Question	Mean	Standard Deviation
Usability of the game:		
I think that I would like to use this system frequently	3.13	1.28
I thought the system was easy to use.	3.07	1.03
I found the various functions in this system were well integrated.	3.60	0.76
I would imagine that most people would learn to use this system very quickly.	3.50	1.15
I felt very confident using the system.	3.17	1.04
Learning objectives:		
The game increased my interest and knowledge in supply chain management.	3.63	0.91
I better communicate, cooperate and share knowledge with my group members via the game	3.63	1.02
The game improved my decision-making and problem-solving skills.	3.60	0.92
The lessons learned from the game can be applied to the real-life situations	3.77	1.02
The game helped me in understanding the concept of lead time	3.77	0.92
The game helped me understand the concepts of supply chain network collaboration	3.90	0.94
I think sharing information between players helped to improve my decisions	4.00	0.77
The game helped improve my strategies for inventory management	3.70	1.00
I was able to calculate the order quantity easily using information provided by the game	3.23	0.92
Teaching Aspects:		
The game is a positive contribution to the curriculum.	3.77	1.15
I prefer the simulation game approach to conventional teaching methods.	3.97	1.14
I am interested in playing the game for more sessions.	3.50	1.15
The game motivated me to learn the rules of calculating the order quantity by clicking learn about order quantity button.	3.57	1.02
Optimiser Integration:		
The optimiser was helpful to direct me to take better decisions.	3.60	0.71
Optimiser enabled me to understand concepts like optimum order quantity	3.57	0.88
Checking my previous decisions and compare them with the optimiser decisions enhanced my decisions	3.63	0.84

Table 1: Questionnaire Mean and Standard Deviation

Results and discussion

The results collected from the questionnaire showed a remarkable degree of acceptance of the

game on the part of the students (see Figure 8). Their comments and discussions revealed

they were interested in playing for a longer period and over more sessions. The usability

survey results emphasised the efficiency of the game, which enabled students to progress through the game functions with minimum help from their supervisors. Using game elements to motivate students such as points and ranking boards (to show the rank of each student) improved students' motivation and engagement (Boyce & Barnes, 2011).
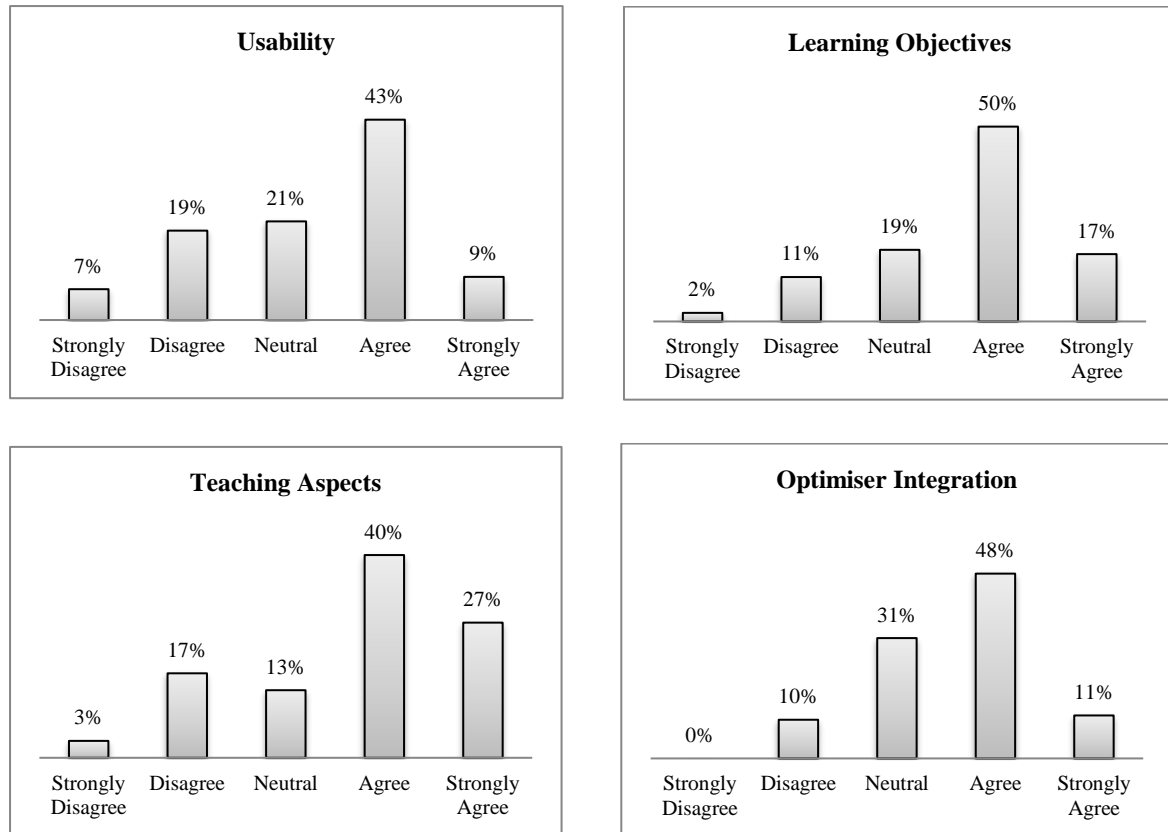

Figure 8: Acceptance figures for the different sections of the questionnaire

Students were very interested in the game features, to the degree that some students explained some options to others. Discussions about supply-chain concepts between students were observed during the playing session, which highlighted both the game's advantages for improving both the social dimension and knowledge exchange, which improved the learning process (Attali & Arieli-Attali, 2015). Some students were so motivated that they used pen and paper to make calculations to decide the order quantities. This demonstrates that gamification can affect students attitude in the real world and not only in the virtual world (as discussed in Deterding, 2011).

Students' comments on the game session included:

- The animation was very helpful in illustrating the movements of elements through the whole supply chain network.

- Being mindful of the three areas (manufacturer, retailer, and supplier).

- Enjoyable way of learning

- Learned new supply-chain concepts like ordering, lead-times, stock levels and replenishment.

- Gave good insights about the importance of simulation in SC and better understanding of supply chain network

- Best learning concepts were SC flows and replenishment

- Learned about the risks of holding too much stock, receiving and delivering orders, and lead times.

Data were collected about the game's teaching ability and the achievement of learning objectives which shows that – in general – the students 'agreed' or 'strongly agreed' that the game succeeded, in that they achieved greater understanding and improved their skills during the game session (see Figure 8 – Learning Objectives and Teaching Aspects). Simple statistical analysis of the relevant section of the questionnaire was used to evaluate the optimiser feature: as Figure 8 (Optimiser Integration) shows, the assessment of the value of integrating this feature is significantly skewed towards 'agree' and 'strongly agree' responses.

Table 1 illustrates students' responses regarding the usability of the game, learning objectives, teaching aspects, and the optimiser integration. As shown in the table, most of the mean scores skew towards general agree and strongly agree with the game usability – see Figure 8 (Usability), learning and teaching features and optimiser role. It also shows that they

were keen to play the game for more sessions and they were satisfied with the level of communication and cooperation created by using the game. Meanwhile, they commented on the interface of the game that it needs to be simplified or they should be given some more time for free playing to get used to it before the start of the experiment.

The ARCS model (Attention, Relevance, Confidence, and Satisfaction) was used as an instrument to measure the continuous engagement of students. Components of the model were reflected in a five-level Likert scale questionnaire and analysed after the experiment. Figure 9 shows an achievement above the average for students regarding the engagement components. Using motivation elements such as points, ranks and performance indicators are more effective with higher students than extrinsic motivators (Coopman, Gao, Morgan & Coopman, 2014; Ejsing-Duun & Karoff, 2014).
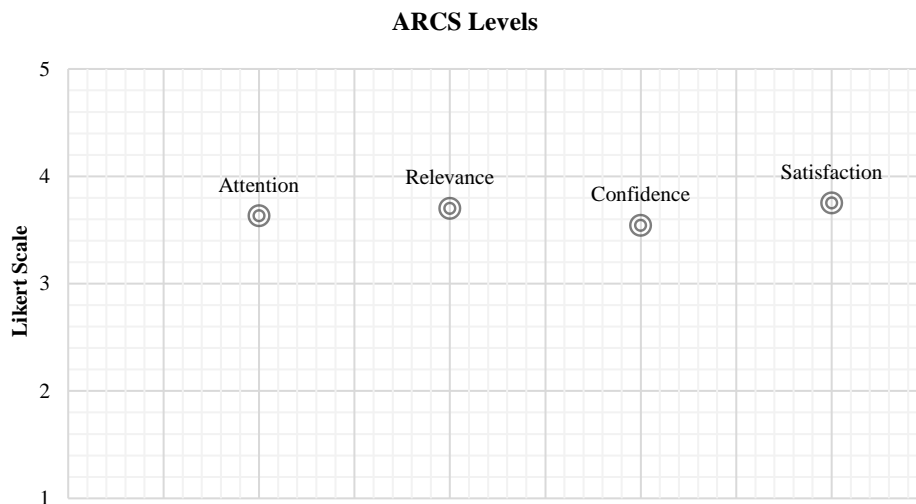

Figure 9: ARCS Model result analysis

Conclusion

Understanding the performance variables of supply-chain fields, which are characterised by complexity and uncertainty, imposes pressure on instructors and trainees to explore novel

techniques for delivering and learning knowledge. Simulation-based games have been shown to be a suitable way of engaging students in the learning process, as they are consistent with their reputation of belonging to a 'virtual generation'. The main contribution of this work is the validation of a new framework for designing and integrating serious games for complex study fields in classrooms. This framework describes the required components to achieve both pedagogical and entertainment aspects in the learning process, to keep the suitable level of student engagement, as well as of knowledge retention.

The validation process involved the design and implementation of a supply-chain game (AuSuM) based on the proposed framework and its experimental application in a real classroom context. An evaluation of the experiment revealed that the facilities given to the instructor encouraged the use of the game as a teaching tool for a particular and relatively complex subject to a group of learners. Statistical analysis of the questionnaire results validated its effectiveness for teaching supply-chain concepts. One of the game's motivational and engagement factors is its social component, where the collaboration between students required in some situations adds a social dynamic to the game that is lacking in traditional challenge-based games.

Observations during the experimental session demonstrated additional conclusions. First, motivation and engagement increased during the game session and remained high to the end. Second, indicators of the students' ability to learn the system rapidly are noticed, such as quick engagement and usability familiarity, and quick drop in confusion about interfaces. Students quickly engaged with the game and showed entrepreneurship in using the tool without asking about its usability instructions – indeed, even before such instructions had been given. The optimiser feature integrated into the framework achieved a significant

improvement in players' decisions. Students' response to the questionnaire showed a remarkable acceptance for the optimiser role in the game and explained how they get help and motivation by comparisons between their decisions and the optimum values using the provided historical charts. The findings of this study are consistent with Machuca (2000) and Zantow, Knowlton and Sharp (2005) in highlighting the effect of using games in explaining complex concepts for students. It also helped them to practise the decision making process for the multi-objectives environment.

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