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Distributed Supply Chain Simulation Portal: Design and Implementation

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DISTRIBUTED SUPPLY CHAIN SIMULATION PORTAL: DESIGN AND IMPLEMENTATION

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Abstract

The emerging paradigm of eLearning is becoming increasingly in evidence across many academic disciplines acknowledging the concept that learning processes no longer support traditional teaching methods alone. It can be argued that today's third level education students are part of a new virtual era where the blackboard has been replaced with an interactive whiteboard. To assist in the transition from traditional learning to eLearning, more interactive and virtually orientated teaching aids are needed. A simulation-based learning framework that integrates web-based simulation and a web content management hierarchy model is the key objective of this paper. Using the highly complex subject of supply chain management as a case study, the new framework allows users to examine various management strategies of real-life scenarios, encourages group work and has remote access capabilities for distance learning. Interactive learning is facilitated using the web-based simulation portal, enabling instructors to demonstrate the complexity of decisions in multiple criteria environment and also show the users the impact of strategies on performance. Supply chain simulation creates an animated experience and better understanding of the system dynamics including risks. The portal interface is friendly and hence there is a potential to be applied in other subject areas.

Keywords

Web-based Simulation – Distributed Simulation – Supply Chain Management

Introduction

The ability to learn has always been the foundations of any successful society. Learning can be defined as the acquisition of knowledge through cognitive processes that translate into new understandings, behaviors and skills (Moore et al., 2009). In today's knowledge driven society, gaining such valuable understandings through education is a very important resource (Schleicher, 2003). The advances made in computer technology, coupled with educations drive to take advantage of such advances have given rise to eLearning.

The emerging paradigm of eLearning is becoming increasingly in evidence across many academic disciplines and provides further support for the concept that learning processes no longer support traditional teaching methods alone. It can be argued that today's third level education students are part of a new virtual generation, where the blackboard and refill pad have been replaced with an interactive white board and laptop respectively. To assist in the transition from traditional learning to eLearning, more interactive, animated and virtually orientated teaching aids are needed.

The objective of this paper is to develop an interactive web-based simulation portal using an integration of; simulation-based learning, web-based simulation and a web content management hierarchy model. The portal will create a medium that is easy to use and enables teachers to create a more interactive learning environment for students. Section 1 acknowledges the importance of third level institutes to Ireland's knowledge economy and the challenges they face. Simulation-based learning frameworks are then discussed before a review of web-based simulation in Section 2. An overview of the complexities in supply chain management takes place in Section 3's case study which is used in the building and implementation of the distributed simulation portal in Section 4. Finally the results, findings and future work in the implementation of the portal are discussed in the conclusion.

1. Third Level Education in Ireland

The quality of third-level educational (TLE) systems has a significant influence on the economic wellbeing of society (Prendergast et al., 2001). In Ireland, the effectiveness of TLE is extremely important when obtaining the necessary high levels of knowledge and skills required for sustainable competitiveness (Breena et al., 2009). Consequently, there has been an increased emphasis put on TLE by Irish governments in recent decades, culminating in a large increase in student numbers (Fig.1) (Department of Education, 2010). In particular, government incentives such as the abolition of college fees in 1996 (Clancy and Kehoe, 1999) and the "Charting Our Education Future" white paper in 1995 (Department of Education, 1995) laid the foundations for the knowledge economy.

While preparing students for a successful career in a knowledge-based economy, TLE processes require an integrated educational environment that will encourage creativity and a commitment to lifelong learning (Brewer and Brewer, 2010). To achieve this transition into a more creative and long-term learning environment, TLE institutes have faced many challenges.

1.1. Challenges to Third Level Education Process

With such a high level of investment in Irish TLE, it is critical that the challenges within the teaching/learning relationship are understood and addressed to ensure that college graduates make a successful and optimized transition into the workplace (Tobail et al., 2010b). Studies made by Cuban (1984) on teacher education in the USA suggest that teaching adapts to requirements of particular era's. However, sometimes these changes have not adapted sufficiently or been reviewed regularly, becoming ineffective and outdated (Hess, 2009). The primary example of this would be the use of traditional 'rote' learning techniques in TLE, which has been proven to discourage the transfer of core/key skills (Billing, 2007). This learning process consisted of a knowledgeable educator on a particular topic, who constructed and communicated knowledge on such topics to learners to memorize using the common instructional technologies of the day; books, articles and classroom lectures (Ruben, 1999).

During the past 30 years, TLE has been evolving steadily and the objectives of TLE institutes have changed. Memorizing facts and figures are now recognized to be less important than developing knowledge based skills for; problem-solving, interactive team work and life-long learning (Knight and Wood, 2005). The introduction of the learning pyramid has instilled a new focus on the way teachers interact with students in relation to the retention of what is being taught (DeKanter, 2004). Although there is only 5% retention rate given to the traditional class lecture when used alone, when all teaching methods of the pyramid are used in continuum rather than hierarchal, the level of retention is up to 90% greater (Lalley and Miller, 2007). The theme of this paper is centered on the concept of the learning pyramid in continuum, because to retain conceptual knowledge effectively using simulation, the class lecture and teacher instruction are still very important.

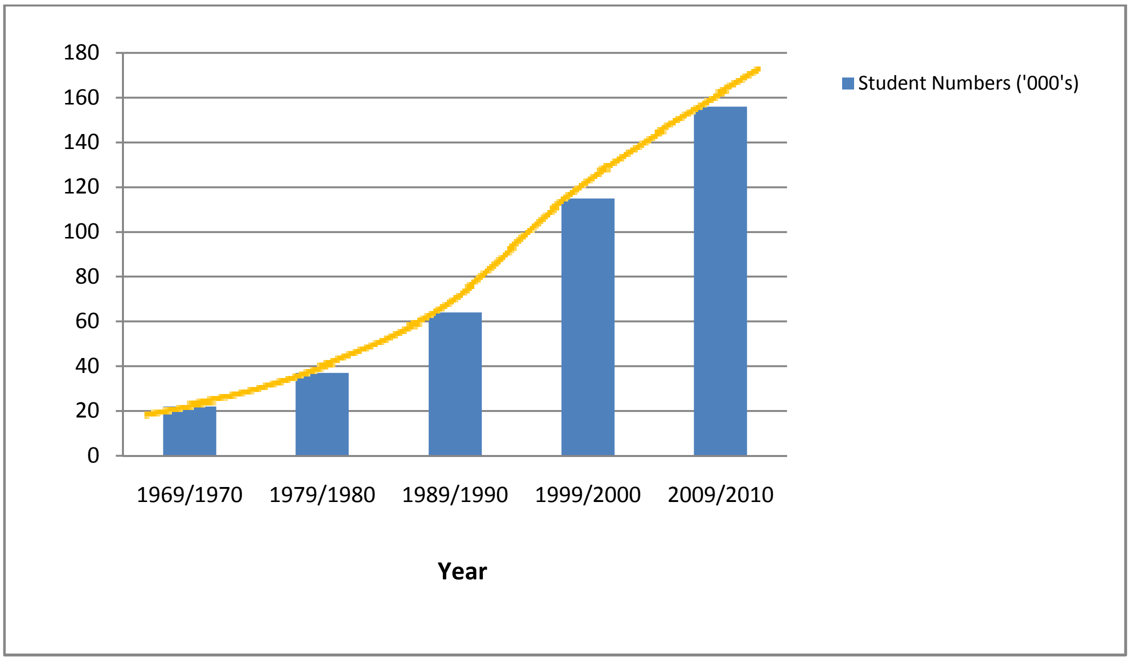

Figure 1. Full-Time Students in TLE Institutions in Ireland

1.2. Simulation as an Education Solution

Although using simulation as a method of teaching is not a new concept, particularly in medical, military and aviation education (Murphy et al., 2010), it is growing rapidly in many other academic disciplines. The reasoning for such growth lies with simulations potential to create clinical experiences that closely mimic the real life scenarios of a system (Zhang et al., 2010). Whether simulating medical procedures without doing harm to a patient, or simulating a supply chain management concept without the costly change in business strategy, simulation is a powerful learning aid.

Another important driver for the growth in using simulation technologies in TLE is the fact that today's TLE student is part of the digital generation. In this virtual age, online multi-player games, virtual reality and simulations are a part of everyday life, making gaming and simulation a very important catalyst in the TLE learning process (Proserpio and Gioia, 2007).

1.2.1. Simulation-Based Learning Framework

Simulation is not a technology; it is a technique to replicate the real world in a completely interactive way (Gaba, 2004). However to aid in its effectiveness, technologies such as computer software are often utilized. The technological foundations of the simulation portal developed in this paper are based on Tobail et al's (2010a) simulation-based framework (Fig.2).

Using detailed conceptual models of a supply chain, the framework was developed to assist in the future creation of an actual simulation-based teaching aid to TLE SCM lecturers. The whole framework depended on modeling the basic concepts and theories of SCM and integrated them into a powerful simulation tool. Designing and implementation process of this project involved computer engineering and SCM experts to achieve the required aspects of the system. The implementation of the framework can be divided into two stages.

The first stage was the design and implementation of a simulation model for SCM using a powerful simulation tool. The second stage of web-enabling applications was developed using a communication protocol layer and interactive graphical user interface. This paper focuses on developing stage 2, the use of web-enabling technologies in the TLE learning process.

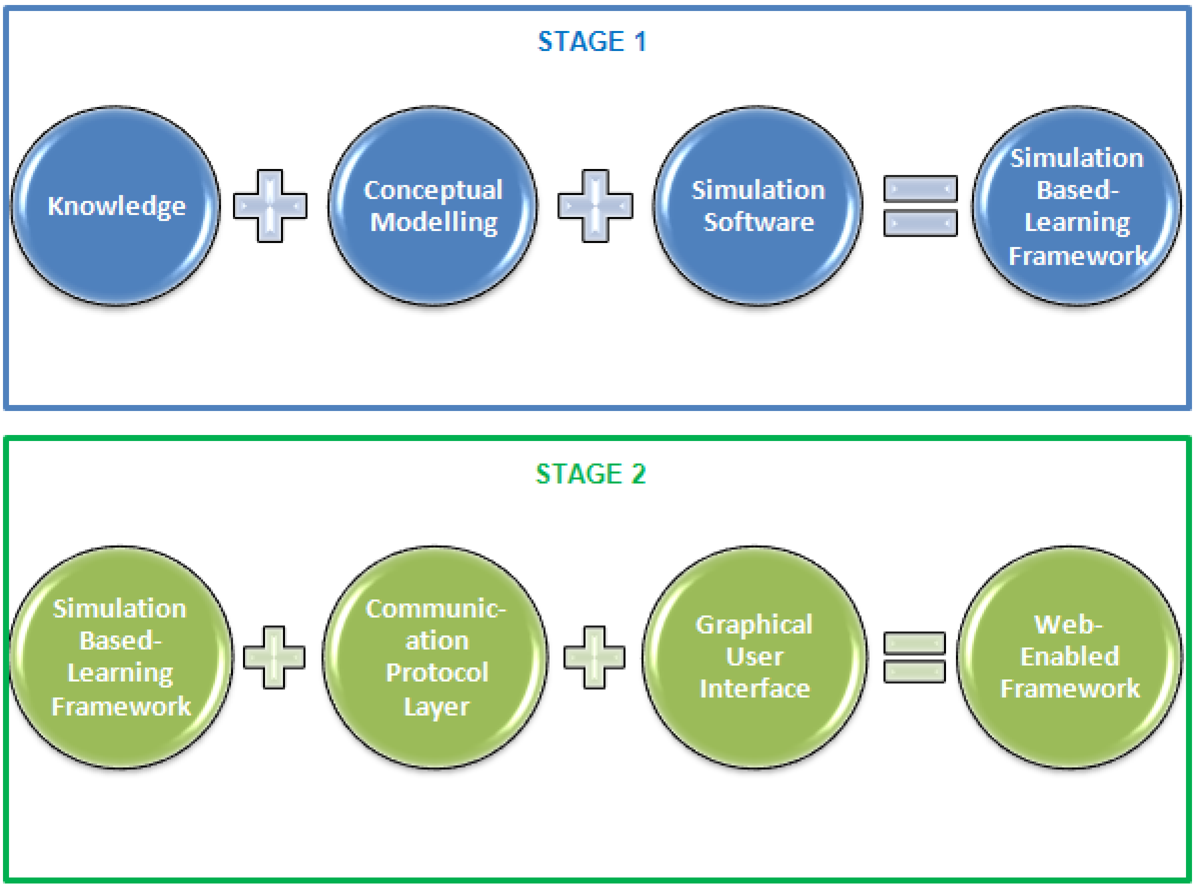

Figure 2. Simulation-Based Learning Framework

2. Web-Based Learning

The increase in demand for education, as stated in Section 1, coupled with the increase in the amount of information available are the main reasons for the integration of education and computers, primarily the internet (Bicen et al., 2010). This novel approach to education is commonly known as web-based learning and is an eLearning technique that has made the learning process more accessible by stretching spatial and temporal barriers (Khalifa and Lam, 2002). Web-based learning is the step in the learning/teaching relationship where the communication and interaction of students with a lecturer/teacher takes place with the use of computer science and network technologies.

A web-based learning field that has been growing steadily over the past number of years is that of web-based simulation (Yingping and Madey, 2005).

2.1. Web-Based Simulation

Although the field of web-based simulation was first introduced by Fishwick (1996), the concept is said to be as old as the Web itself (Reichenthal, 2002). In his paper, Fishwick formed an introductory overview of web-based simulation, to be used as a backdrop to a more formal discussion, with the objective of potentially forming a new simulation track. This in-turn, gave rise to a new era in simulation study and research into the field grew rapidly, but despite such a promising start, the number of real applications in the field is relatively small (Wiedemann, 2001).

According to a review made by Byrne et al. (2010), web-based simulation can be separated into 7 categories:

1. Local simulation and visualization
2. Remote simulation and visualization
3. Hybrid simulation and visualization
4. Web-based simulation documentation
5. Web-based simulation model repository
6. Component-based simulation in relation to Web-based simulation
7. Distributed simulation in relation to Web-based simulation

Incorporating web content management, the portal developed in this paper lies in category number 7, distributed simulation in relation to web-based simulation. In theory, all web-based simulation to some degree can be regarded as distributed simulation (Page et al., 1998). In a distributed simulation system, the model designer should not have to have knowledge about technical details used by the system creator to produce distributed simulations (Byrne et al., 2010). This is an important factor in the development of the distributed simulation portal in this paper. The goal of which is to develop an accessible simulation portal to TLE students, many of which are not technically minded.

2.2. Web Content Management

Web content management (WCM) is defined as an organizational process, aided by computer software tools, for the management of content on the Web, encompassing a life-cycle that runs from formation to destruction (Vidgen et al., 2001). In basic terms, WCM is an infrastructural support management system for websites. There are main 3 roles that WCM must support; the writer ,the reader and the collection manager (Rein et al., 1997). To manage these roles in the simulation portal developed in this paper, McKeever's (2003) four-layer hierarchal layer WCM has been used. The hierarchy consists of 4 layers (Fig.3), which reflect each of the interacting layers in WCM. They are; content, activity, outlet and audience.

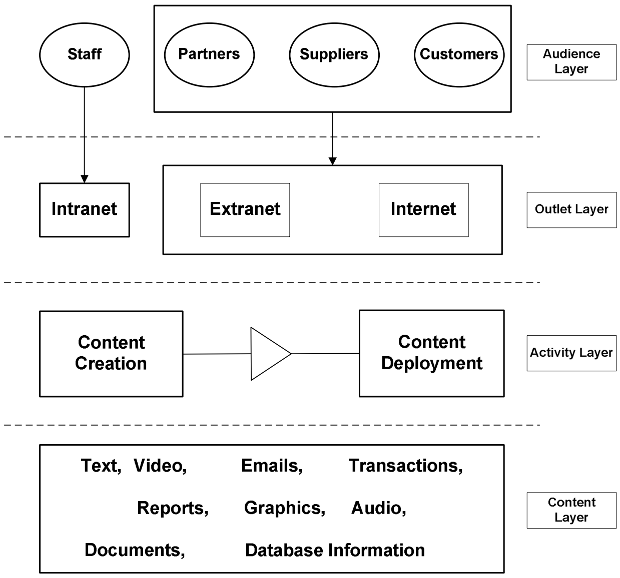

Figure 3. WCM Four-Layer Hierarchy

3. Supply Chain Management Case Studies

The introduction to this paper highlighted that education is a very important resource in today's knowledge driven society. Similarly, knowledge is a very important resource in managing and understanding the supply chain (Lambert et al., 1998). At its basic level a supply chain is made up of multiple partners (supplier, manufacturer, distribution centre etc.), multiple flows of items, information and finances and is sometimes described as looking like an uprooted tree (Lambert and Pohlen, 2001). Each network node has its own customers' and suppliers' management strategies, partnerships, inventory control policies and items mixture (Longo and Mirabelli, 2008), with many challenges to overcome. Challenges to overcome at all strategic levels of SCM include; complexity, uncertainty, risk, resilience, visibility, and cost to name a few. The capabilities of simulation software to replicate uncertainty are high, mainly through discrete event simulation, as it is capable of manipulating the variability and uncertainty of a system (Mahfouz et al., 2010).

To illustrate how TLE students can visually and interactively learn the complexity of SCM, important network nodes; a distribution centre and a manufacturing plant were chosen as the case studies used to build the simulation portal.

3.1. Distribution Centre/Manufacturer Relationship

Up until recent years, the relationship between supply chain partners has been adverse in nature. Relationships were traditionally transactional, focusing on; cost, delivery time and quality alone (Goffin et al., 2006). To demonstrate the effectiveness of the simulation-based learning framework in teaching SCM complexity, two key supply chain members; a first tier supplier distribution centre (Fig.4) and a manufacturer (Fig.5) were modeled, simulated and measured.

Using hypothetical, yet accurate input data, including; forecasted and actual sales figures, production process capacity, product specifications, lead-times and product costing, the relationship between the two supply chain members were studied. Equations, management strategies, statistical analysis and other management science techniques that SCM students will learn in their degree were integrated into the model results to illustrate the impact of input and process decisions on the model outputs, which include warehouse capacity utilization, cycle throughput time and queue lengths. The end objective is for the user to practically understand the complex relationship between the manufacturer and supplier, and how the impact of their management choices and input decisions affects the efficiency of the partnership.

3.1.1. The Distribution Centre

Using integrated definition modeling language for functional process (IDEF0), the operational processes of a generic supplier distribution centre were studied and modeled (Fig.4). There are two main streams to the model; the order process (demand management) and the warehouse operations process. The main warehouse functions are; inbound planning, tipping, storing, order picking, dispatch planning and dispatch.

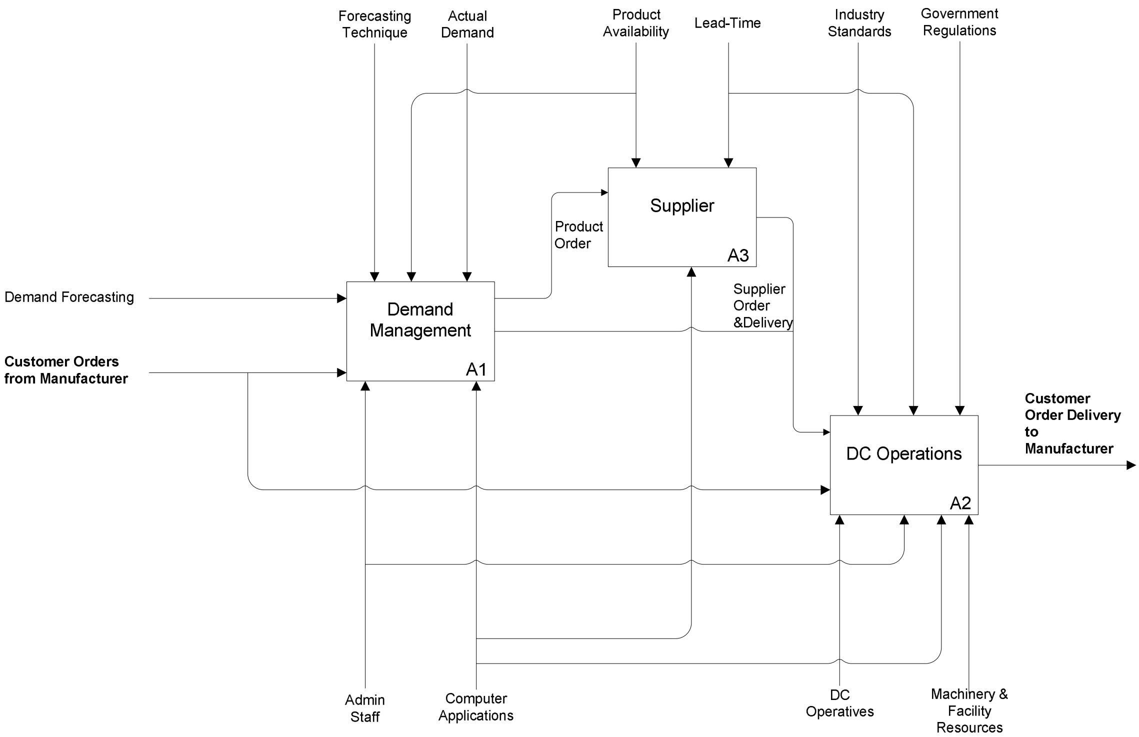

Figure 4. IDEF0 Conceptual Model of Distribution Centre Operations

3.1.1. The Manufacturing Plant

Studying a plastic bag manufacturer, IDEF0 was also used to create a detailed conceptual model of the manufacturing process (Fig.5). The production system begins with the arrival of orders from the customer (Distribution Centre), beginning a 'pull demand' strategy through the production plant. Items have a number of various routes possible, with all products having their own individual characteristics. Elements that make up these characteristics are attributes such as height, thickness, quantity needed and extrusion weight which lend themselves to the specific tailoring required for the production of individual items.

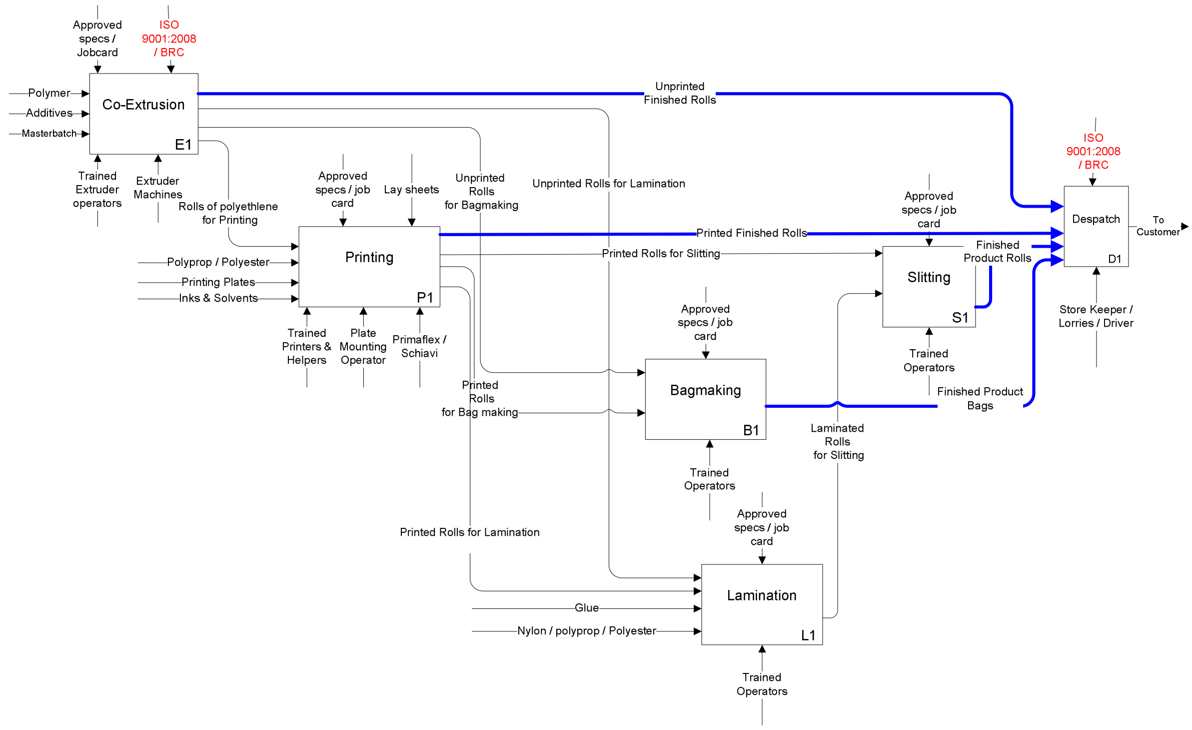

Figure 5. IDEF0 Conceptual Model of Distribution Centre Operations

4. Web-Based Simulation Portal System Structure

The proposed web-based simulation portal structure consists of a client site and a server site connected over the web by TCP/IP protocol.

4.1. Server Site

The main structure of the system has been built on the server. This part consists of web-server, simulation tool, content management system and database, controller and listener (Fig.6). Each area is described briefly below:

Web server — the web server's main objective is to host the main web sites responsible for the portal, manage the client requests and data storage. The most common managed requests are Hypertext Transfer Protocol (HTTP).

Simulation Tool — a professional simulation toolkit has been employed to serve the considerable simulation requirements. Using a professional simulation tool with all simulation capabilities is considered as one of the privileges for this framework over the other web-based simulation tools which run the simulation tool on the client machine. This leads to limitations in simulation capabilities in the client simulation tools. The main option of this tool is to run the required simulation model based on the client requirement (Fig. 4 & 5) and save the results to be transferred later to the client.

Controller — this is the part which is responsible for translating client requests to the simulation tool commands. The inputs to the simulation tool are applied from the client side through the controller and the output is then transferred back to the client using the web and TCP/IP protocol. The controller uses a shared communication space and two types of commands. The shared space is to exchange data and commands with the simulation tool. There are two types of commands; commands to exchange data by applying inputs and getting outputs to/from the simulation tool; and commands to execute options and services of the simulation tool.

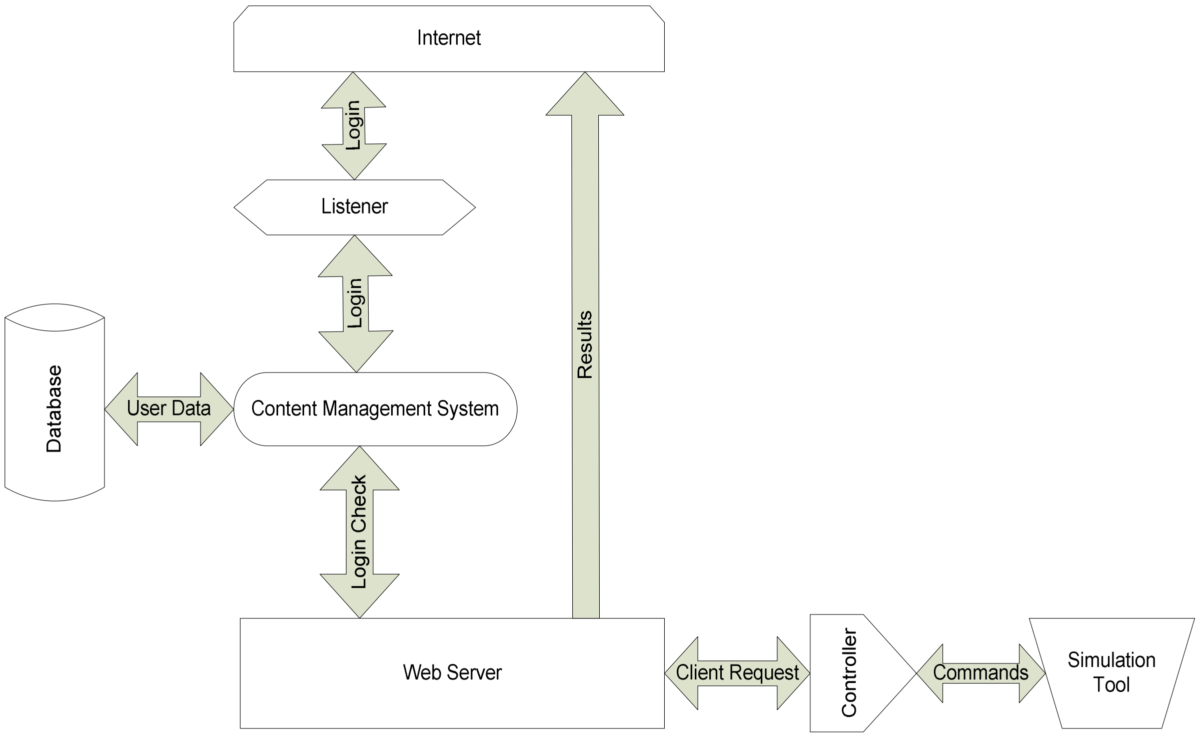

Figure 6. Server Site System Structure

Content Management System and Database — to control the accessibility of the system and simulation model, a content management system has been built using the four layer hierarchy method, as illustrated in figure 3. This system differs between the two main types of users; TLE instructors and students. Instructors have controlling options such as assigning models to users and modifying models. Students are able to run their assigned models and check the results. Login to this system is achieved through a username and password interface (Fig.7). A database system has been built to support the content management system. The database management system stores the registered users, assigned simulation models and the privileges assigned to different types of users.

Listener — the listener module is the interface between the client and the web server. It is running to wait and listen for client requests and pass them to the web server to be managed by the controller. The client uses a graphical user interface to apply requests which are encoded and sent over the web in TCP/IP protocol to the server.

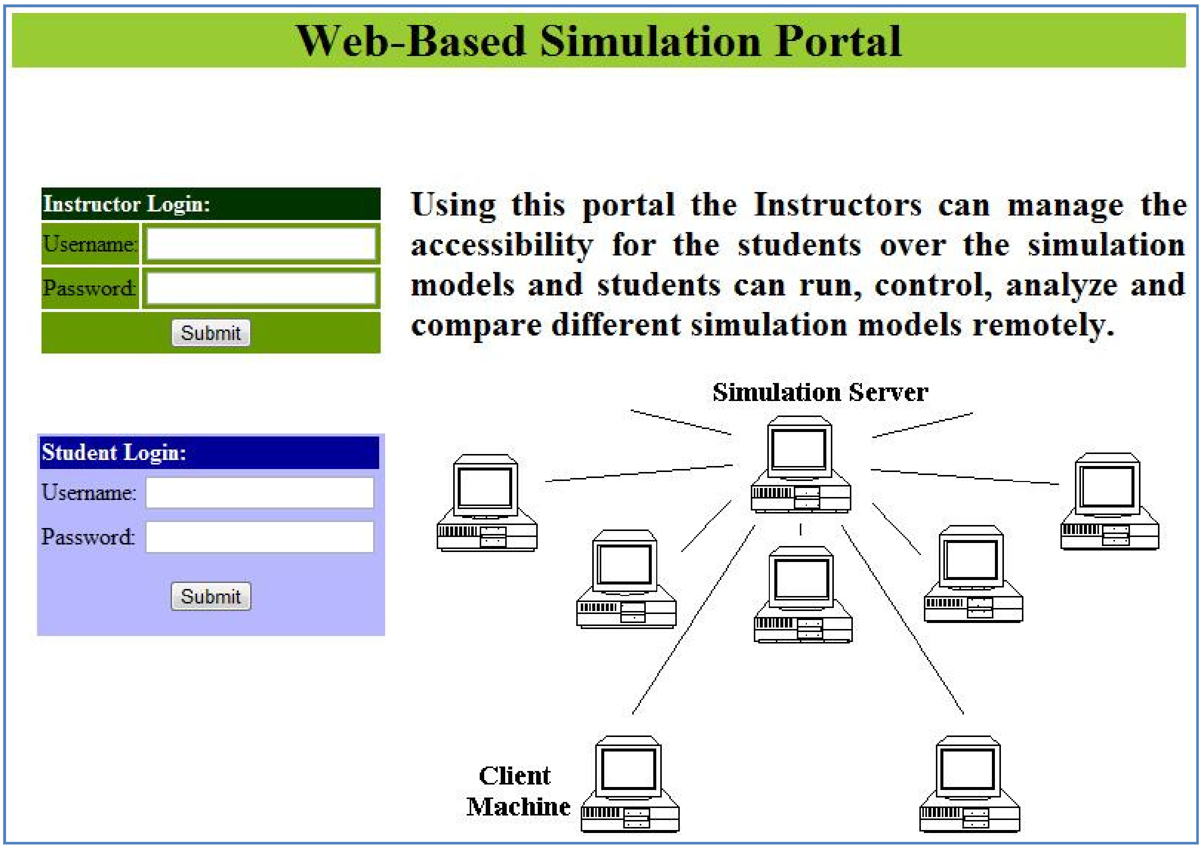

Figure 7. Client Graphical User Interface

4.2. Client Site

A client site represents the part of the system running on the client's machine. The client site consists of two main parts; graphical user interface GUI and translator module (Fig.8). These main two parts are described as following:

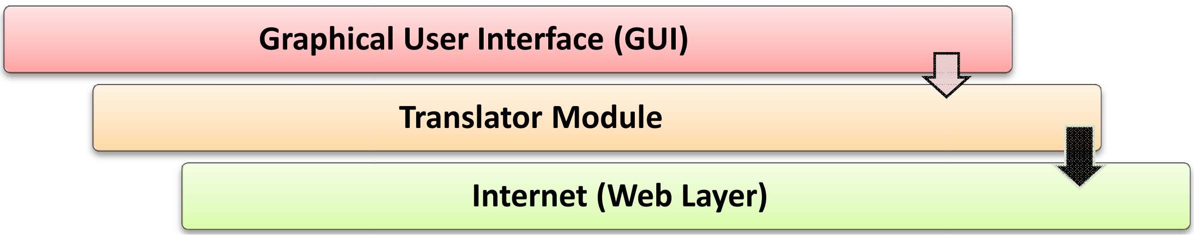

Figure 8. Client Site System Structure

Client Graphical User Interface (GUI) — this interface works to receive the client commands to be transferred to the server and display the results received from the server to the client. Main software engineering capabilities have been taken into account while building this interface, including; usability, accessibility and reliability. Many operations can be achieved from the client side using this interface. They are; login to the system, controlling the simulation model; applying inputs and check the results, comparing two simulation models and passing results from one model to other (Fig.9). One of the main benefits of this interface is to ease the capabilities of accessing distributed simulation systems with keeping the professional simulation tools capabilities.

Translator — the translator is a background running module which encodes the client commands in a way to be understood by the controller on the server site. When the client/student chooses to run a simulation model, the translator encodes these actions as a running command and the model name, and then sends them over the web. This translator encodes all actions from all types of users; students and instructors.

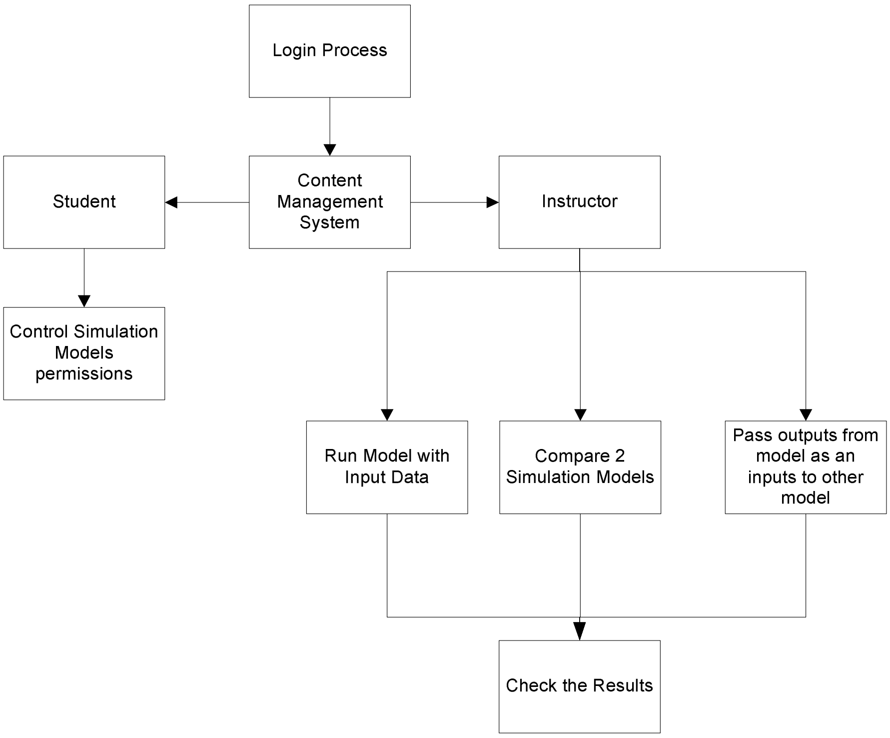

Figure 9. User's Operations Scheme

Conclusion

The close relationship today's TLE students have with the technological world can no longer be ignored by educational institutions. The emergence of eLearning as a valid and effective educational process has never been more relevant. This paper discussed the potential benefit of developing an interactive web portal that will validate the emergence of eLearning techniques. Using simulation-based learning, integrated with web-based simulation and a web content management hierarchy model, an easy to use web-based simulation portal was developed. The portal enables teachers/instructors of supply chain management to experience a more interactive eLearning environment for TLE students.

Using a web-based platform has shown several advantages such as; (1) portals are less expensive than simulation software packages, (2) easy to access from anywhere (i.e. college or home), (3) authorization for teachers to manage the class, and (4) instructors can assign different models to be used by different students' groups and customize the input and outputs for the systems. The system is designed to enable students to work in groups and access different distributed models concurrently. It enables many users to get access into a single simulation model from different sites, and/or a single accessibility to distributed simulation models to upgrade the decision making capabilities.

Students can apply various inputs and examine the outputs, compare simulation models, connect between distributed models by passing the output of one as an input to the second. In the case study, supply chain simulation creates an animated experience and better understanding of the impact of uncertainty and risks within supply chains. The portal interface has a potential to be used in other subject areas that have high levels of multiple parameters and objective criteria in decision-making process.

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