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DOCTORAL THESIS

The design and evaluation of distributed virtual environment to support learning in global operations management

Tunyawat Somjaitaweeporn

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THE DESIGN AND EVALUATION OF DISTRIBUTED VIRTUAL ENVIRONMENT TO SUPPORT LEARNING IN GLOBAL OPERATIONS MANAGEMENT

TUNYAWAT SOMJAITAWEEPORN

Doctor of Philosophy

ASTON UNIVERSITY
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Title: The Design and Evaluation of Distributed Virtual Environment to Support Learning in Global Operations Management

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The primary goal of this research is to design and develop an education technology to support learning in global operations management. The research implements a series of studies to determine the right balance among user requirements, learning methods and applied technologies, on a view of student-centred learning. This research is multidisciplinary by nature, involving topics from various disciplines such as global operations management, curriculum and contemporary learning theory, and computer aided learning. Innovative learning models that emphasise on technological implementation are employed and discussed throughout this research.

Keyword: global operations management, learning support system, distributed learning environment, computer aided training, virtual world technology

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To be honest, PhD was something that had never been in my mind. Although I had an excellent academic profile, I was not at all an academic type of person. However, for some reasons, I ended up doing PhD just after finishing my master's. I believe this thesis would be the last piece of my academic work. So, I think it is a great and special opportunity to express my true feelings to all of my supporters.

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Chapter 1: Research Overview

Globalisation is changing the way every business works. In order to enhance business capability, modern management strategies and innovative practices have been developed to encounter the rapidly-changing global conditions. A range of factors such as social heterogeneity of a community, political and economic differences among countries are considered as significance factors for defining business strategies. Since the process of globalisation increases the complexity of how business works, the manager must understand how to respond to this phenomenon in a constructive way. It is considered necessary to train managers to develop skills to deal with the challenges arising from globalisation. The central focus thus becomes on the improvement of training aids and instructional methods to meet the challenges.

1.1 Motivation and Problem Statement

Business practices have undergone radical changes as a consequence of globalisation. In order to respond to these changes, organisations have already started to rebuild and undertake continuous improvement through changes in organisation structure and administrative process (Parker 2005). Angehrn and Nabeth (1997) suggest that in order to encounter such drastic changes, managers must possess new skill sets which will enable them to:

- operate internationally and have a good understanding of cultural differences
- select essential data, interpret signals, determine clear objectives and act rapidly, often on the basis of excessive though incomplete information
- be flexible and adopt continuous learning as a philosophy of life
- get things done with others rather than through others

Angehrn (2005) states that these skill sets have enormous implications for the training and education of managers. Taking the perspective that information and knowledge are resources to be utilised to achieve corporate goals, managers need to develop skills and processes which enable them to select, analyse, interpret and communicate information in a more effective fashion. This implies a need for managers to be more proficient at handling challenges by adjusting their mental model through action and critical reflection through education and training.

From a corporate perspective, it is necessary to institutionalise these practices, adopt a systems thinking approach to understanding complexity, focus on team rather than individual performance and create a safe environment in which team members can learn with and from each other. From a training perspective, the key to translating this ideology into practice is to cultivate the relationships between course content and delivery. Reaching these ambitious aims will require a completely new educational infrastructure.

While business, industry and society have been enhanced by the integration of computer and telecommunication technologies, the field of management education is still based on pedagogical design principles which fails to take advantage of the latest generation of technology and global telecommunication infrastructure (Angehrn and Nabeth 1997). In the fields of management education and teaching, computers were used primarily to speed up mathematical calculations and to run simple business simulation games. As a result of recent technological innovations, this is now changing. For example, multimedia and internet technology can by employed to enhance the interaction between human and computer. By such integration, it would overcome the limitations of computer-based training tools (Sherman and Craig 2003). In the field of operations management education, such technology can enable realistic and practical tasks to be performed, providing an innovative and challenging learning experience. Such experiences would have improved managers' understanding of what they need to operate a business (Mujber, Szecsi et al. 2004).

Multimedia and internet technologies have long been progressively improving instructional design (Bates 1999). This environment provides exceptional learning opportunities and encourages the development of positive attitude beyond formalised education. However, the benefits of multimedia and internet cannot be gained without modern computer technologies such as artificial intelligence and advanced communication systems (Somjaitaweeporn and Love 2005). The advent of these technologies create a richer learning environment which improve learning capability (Shih 2002). In such an enhanced environment, strong professional support can provide leverage for constructive learning activities (Rickel and Johnson 2003). This means that a global company can conduct a more systematic and rigorous training programme.

1.2 Aim and Research Questions

This research aims to design a computer-based training system for a global operations management course. In order to reach this main aim following research questions are formulated:

- How the forces of globlisation influence the need of a specific training programme for global management team?
- What are the current issues that implicate in teaching and learning in global operations management?
- What are the learning methods that are particularly effective for the global operations management training?
- What are the representational technologies that enhance the learning process regarding those learning methods?
- What is the conceptual design of the computer-based training system that would enhance the learning in global operations management?
- How to create the system with the available technologies?
- Would it be a more effective teaching and learning tool for a particular learning situation in global operations management training?

1.3 Research Framework

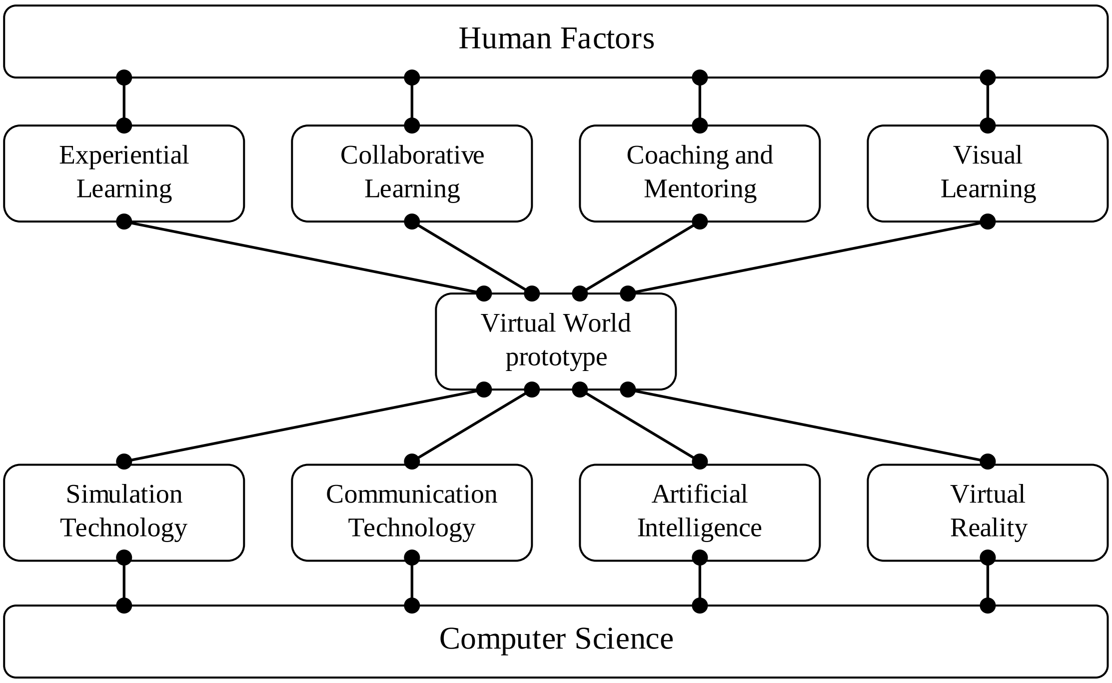

Figure 1-1: Component disciplines that contribute to the virtual world prototype

The field of human factors is concerned with the design of environments, procedures or systems that allow people to perform certain tasks. The vector nature of the field provides an intuitive understanding of the cognitive and perceptual attributes of the work environment. This field is not a pure science; it is more closely affiliated with philosophy than it is with designing and constructing facilities. The primary objective of human factors is to ensure that objects used and activities performed are compatible with human capabilities, limitations, and preferences (Vicente 2006). The incorporation of the study of human factors in engineering design often results in a system that is more efficient, safer, and easy to use. In this study, human factors provide theoretical ground for the design principles underlying the development of the virtual world prototype. The diverse set of branches of human factors in this body of research consists of experiential learning, collaborative learning, visual learning and coaching, all of which have mutually independent features that contribute to the design specification.

At the other end of the framework, computer science is the study of the theoretical foundations of information and applications. Computer scientists seek to understand how to represent and to reason about the processes and information residing on computers (Tucker 2004). They develop models and methods for creating and analysing the phenomena involved. The research and development activities in this area are conceived as a field of empirical enquiry as opposed to traditional human factor approaches. Under the domain of computer science – this study uses simulation technology, communication technology, artificial intelligence and virtual reality to develop new technological training tool.

1.4 The Research Approach

Two models are used in most research studies: deductive and inductive (Engel and Schutt 2005). The deductive model deduces or derives properties of the real world from theories, whereas the inductive model induces or generalises theories from observations of real world phenomena.

A typical deductive reasoning model explains observations in terms of facts and hypotheses. The purpose of this model is to generate a set of hypotheses that can explain real-world phenomena (Engel and Schutt 2005). The deductive researcher begins with a theory about a phenomenon and makes a prediction about its behaviour in the form of hypothesis. In this approach, a laboratory experiment is conducted to determine a set of independent variables and to measure the results with respect to a set of dependent variables. Other factors that may affect the result are either eliminated or changed through controlled conditions. Once the results of the experiment are analysed, the original theory is re-examined and a revised hypothesis is created. The researcher can then test the revised hypothesis with a new set of controlled experiments. In the social sciences, experimental psychologists are most likely to follow this model. This approach is employed in the experimental study of this thesis.

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Figure 1-2: A block diagram of deductive approach. (Mackay and Fayard 1997 p.4)

The inductive model constructs the most precise description, not explanation, of a phenomenon. The inductive scientist observes phenomena in the real world without having a preconception or theory of what he or she is looking for (Engel and Schutt 2005). Then the scientist creates a model that explains the phenomenon. By returning to the real world the model can be validated and changed if there are contradictions between the model and the phenomena under study. Traditional sociology and anthropology follow this model. The qualitative study in this thesis uses this approach for requirements elicitation and to make design recommendations.

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Figure 1-3: A block diagram of inductive approach. (Mackay and Fayard 1997 p. 4)

Both the deductive and inductive models consist of cyclical sequences between theory and observation. This research, however, poses a wide range of questions, crossing disciplinary boundaries; the design process is quite different from the traditional scientific method. The object of the study is not an independent natural phenomenon. Some unique forms of observation and experience in this study do not yield results that agree with experiment or analysis of the phenomena. Nor it is solely the creation of new technological tool, as in the design and engineering disciplines. Figure 1-4 illustrates how designers and engineers work from early prototypes to finished products, using guidelines and rules of thumb or principles drawn from experimental psychology.

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Figure 1-4: Designers and engineers work with guidelines and rules of thumb to create new technology. (Mackay and Fayard 1997 p. 5)

The research process applied in this thesis is designed to obtain validated design knowledge. At the theoretical level, the research process creates and revises interaction models based upon a review of literature. At the empirical or real world level the research process is involved with observation on how people interact with technologies. Figure 1-5 illustrates the combination of the research and design activities of this iterative process. These activities include acquiring design knowledge from various learning models in behaviourist psychology to technological design guidelines for a computer-based training environment. Further activities consist of developing the prototype and technical objects and then testing them at both the technical and user levels.

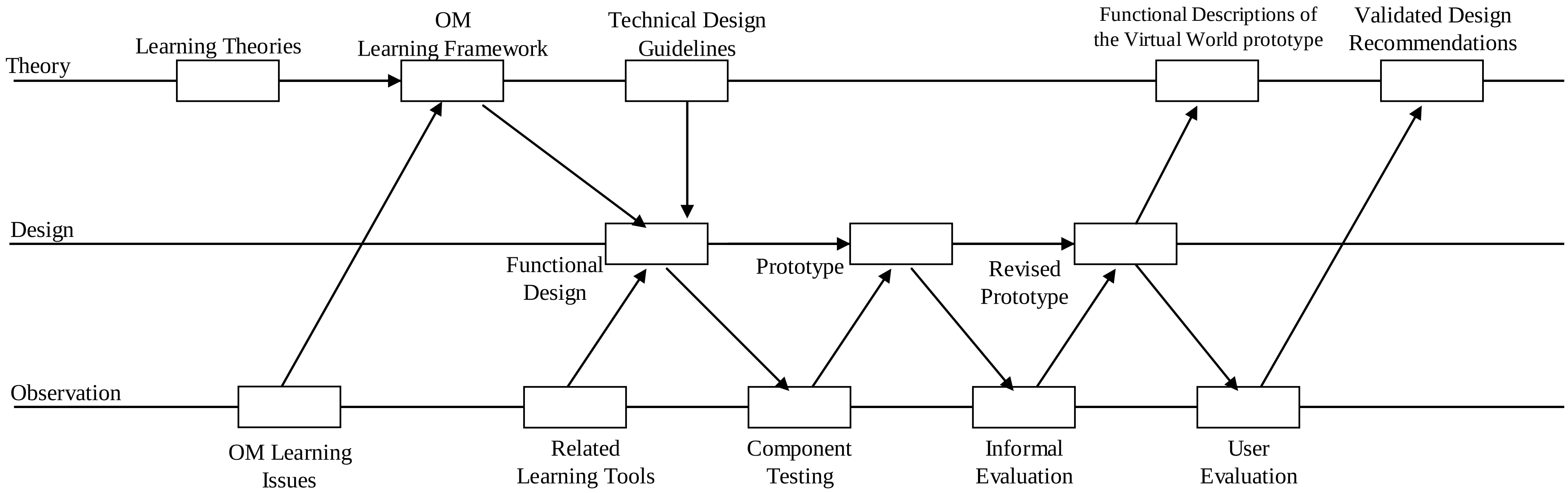

Figure 1-5: This research uses diverse approaches, involves both inductive and deductive processes.

The model begins with a comprehensive review of contemporary learning theories in the context of supportive learning environments in higher education. The outcome of this process is a classification of learning models that can enhance and foster knowledge integration for global operations management learning. Along with this evolutionary process, the issues surrounding learning strategies in operations management curriculum are comprehensively investigated through a desk-based study which subsequently helps define a theoretical framework for best practices of operations management learning. After establishing the learning framework, the process of research then focuses exclusively on the functional design of the computer-based training system which is fundamentally based on technical design guidelines and information obtained from observation of the related learning tools. A series of working prototypes is constructed according to the design requirements and the technical findings resulting from component testing and informal evaluation by domain experts. End-user evaluation of prototype systems is conducted to ensure that the system will work in practice. This also sequentially helps will substantiate the validity and reliability of the design recommendations made in this study.

1.5 Summary of Research Processes and Contributions

Just as technology is improving effectiveness in numerous sectors of society, it has the potential to reshape and add a new dimension to learning. This research is designing a novel technology that enables its user to understand the phenomena of global operations management. Although, the focus of this research is on the technological aspects of the tool, its contribution lays into several domains such as computer science, human factors, and operations management. Figure 1-6 illustrates the significant contributions throughout the research process.

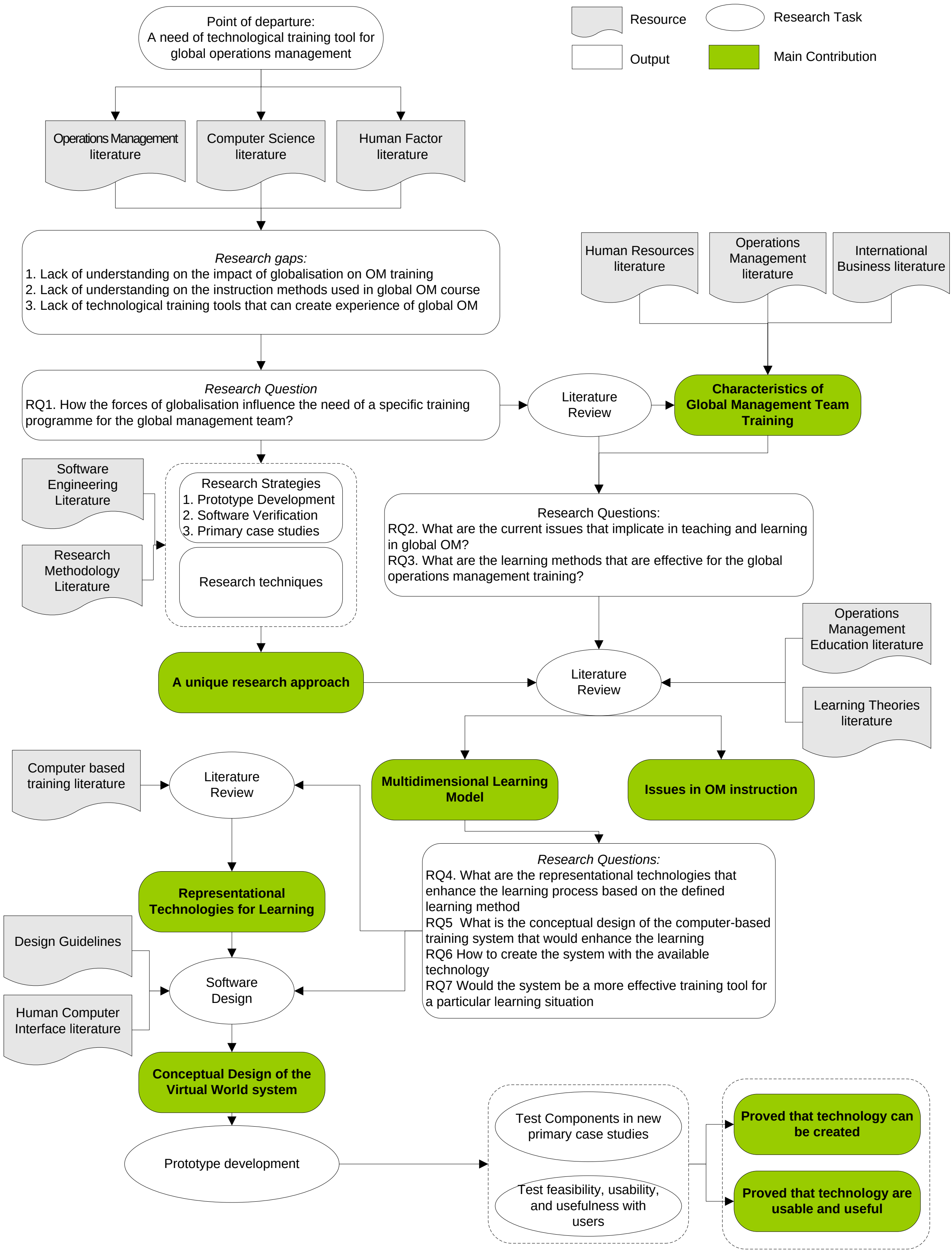

Figure 1-6: Summary of Research Processes and Contributions

The review of multi-discipline literature indicates gaps relating to the understanding about the impact of globalisation on operations management training. There is also a lack of understanding on the instruction methods and a lack of technological training tools that can be used in global operations management. These issues represent unique challenges and opportunities for this research.

Since this research involves technological design and development as its main part, it needs a unique research approach. Both the design and development from the side of technology innovation and the research activities are relevance to this study. Therefore, the approach is derived from both software engineering literature and research methodology literature. The model could also be useful as a research guideline for other computer-based training projects.

The results of initial literature review formulate the very first research question about the relationship between the globalisation phenomena and a training programme: How can the forces of globalisation influence the need of a specific training programme for the global management team? By reviewing literature in the area of human resource, international business and international operations management, the influence of globalisation on operations management becomes more sensible. These reviews also provide an indication that training is a key that helps team of managers coping with globalisation.

As a consequence, two more questions regarding on the principle of teaching in the field of operations management: What are the current issues that implicate teaching and learning in global operations management? and What are the learning methods that are effective for the global operations management training? This requires an additional review of the literature in the field of education and operations management curriculum. The result of this stage provides a theoretical model which can serve as an initial requirement for the development of the technology.

The rest of the research questions are focusing on the technological side. They are concerning with the design and implementation of related technologies, based on the predefined theoretical model. Starting with a question regarding with the representational technologies that can be applied to the learning process, the study is trying to explore the possibility of technological design as well as its broad performance. The contribution on this part is constituted by the development of the technology and its preliminary evaluation.

Although, the contribution of this research is mainly due to the technological aspects of the training tool, many parts of this research can be extended and contributed more in its major discipline. For example, the diverse research model employed in this study may be crucial for any computer-based training research. This may require a further design work to make a universal model that can be employed into the other related research projects. Also, the issues regarding with the instructions of operations management could be substantial for a learning framework. As well as the other parts that could be pushed into a deeper level in their proper disciplines.

1.6 Scope and Outline of the Thesis

The body of this research is divided into ten chapters as follows:

Chapter 1 points the direction this research is taking. It provides discussion about research design and approaches that are employed in this research. Some preliminary remarks are made concerning the outlines and directions.

Chapter 2 examines the globalisation of business and its profound impacts on operations management practice. The details of how these global forces have widely differing effects on business environments are discussed through this chapter. It argues that globalisation has brought significant changes in operations management and that these changes are an important element of competitive advantage for a business.

Chapter 3 demonstrates the influences of globalisation on global management team. A discussion of characteristics of a global manager and the key challenges in developing the global manager is included in this chapter. It argues that there is a need for the development of global management team for the success of business under globalisation era.

Chapter 4 discusses key issues of classroom instruction and curriculum development efforts in operations management education. The problems of traditional classroom learning, with emphasis on connecting curriculum design and real world practice are presented throughout the chapter. It argues that there is a need to improve instruction methods in order to construct and operate a meaningful programme for operations management.

Chapter 5 introduces key concepts of multidimensional approaches in learning, emphasising on the case of global operations management curriculum. It presents the central theoretical perspective behind each of these approaches as well as illustrates their implications in teaching and learning global operations management. It also concludes with a proposed model for designing an effective learning environment for global operations management course.

Chapter 6 highlights techniques in which educators implement learning technologies and reflect on themes of current interest on global operations management education. It describes the tools that educators are using, outlines their strengths and weaknesses, and highlights issues that need to be considered when implementing learning technologies in global operations management course. The tools covered in this chapter consist of learning-based simulations, computer-mediated communication, intelligent agent, and virtual reality.

Chapter 7 provides a conceptual design of virtual world prototype, which is intended to support instruction in global operations management. It starts with a brief introduction of virtual world technology with an example of a virtual world application in education. It then shows the design of technological models described in the previous chapter.

Chapter 8 describes how the components in virtual world prototype are developed. It provides technical details of the development. The details include the review of major technical components and the coding concepts. Software tools and system libraries that are required for the development are introduced and explained in the body of the chapter.

Chapter 9 provides functional descriptions of system's components according to the structure of the virtual world prototype. It demonstrates an interrelationship between inputs and outputs and shows the logical data flow of the system components. A demonstration of how the system should perform is also provided at the end of this chapter.

Chapter 10 evaluates the potential of the virtual world prototype as a learning environment for global operations management. The context of the evaluation is covering two broad topics, the evaluation of the performance of the intelligent agents and the preliminary investigation of the prototype.

Chapter 11 provides an overall conclusion of the studies presented in this research. It begins with a brief summary drawing from all chapters and then presents the conclusions. The research outcomes and the contributions are then described. Recommendations for further research are also provided in this chapter.

1.7 Conclusion

In keeping with the trend toward globalisation, business organisations have started to undertake extensive improvements through changes in organisational process. Along with these changes, there have been recommendations for managers in acquiring new skills and capabilities necessary to counter the new situations. Education and training technology are considered to play a key role in fostering the development of the required skills. The main aim of this research is to create a learning tool through computer-based training technologies for a global operations management course. Although software development methods have commonly been employed in this type of research, an empirical validation presented under such methods is very limited. In order to achieve the main aim, this research undertakes multidisciplinary approaches to define the architecture, develop the system, and assess the performance of the training technology.

Chapter 2: Globalisation and the Changes in Operations Management

Globalisation is revolutionising the way business is conducted. Modern management strategies and innovative practices are adjusting to rapidly-changing global conditions in order to enhance and sustain business viability. This chapter examines the globalisation of business and its profound impact on operations management practices. It opens with a discussion of how these global forces have widely differing effects on business environments. After all, it comes with a conclusion that globalisation has brought significant changes in operations management and that these changes are an important element of a business' competitive advantage.

2.1 Business in Globalisation Era

Covering a wide range of topics, including social changes, cultural diversities, economic equities, and political independences; globalisation becomes a more prominent aspect of the ongoing business transitions. Globalisation embraces a more thoroughgoing internationalisation in production and trades of goods and services (Dunning 1999). Under globalisation, financial and market integration is grounded in international settings. Social diversity and cultural interconnectedness are spectacularly situated in a larger global context (Held, McGrew et al. 1999). Political and economic changes are also occurred on a global scale (Wang 2006).

Under globalisation, events occurring in different world locations can have dramatic effects on others. This has been demonstrated by various events that captured world attention. For example, the Asian financial crisis in 1997 affected the economic performance of the world economy. The crisis started in Thailand by a move from a fixed to a floating exchange rate of the Thai baht which resulted in the loss of 40 per cent of its value. This sharp depreciation dramatically impacted many corporate sectors which were heavily burdened with debts in U.S. Dollar. As the crisis spread throughout Southeast Asia countries, the currency crisis became a financial crisis, which later became an economic and social crisis on a global scale. (Julian 2000) Another example is the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003. SARS was first recognised in Guangdong of China in November 2002, and by August 2003, it had spread to 29 countries including Australia, Brazil, Canada, South Africa, Spain, and the United States. Industries around the world especially, tourism, airline travel, and healthcare were impacted severely (Lee and McKibbin 2004). These events are accompaniments of globalisation phenomenon.

To business, globalisation brings significant benefits by helping businesses accelerate market penetration, expand trade and investment potential, and improve access to resources (Young and Nie 1996). Under the globalisation era, it is not inconceivable for a firm to design a product in one country and manufacture it in another. An example of this is the origins of the component parts of an IBM computer. “The popular IBM PS/2 Model 30-286, for example, contains a microprocessor from Malaysia, oscillators from either France or Singapore . . . diskette controller, ROM, and video graphics array from Japan; VLSI circuits and video digital-to-analog converter from Korea . . . and all this is put together in Florida.” (Walker and Fox 1996). Walker and Fox note that the driving force behind the growing transnational connection of IBM is the need to access intellectual capital. Another example of business globalisation is the way in which Nike has expanded its market overseas. When Nike decided to establish a branch factory in China, important considerations included not only the costs of labour and material but also China’s massive market potential. The prospect of capturing one percent of China’s total population of 1.2 billion people would dramatically increase the number of Nike’s sales. Being close to the local market not only enables Nike to customise its products to local needs but also allows it to be more responsive to market changes (Young and Nie 1996).

Although globalisation offers the potential to increase economic growth, but at the same time it exposes firms and economies to a great deal of uncertainty (Mrak 2000). The increase in the size and number of firms, the acceleration of technological change, and shifts in public policy have created a chaotic business environment which can be destructive to a firm’s performance (Thoumrungroje 2004). The intensification of competition can complicate planning decisions. Current technologies which allow retailers to reach buyers directly can make demand less predictable, and this leads to greater uncertainty in business (Shi and Gregory 1998). With all of these shortcomings, globalisation can be economically damaging to the weaker companies, causing declines in output, productivity, and investment growth. Effective management practices and strategies will inevitably ensure global competitiveness and profitability.

2.2 Globalisation Challenges in Operations Management

Globalisation has continued to evolve as a more sophisticated set of management principles has emerged. Once firms have decided to operate internationally, they must choose a form of global operations. (Schroeder and Flynn 2001) classify firms as global, multinational and export. *Global firms* spread their operations and production facilities through corporate groups in other territories. They view the world as a single market and assume that there are no differences in consumer tastes and preferences. Personal care products are generic in the sense that the consumer preferences for its specific attributes and usage do not change from one country to another or from one material substance to another (UnitedNations 2005). *Multinational firms* have independent substantial operating units located in several countries. They produce and market goods or services that are tailored to local needs. A large-volume refrigerator which is popular in western countries may be impractical in China where living quarters are smaller and people are in the habit of buying fresh vegetables (Young and Nie 1996). At the other end, *Import-Export firms* produce tangible goods in domestic facilities and distribute them to foreign markets. The products are usually acceptable and generic to the local market (Schroeder and Flynn 2001).

After the international firms have decided to invest their business on a global basis, they have to do more on detailed planning. In responding to international markets, firms need to adopt operational strategies from holistic global perspective. Activities related to the export of goods or services that face wide global international competition, either by entering several national or regional markets, or by meeting competition from competitors in a market often focus on the perception of comparative advantage (Parker 2005). Porter (1985) argued that all corporations can achieve the competitive advantage by implementing some form of three basic strategies: low-cost production, product differentiation, and differentiation focus. The exploitation of low cost production factors, such as labour, material, energy and capital is often the primary reason for manufacturing internationally. However, sometimes a country that has a special competitive advantage may be delusive if the environment is not conducive to investment and cannot attract foreign partners

(Kuada and Sørensen 2000). In the later period, researchers such as Mehrabi and Ulsoy (2000) believed that competitive advantage can be achieved by developing and focusing on an organisation's tangible internal processes and strengths. By this, the firms could increase their productivity by applying lean production in response to the intensifying global competition. Greater productivity was attained by eliminating the waste from the manufacturing operations. However, the massive improvement in productivity that resulted from lean implementation is very limited under globalisation. As globalisation broadens the marketplace and increases competition, customers are placing greater demands on the firms to improve quality, serviceability, and flexibility while maintaining competitive costs (Shi and Gregory 1998). The international firms have to achieve lower cost, higher quality, faster product introduction, greater flexibility, and shorter delivery time despite unpredictable customer demand and under the uncertain business environment (Lewis and Slack 2003). Gaining a competitive edge under global business environment becomes increasingly difficult.

2.3 The Characteristics of Operations Management in Globalisation Era

Nowadays, communication technologies enable businesses to operate in multiple countries with diverse forms of organisation and control. Customers, suppliers and business partners in the most remote corners of the world are able to share information and resources (Archer and Yuan 2000). Modern industry and business are giving greater weight to the social heterogeneity of a community. They are learning to overcome the general tradition of ideological disagreements and economic differences among countries (Suh and Kwon 2002). This trend is unlikely to be reversed.

Baumann (1998) states that the world is currently living under the third stage of the globalisation process. The first one was constructed in the 1970s. It was *the financial globalisation*, which resulted from the deregulation of financial markets and accelerated by the advance of computing and telecommunication technologies. The second one was *the commercial globalisation*, which was emerged during the 1980s from the reduction of barriers to international trade and supported by the development of transportation technologies. The third one, which is in the present time, is *the productive globalisation*. Production and operations systems start to be organised from globally integrated production logic. The transnational corporations act like an advance regiment of the great capital, organising their attributes and their operations strategies in a more systematic global context.

Despite the complexities of the current stage of globalisation, the traditional manufacturing and related operational strategies are clearly not enough for the firms to meet the challenges. Under this stage, the productivity and quality management systems have to be coordinated among plants worldwide (Ponte and Gibbon 2005). The material management systems are tied together across plants and warehouses on separate continents (Jagdev, Wortmann et al. 2003). The choice of location and the assembly design of the production process have to be adequate to plants across globe (Duesterberg and Preeg 2003). Cultural networks and cultural factors in the context of global operations are more vital than ever to organisational success (DiStefano and Maznevski 2000). As the firms respond to this stage of globalisation, the operations strategies must be tailored to suit the global environments.

In responding to the current stage of globalisation process, firms need to adopt more international operational strategies to ensure that they can achieve the expected benefits through global symmetries (Mckern 2003). Under globalisation, the companies that have plants around the world have to coordinate their systems since two plants may be operating under different sets of constraints. Cross-cultural communication with customers, clients, and other organisations are assumed special significance since it becomes a part of an organisation’s global business strategy. The international companies may require extensive implementation of technology to enhance productivity in materials management and sourcing. They may also need more advanced methods and mathematical models for planning and decision.

2.4 Conclusion

Although globalisation brings benefits in terms of increased growth and prosperity for businesses, it exposes a great deal of uncertainty which can be destructive. With the force of globalisation, firms need a broader and more sophisticated management infrastructure to achieve efficiencies. A novel set of management strategies and technologies along with the implementation of policies such as cultural assimilation are regarded as important elements. In order to maintain the business performance under globalisation era, it is imperative for the international firm to undergo continuous change within its operations activities to suit the changing conditions.

Chapter 3: The Need for an Effective Global Management Team

To achieve global success, a manager must understand and respond to globalisation in a constructive way. As a consequence of the change in operations management caused by business globalisation reviewed in the previous chapter, this chapter demonstrates the effects of globalisation on the global management team. It starts by describing the importance of a skilled workforce for a competitive economy in the global market. The characteristics of a global manager and the key challenges in developing the global manager in the diverse global environment are also examined. After all, it indicates that there is a need for the development of effective global management team for the success of business under globalisation era.

3.1 Global Manager as a Potential Source of Global Competitive Advantage

According to the resource-based view of a company, a competitive advantage can be achieved by developing resources and capabilities (Fahy 2001). The success of a company depends on its possession of distinctive capabilities that cannot be replicated or reconstructed by a firm's competitors. As a new market model emerges from the effects of globalisation, these resources and capabilities shift away from physical and financial resources and towards the creative exploitation of intangible properties. These intangible properties derive from knowledge assets, which have become essential ingredients of business success (Shi and Gregory 1998).

It has been recognised that knowledge is typically embodied in the skill of employees who are working in an industrial organisation (Teece 2003). This fact transforms human capital into a key competitive advantage. Economists and organisational theorists have contended that the human capital is the central determinant of a company's positioning and competitive differentiation (Acquaah and Amoako-Gyampah 2003). This is because the knowledge structure embedded in employees is often difficult to articulate and can be more difficult for competitors to imitate (Khandekar and Sharma 2005). In the aspect of manufacturing process, Hays et al. (1988) and Schroeder et al. (2002) state that when employees possess the skills and expertise necessary for the manufacturing function, they enable the firm to reach higher productivity and performance levels. Along with this point of view, Snell and Dean (1992) note that human capital increases productivity because when employees are skilled and adaptable, they enhance the potential for the implementation of integrated manufacturing practices (i.e. advanced manufacturing technologies, Just-In-Time inventory control, and Total Quality Management). This is also supported by Snell and Youndt (1995) who have identified a direct connection between the development of human capabilities in relation to multiple dimensions of operations competence. They can see human resource management as a critical link in the conversion to the modern manufacturing paradigm.

At the core of the knowledge assets of a global firm are the global managers who can make the plans more profitable (Tan, Kannan et al. 2000). As a firm evolves and grows, its global managers develop a range of skills and experience which become the knowledge that enhances the performance of the organisation (Bandyopadhyay 1994). If the product is of industry standard, more competent managers will increase the firm's competitive competencies and lead the firm to the desired level of global success (Young and Nie 1996). Improving international competitiveness by enhancing the performance of a global manager is critical to the success of a global organisation.

3.2 The Challenges Encountered by Global Manager

As the complexity of the environment in which companies operate increases, the global manager becomes involved in tremendous diversities arising from differing cultural identities and physical boundaries (DiStefano and Maznevski 2000). Factors such as different culture often complicate interpersonal interactions. Appropriate and effective communication in one culture may be inappropriate and ineffective in another (Kim 2001). Given the cultural differences on multinational team, a manager might mistakenly attribute interpersonal conflict arising from cross cultural misunderstanding between the managers of different cultural groups. Organisations that operate in unfamiliar territories are sometimes miscomprehended at the reactions of the local communities as different cultures can hold radically different expectations about the way communication or negotiation should be initiated. Differences in labour union systems, power structures, and stakeholders, all these add complexities and difficulties to the common manager tasks (Young and Nie 1996). Thus, the global manager must be aware of these differences and be prepared to deal with them.

The companies that develop their global managers successfully tend to focus on creating knowledge and developing global leadership skills to ensure that the global managers have characteristics and skills that match their technical abilities (Büchela and Raub 2002). Pucik and Saba (1998) define a global manager as "an executive who has a hands-on understanding of international business that has an ability to work across cross-cultural organisational and functional boundaries and is able to balance the simultaneous demands of short-term profitability and growth". In addition to this scheme, Black and Gregersen (1999) suggest that global managers must possess five characteristics to create global business goodwill. These characteristics are: Drive to Communicate, Broad-Based Sociability, Cultural Flexibility, Cosmopolitan Orientation, and Collaborative Negotiation Style. In a global context, the Drive to Communicate is associated with the smooth transfer of information in different languages, while Collaborative Negotiation Style ensures that agreements are respected. Broad-Based Sociability, Cultural Flexibility and Cosmopolitan Orientation are associated with the interest in or curiosity about other cultural groups. These characteristics reinforce the need for international business people to demonstrate a variety of skills and competencies when working in a global environment. It is important to note that these attributes constitute soft-skills: fitting into the social relations of the workplace, in contrast to the hard technical skills that can be taught on the job or through a training programme.

3.3 Multinational Teamwork – The More Significant Challenges to Global Manager

Along with the globalisation trend, there is a greater need to develop multinational team to work together in global organisation (Quintanilla and Ferner 2003). However, many multinational organisations consider such action as problematic which can lead to difficulties in achieving and maintaining team productivity. These difficulties are exacerbated by geographical distances and national differences (Jonsson, Novosel et al. 2001).

According to Snell et al. (1998), geographically-distributed teams are expected to meet three objectives: to achieve global efficiency through standardised designs and operations, to respond to local differences, and to promote organisational learning across international networks. These objectives often clash, especially when team members are dispersed across several countries and are functioning within multiple culture norms in different time zones (Armstrong and Cole 2002). The members of geographically-distributed team are often disproportionately burdened by the same difficult group dynamics as physically proximate ones. As a result, this can create mistrust among team members, breakdowns in communication, and more interpersonal conflict.

National differences among multinational team members can interfere with team functioning due to the resulting process losses that prevent a group from reaching its performance potential (Snell, Snow et al. 1998). These potentially derive from the differing perceptions, attributions and communication patterns that are structured by the internationalised cultures (Adler and Gundersen 2007). Indeed, a study conducted by Thomas (1999) had found that cultural diversity can generate conflict, which limits the ability of a group to maintain itself over time and to provide satisfying experiences for its members. By examining 24 multicultural teams performing five group tasks, Thomas found that culturally homogenous groups had higher performance than culturally heterogeneous groups on all five tasks. A similar study conducted by Watson et al. (1993) also indicates a relationship between cultural diversity and performance where culturally homogeneous groups scored higher on all the ratings made by the independent judges.

3.4 The Need for Training and Development of the Global Management Team

Global managers are specifically influenced by their previous knowledge or experience, in which they incorporate into their decision making process. Hambrick and Mason (1984) state that the outcomes of an international firm can be reflected by the experiences of its global management team. This idea is supported by Oviatt and McDougall (1991) which shows that the experience of a management team is likely to influence the behaviour of its firm, and these behaviours, in turn, influence the firm's subsequent performance. Reuber and Fische (1997) expand this idea by identifying two behaviours that internationally management teams may influence their firms to a greater degree of internationalisation. The first is the use of foreign strategic partnerships. They state that decision makers with more international experience are more likely to have acquired the skills needed to identify and negotiate with firms in a different culture. This is an important advantage if the firms wish to enter and remain in foreign markets. The second behaviour is the speed in which foreign sales are obtained after start up. Firms with more internationally-experienced management teams are likely to obtain more foreign sales in the start up phase. Being early is particularly important for international firms which need international enforcement mechanisms to protect their commercial value from expropriation (i.e. software and media industry). Figure 3-1 depicts the influence of management team with international experience on internationalisation.

Aston University

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Figure 3-1:The Mediated Relationships of Experienced Management Team and the Degree of Internationalisation (Reuber and Fischer 1997) p. 810

Despite the apparent benefits of globalisation for business systems and firms, the multinational firm should place an emphasis on the management team with international experience. However, some studies such as (Carpenter and Fredrickson 2001) hold a generally negative view of this situation. This is mainly because many international firms still lack managers who posses knowledge of foreign markets, management skill and international selling ability (Reuber and Fischer 1997). Moreover, new international firms have the additional disadvantage of lacking the experience and credibility to achieve a global reach (Eriksson, Johanson et al. 1997).

Global business restructuring may not be possible without the qualified personnel who have a proper combination of such productive factors. However, most companies still do not have enough globally-experienced managers (Gregersen, Morrison et al. 1998). Apart from other demographic factors such as education, not every manager has prior experience in international business. It is now necessary to train people to develop more competence on global sense in order to deal with the increasing complexities of global challenges (Sambharya 1996). The training of cross-border managers has received considerable attention as the world economy has become more international (Harris and Kumra 2000). Managers with experience and training beyond their home market are the most likely to meet the goals of international firm. As international firm adjust to the new global framework, they need leaders who are agile, astute and have an inherent ability to make decisions in a complex global matrix of social, economic, political, and cultural differentiation (Young and Nie 1996). Developing these experiences through education and training is therefore more important than ever.

3.5 Conclusion

In responding to the current stage of globalisation, firms need to develop their competitive advantage around unique strategies and specialisations rather than rely upon cheap production costs. As human capital is an essential element for acquiring such competitive advantage, there is a need for a management team who thoroughly understand global business environment. One of the ways the firms can respond to this challenge is to develop the skills on their managers through education and training. Thus, training becomes an essential step for gaining competitive advantage for business under globalisation.

Chapter 4: Issues and Challenges of Instructional Design in Operations Management Education

From the teaching and learning perspective, operations management is radically different from other areas of business education; the learner acquires skills and knowledge through hands-on experience. To ensure an effective learning, instruction should simulate the operations and environment conditions that the learner will encounter in actual practice. However, this cannot perfectly be implemented through traditional classroom instruction. This chapter discusses the key issues of classroom instruction and curriculum development efforts in operations management education. It presents the problems of traditional classroom learning, with emphasis on connecting curriculum design with the real world practice. This is followed by reviews of these relationships within the context of operations management learning. The findings of these reviews highlight the need to improve instruction methods and practices in order to construct and operate a meaningful programme for operations management.

4.1 Traditional Classroom Instructions and Real Life Practices

With regard to the dramatic changes in business environment toward globalisation in the previous chapters, it is apparent that international business requires more experts who understand global issues. As business schools provide an education and training for students who are eventually hired as managers, the focus is now within the ability of the business curriculum to make the best response to this need (Gough 1999). The academic community has the challenge of having to design ways to meet the emerging needs and trends of the modern business world.

In order to achieve this aim, Beasley and Pearson (1998) states that learners must acquire the skills to handle the management part of the business. These skills can be cognitive (acquiring knowledge and understanding phenomena), conceptual (diagnosing problems and identifying solutions), technical (numeracy and computing), and relationship (collaboration and teamwork). Apart from these characteristics, there is a consensus in the business community that the development of social skills is a major requirement (Sheppard, Dominick et al. 2004). These social interaction skills are especially important in contemporary business since most of the business is being embedded in multicultural corporative environment. Despite the desirability of all of these characteristics, many business courses, unfortunately still adhere to traditional rather than innovative classroom procedures.

In the traditional classroom, instruction takes place through lectures and tests. In this setting, the teacher stands in front of the classroom, while students usually sit at desks, listen to the teacher, and take notes from the blackboard or overhead projector (O'Banion 1997). The teacher models a phenomenon and provides the students with an observable experience, sometimes followed by an explanation or a discussion (Llewellyn 2005). Regarding the nature of traditional learning environments, the teaching and learning techniques can be divided into three categories (Killen 2007): questioning (which requires the students to retrieve or analyse information previously learned), writing (which engages the students in processing and recording information), and general information processing strategies(which encourage learners to construct, abstract, encode, match, analyse and represent knowledge). These techniques can be employed in a wide range of situations and constitute formal activities in education.

Given the simplicity and ease of execution of the traditional classroom methods, their usefulness in enhancing thinking appears limited in real world situations. In most traditional instruction settings, people are expected to learn predominantly through individual reading and assignments (Chwif and Barretto 2003). In the modern business world, however, recreation and work all take place in a setting where most activity is collaborative and learning is usually distributed among the members of a project team (Cavaleri and Fearon 2000). In addition to this limitation, traditional learning is based on pure thought activities in which the students undertake their learning without tools or extra equipments. Almost all solutions in the business world, however, provide tools such as computer programmes (Resnick 1987). Moreover, school learning tends to stress symbolic activities in which objects and ideas are translated into textual description. This contrasts sharply with ordinary activity outside of schools, in which actions are intimately connected with objects and events, and people often use them directly in their reasoning (Resnick 1987). In order to overcome there limitations, there is a need for an innovative instructional method that can relate curriculum to real world events.

4.2 Traditional Classroom Instructions and Operations Management Course

Operations management focuses on how organisations manage the processes to produce goods and services. The way a fast-food restaurant prepares food and serves its customers, the way an insurance company handles claims, the way a manufacturer manages its inventory – are all practices that are directly related to principles of operations management. Once the operations management students leave their institution, they often realise that operations have a central part to play while others, such as accounting analysis, have less to do with business than they did in the classroom (Nicholson 1997). However, universities and higher education institutions do not seem to be effective in preparing the students to handle the operations functions in industry. In a survey of 116 American students conducted in 1990s, Banyopadhyay (1994) revealed that just 24% of them believe that the knowledge gained from an operations management course is useful, 39% thought that the course could help managers understand other managers, while only 40% expect to be able to use these skills later. Although no other research has been published in recent years, the data are clear enough to provide an indication for an improvement in the operations management course.

In general, the operations management teaching still consists of lectures and individual assignments, focusing on abstract analysis techniques of science engineering while neglecting other important aspects of the work (Arias-Aranda, Haro-Domínguez et al. 2005). The present approach often assumes that lectures, discussion of prepared cases, or reading materials can prepare the students for the business world (Kanet and Barut 2003). This consistently relies on decontextualised instructional strategies where the focus of the activities is on abstract concepts and technical definitions (Hamada and Scott 2000). Banyopadhyay (1994) reveals that 97% of faculty in operations management and related fields are using traditional lecture methods. Only 33% have employed case study methods and few if any use computers or production simulation systems. The survey described an apparently unsuccessful effort to bring the real-world experiences into the classroom environment; only 9% of the faculty have supplemented real-life experience of production with video documentaries and field trips. According to the analysis, many institutions of higher education seem to be completely unaware of the situation.

The rationale for this apparent aberration might rest on the erroneous assumption that decontextualised instructional strategies could apply to learning in any area of curriculum (Grabinger and Dunlap 1995). This emphasises a basic misconception that sufficient skills and knowledge can be acquired without a real sense of the contexts in which the learning actually takes place. This concept is also promoted by the delusion that people can transfer learning from one situation to another after they have learned some basic principles and methods (Oblinger 2004).

Educators in the field of operations management (Hill 1987; Bandyopadhyay 1994; Chwif and Barretto 2003) agree that the students must be able to generate concepts, solve problems, and develop synthesis after completing the course. They also agree that the courses should introduce a new body of knowledge which could be applied and evaluated in other situations. Since operations management is radically different from many other areas of business education, it needs to adopt a different approach for teaching and learning to reach optimum effectiveness in curriculum development. Hill (1987) identifies three key features of operations management which distinguish it from other business education subjects. First, operations management is an applied field whose core is the application of knowledge, not the knowledge itself. Next, operations management is fundamentally dynamic in its nature. The teaching approaches which depend upon the fixed dimensions are unlikely to succeed. Moreover, since operations management is concerned with managing the process for production, teaching must concentrate on what is relevant rather than what can be delivered in the classroom. In terms of these striking characteristics, it is essential to ensure that the teaching could convey the substance and complexity inherent in the management task; otherwise, the teaching of operations management could be infeasible.

4.3 Educations and Realities

In spite of a remarkable need to improve the effectiveness of operations management education, the programme curricula have been severely criticised for being overly theoretical and abstract (Kanet and Barut 2003). Some specific topics such as inventory control, production planning, and operations scheduling are overloaded with theoretical and mathematical content, with little emphasis of the factors that exist in real factories such as machine downs and surges in demand (Dessouky, Bailey et al. 1998). As a consequence, many students must struggle to externalise the knowledge gained from the course because the information presented to students has no relevance or meaning for them. The students tend to treat new information as facts to be memorised and recited, not as tools to solve problems relevant to their own needs. They can at best absorb concepts and techniques in the classroom but, when they return to the workplace, they often experience an interruption in managing interactions or keeping the real life working situation static as they engaged in classroom activities (Machuca and Luque 2003).

In addition, mathematical content is often considered as the main emphasis in operations management course. This approach also gains favour because of its simplicity and directness in teaching and examination (Nicholson 1997). While organisations continue to value individual quantitative and technical abilities, the contemporary business environment demands additional skills: critical thinking for problem solving, effective intergroup communications, and teamwork (Gremler, Hoffman et al. 2000). In addition, calculation can only be used to solve isolated problems, such as determining optimal inventory control parameters using a given formula (Machuca 1998). They do not reveal the cause-to-effect direction between variables, leaving unanswered the question of internal causality. For these reasons, the calculation exercises are of greater practical utility in the area of mathematics or physics than in operations management.

Traditional teaching methods in operations management course also assume that operations system can be compartmentalised into knowledge domains such as production, scheduling, and control functions (Hill 1987). This results from the assumption that the delivery of learning is best accomplished by dividing the teaching effort by areas of specialty (Lainema and Hilmola 2005). According to this concept, teaching emphasises static presentations for each topic without providing an integrated view of whole system’s behaviour (LaForge and McNichols 1989). For example, models and procedures for inventory planning are typically studied in isolation from forecasting, master scheduling, capacity planning, and shop floor control issues. In real world, however, these functions are interconnected by means of nonlinear relationships, forming feedback loops inside the sequential process (Machuca 1998). Actions aimed at achieving certain results would have different effects, and actions taken to solve a problem in one sector would create problems in others. If subsystems are broken into their basic components, many interactions will not be taken into consideration and the perception of the system as a whole will remain undetermined. As a result, the students often encounter problems when they seek to apply their new knowledge and skills to specific situations in the workplace. More importantly, traditional teaching usually fails to produce the effective transfer to new problem solving situations that most educators would like to see (Grabinger and Dunlap 1995). Although this teaching approach is eminently easy to form composite concepts within recognisable sessions, it has seemed to offer students straightforward solutions to the management of complexity. The students commonly fail to understand the complexity of operations or form a misconception the problem solving situation.

In traditional instruction, the core curriculum is established by a reduction of reality to simple theoretical propositions, excluding many critical aspects of decision making and the understanding of business problems (Machuca 1998). Although a running operation can be a highly visible entity in which people or machines seem to be working, a running operation will neither come right nor stay right of its own accord (Coughlan and Coghlan 2002). When the student faces a specific problem in the workplace, it may not be clear to them what areas should be dealt with, so that it is often the symptoms that are tackled, while the underlying causes remain unaltered. In addition, the operations usually interact with a changing environment which demands constant adaptation, further increasing its complexity (Machuca 1998). Solutions to a short-term problem may possibly lead to medium- and long-term problems. Since all learning is to be translated back into the workplace, a large gap still remains.

Operations management is therefore a complex discipline requiring a multitude of skills. Bringing this complexity into the classroom is not an easy task. In order to reflect on their experiences and include them in any future plans or actions, feedback is required (Luque and Machuca 2003). In the context of operations management the feedback mechanism must be as the sophisticated and complex as the topic. This is unlikely to be achieved by providing comments on course work. Rather, it is more appropriate to provide performance analyses, stock reviews and cost reports. Conventionally, this may have been covered by a series of tutorial problems in which a single technique is applied to a simple problem. Such an approach, however, fails to reflect the necessary trade-offs demanded by real industrial problems (Love and Boughton 1994). In addition, oversimplification leads to an incomplete understanding. Compared with other topics such as strategy, accounting, human behaviour and marketing, operations management instruction still requires careful development (Kayes 2002).

The experience of operations management is very particular to the context. For those who worked in managing the operations in companies, they develop their experience and their own special way of working the operations. Traditional instruction methods can fail to convey such inherent properties. What is often offered is usually a support process that does not take the nature of the programme design into account. Nor do support processes relate to the specific barriers and facilitators to transferring learning from a programme to the workplace (Belling, James et al. 2004). For operations management, students need timely, constructive feedback on what they are doing well and what they can improve (Gremler, Hoffman et al. 2000). This poses a significant challenge to the educators in this discipline to go beyond the general pedagogical strategies into the area in which innovation and technology can make a positive contribution.

4.4 Conclusion

The root of criticisms for the limited effectiveness of traditional instructional methodologies is based on the view that learning processes are not reflecting real life experiences. This is especially critical in the operations management field. From a teaching and learning perspective, this area requires the learners to gain skills and knowledge through real world experience. However, the instructional methods of recent operations management programmes are still too traditional. In order to construct a meaningful curriculum programme for global operations management, there is a need to reshape the operations management curriculum with innovative instructional methods and practices.

Chapter 5: Multidimensional Learning Approaches for Global Operations Management Curriculum

Educational researchers believe that learning is most effective when learners are actively engaged in learning. They also believe that learning is more effective when it is based on social or collaborative functions. Some of them suggest that a learning process can be even more useful when the instructor and the learners are working together as full partners. In addition, many researchers have employed visual objects such as still images and motion pictures to enhance learning. All of these student-centred learning techniques have proven exceedingly useful in many fields of education. This chapter discusses key concepts of these multidimensional approaches in learning, with special attention to the case of global operations management curriculum. It presents the central theoretical perspective behind each of these techniques as well as illustrates their implications for teaching and learning global operations management. After drawing the multidimensional learning techniques into a unified framework, it then concludes with a proposed design for an effective learning environment for a global operations management course.

5.1 Student-Centred Learning and Global Operations Management

The effect of globalisation on economic revolution is more than a proliferation of factories and machines; it is a transformation of business operations processes and systems (Held, McGrew et al. 1999). As a reaction to the growing competitive pressures of the world market, many corporations have sought to change the basic infrastructure of their operations to achieve lower cost, higher quality, faster product introduction, greater flexibility, and shorter delivery time (Shi and Gregory 1998). They have introduced innovative philosophies such as Just-In-Time (JIT) production and focussed manufacturing in their operations process to satisfy the diverse needs of customers (Bandyopadhyay 1994). Despite these efforts, however, regaining a competitive position in world markets still seems to be out of reach.

As detailed in the previous chapter, one reason for such limitations may be that the universities are not preparing their learners for the challenges in the global market place. Education researchers (Hill 1987; Bandyopadhyay 1994; Machuca 1998; Shi and Gregory 1998; Chwif and Barretto 2003; Luque and Machuca 2003; Machuca and Luque 2003; Kanet and Barut 2003 ; Arias-Aranda, Haro-Domínguez et al. 2005; Lainema and Hilmola 2005) have concluded that a large gap exists between what is taught in operations management courses and what practicing managers should know. Bandyopadhyay (1994) suggests that this occurs because academicians and practitioners disagree on what takes place in the operations management context. According to this situation, it is essential for operations management education to orient itself to today's business.

In order to ensure that education is in line with industry needs, it is necessary to reshape operations management curriculum. The curriculum that is intended to serve industry must balance technical and professional skills to equip learners with a detailed understanding of day-to-day operations. In order to accomplish this, the focus of learning should be student-centred, where the learning is on the needs of the learners, not on the needs of teachers and administrators (Jonassen 2000).

Student-centred learning environments have an advantage over the traditional teacher-centred in that they provide complementary activities that enable learners to identify and follow their own learning interests and needs (Cech and Bures 2004). Under this paradigm, the focus is on working process, requiring the learners to understand concepts and principles in solving problem primarily from experience. For example, in teaching a problem solving process such as Aggregate Planning, where the objective is to balance inventory, production, and employees with demand and sales, rather than offering abstract definitions, the learners are encouraged to immerse themselves in the planning process. The learners should be motivated to understand how much it costs to manage employees and handle inventory, and at the same time they shall produce and provide the right amount of goods and services to meet but not greatly exceed sales demand in order to maximise profits. The learners are given freedom to explore problems according to their interest, with the support of the facilitator. As a consequence, the learners not only achieve better academic results but also experience an increase in flexibility, self confidence and social skills, which are the employee attributes that the industry expects (Rogers 1983).

With the increase of global business activity and the growth of multinational enterprise, an enormous amount of effort has been invested in developing relevant skills for international business students. Bigelow (1994) defines these skills as related to the managerial skills that they will need in an international setting: cultural and organisational understanding, adaptability, establishing relations, system and multiple perspective thinking, attitudes and perceptions, sensitivity, language, culturally influenced decision making, and diplomacy and cross-cultural skill. Distefano and Maznevski (2000) states that global executives must possess the ability to develop and use global business skills, an ability to manage change and transition, an ability to manage cultural diversity, an ability to design and function in flexible organisation structures, an ability to work with others and in teams, an ability to communicate, and an ability to learn and transfer knowledge in an organisation. In addition, Adler and Bartholomew (1998) suggest that to apply these skills, the environment requires global perspective, local responsiveness, synergistic learning, transition and adaptation, cross-cultural interaction, collaboration, and foreign experience.

While the development of international business skills is considered best under international working environment, university is still important in laying out the basics. Student-centred approach allows an interaction among students from different cultures while engaging in multicultural group projects (Devita 2000). Multinational team of students can be formed and the learners can fine-tune their interpersonal, communication and intellectual skills through this activity. This has the obvious potential advantage of allowing the team members to develop a particular skill or solve a significant business problem which would later be encountered in a practical situation.

5.2 Experiential Learning as a Learning Strategy

Experiential learning is a process whereby people learn through thinking and reflecting on a situation (Lainema and Hilmola 2005). This type of learning takes place when people cognitively, affectively, and behaviourally process the knowledge by actively engaging in a learning process (Saunders 1997). As a consequence, people can construct meaning from the material studied, process it through existing mental structures, and retain it in long-term memory where it remains available for further processing and possible reconstruction (Alavi 1994). In a broad sense, experiential learning offers a framework for strengthening the critical linkages among education, work and personal development (Haapasalo and Hyvonen 2001).

The experientialists assert that people learn through a continual process of building, interpreting, and modifying their own representations based on their experience (Grabinger and Dunlap 1995). This premise of this concept is that learning occurs when a learner is actively involved with a concrete experience (Saunders 1997). This type of learning may not occur in a traditional classroom setting where learners simply listen to lectures, memorise information, and take objective examinations (Gremler, Hoffman et al. 2000). For experiential learning, the emphasis shifts gradually from rote learning and exercises to active problem solving and reflective thinking. The success depends on how well the learners explored the context of their experience (Lainema and Hilmola 2005). This process is active rather than passive, requiring the learners to be self-motivated and responsible for their own learning and growth.

While experiential knowledge is arguably best developed in the workplace, learners can actively experience the class material through their own practice (O'Banion 1997). In fact, experiential learning can occur in any situation where actions provide a commitment to valid information, free and informed choice to open monitoring of the interaction (Haapasalo and Hyvonen 2001). For classroom-based learning, experiential learning can be integrated in many forms. Case studies are among the most effective assignments for courses using experiential learning (Gremler, Hoffman et al. 2000). The case methods have acquired the reputation of being more practical than learning theory (Reynolds 1978). They socialise learners to think as professionals and link theory learned in the classroom to its application in the workplace (Saunders 1997). Cases can be used to construct the complex realities of specific business cultures and contexts, thus giving the learners a sense of "competing values, intentions, and rhetorical possibilities" and an opportunity to practice adaptation skills (Saunders 1997).

There are several key theoretical models that are widely accepted in experiential learning. These models are used frequently to explain the nature of the theory as well as to design a practical learning environment. For the interest of this research, three well-known theoretical concepts and models that can contribute to the design of the experiential learning environment are reviewed. These include ten principles of expeditionary learning, Carl Rogers's principles of experiential learning and David Kolb's four stage cycle of learning.

5.2.1 Expeditionary Learning

Expeditionary Learning is a curriculum designed to promote critical thinking, skills and habits, academic achievement, and personal development (Stringfield, Ross et al. 1996). The fundamental idea behind Expeditionary Learning is that students learn more by experiencing the world around them. At the core of the Expeditionary Learning philosophy are ten design principles that provide a framework for teaching and learning strategies:

The primacy of self-discovery: learning happens best when there is emotion, challenge and the requisite support. People discover their abilities, values, passions, and responsibilities in situations that offer adventure and the unexpected. A primary job of educators is to help students overcome their fears and discover they have more in them than they think.

The having of wonderful ideas: this principle places emphasis on fostering curiosity about the world by creating learning situations that provide something important to think about, time to experiment, and time to make sense of what is observed. This principle calls upon learning to take place in a community where learners' ideas are respected.

The responsibility for learning: while learning occurs in the context of a social activity, this principle draws attention to the goal of having learners to become responsible for directing their own personal and collective learning.

Empathy and caring: learning is fostered best in communities where there is trust, sustained caring and mutual respect among all members. Thus, there should be consideration given to the size of the learning community and the deliberate connection between the members of the learning community.

Success and failure: to nurture and develop students' self-efficacy and capacity to take risks, it is necessary for them to regularly experience success. Likewise, it is also important for students to learn from their failures, to persevere when things are hard, and to learn to turn disabilities into opportunities.

Collaboration and competition: this principle embraces the development of relationships between learners as well as the development of the group as a whole. Students are encouraged to compete not against each other, but with their own personal best and with rigorous standards of excellence.

Diversity and inclusion: to ensure the understanding of multiple perspectives, resources and solutions, schools and learning groups should be heterogeneous. Learning should incorporate multiple perspectives from a variety of sources.

The natural world: this design principle helps focus students on their relationship with the natural world and the student's responsibility to become stewards of the earth.

Solitude and reflection: students and teachers need time alone to reflect their own thoughts, make their own connections, and create their own ideas. In addition, opportunities to share reflections are also built into the curriculum.

Service and compassion: learning places emphasis on strengthening students and teachers through acts of consequential service to others. It is important to prepare learners with the attitudes and skills to learn from and be of service to others.

5.2.2 Carl Rogers's Principles of Experiential Learning

Carl Rogers (1969) distinguished learning into two types: cognitive (meaningless) and experiential (significant). Cognitive learning is acquiring academic knowledge, such as learning vocabulary or multiplication tables. Experiential learning is acquiring applicable knowledge through learning by doing such as learning how to repair a car. He believes that the latter type of learning is the most important element for personal change and growth. According to Rogers, experiential learning is facilitated when:

Personal involvement: the learner participates completely in the learning process and has control over its nature and direction.

Self-initiated: learning is mainly concerned with practical, social, personal or research problems of interest to the learner.

Self-evaluation: the learner fosters critical reflection on their own contributions and learning progress.

Pervasive effects: the learning event is based on real-life experiences and concerns.

Rogers determines that everyone has the potential to learn through these principles, and this assertion gives rise to instruction through active problem solving.

5.2.3 David Kolb's Experiential Learning Cycle

The development training process is frequently represented as a cycle which encourages continuity from one mode to another. Kolb (1983) who is noted for his work for experiential education, outlines a four stages-cycle that enables experiential learning to take place: concrete experience, reflective observation, abstract conceptualisation, and active experimenting.

Concrete experience: This stage focuses on full involvement in a learning experience. It requires concrete activities such as interaction with objects and materials rather than learning from textbooks. For example, learners studying electricity may work with batteries, bulbs, and wires to construct different type of electrical circuits.

Reflective observation: This is the stage when learners reflect, observe and interpret new data. This stage requires activities such as brainstorming, discussion, and answering thought and rhetorical questions.

Abstract conceptualisation: This stage involves with using logic and ideas to create generalisation and theories to solve a problem. Learners are involved with this stage in lectures, papers, projects and analogies.

Active experimentation: This is the stage where by learners solve problems and make decision. The learners take new information and discuss it with others or testing it as an experiment.

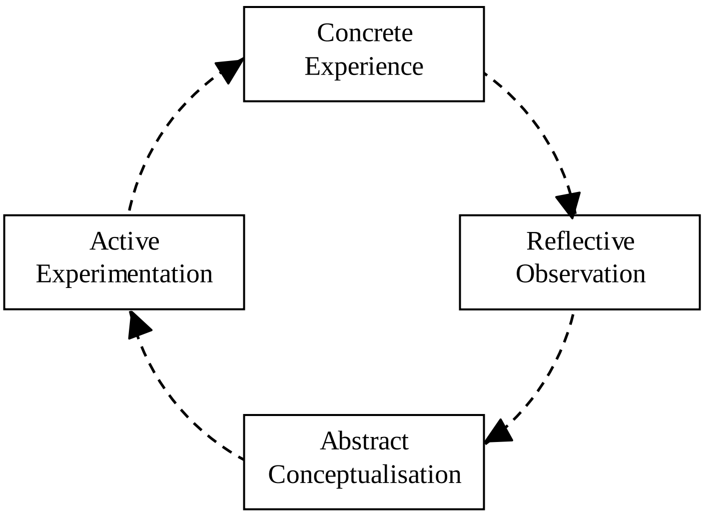


Figure 5-1: Kolb's Experiential Learning Cycle

5.2.4 Implications of Experiential Learning on a Learning Environment

For this research project, the models provide key guidelines to the kind of technology that will be involved in the system design. Although the learning models presented above had been developed from different philosophical perspectives, they share similar key principles that can be employed to define the learning environment:

Experiential learning requires the opportunity to practice skill

The fundamental assumption behind Expeditionary Learning is that learners learn best through experience. Kolb and Rogers also agree that hand-on experience is crucial for learning. This makes experiential learning unique in comparison with mere lecture as it requires practice on the part of the learning. To support experiential learning, the learning environment has to offer a place or situations where learners can practice and upgrade their skills.

Experiential learning needs a supportive and flexible environment

An effective experiential learning environment needs to be flexible and supportive. A flexible environment provides educational opportunities that are focused on the varying learner needs (Gearhart 2008). A supportive learning environment provides opportunity for personal development through a positive setting (Young 2007). These environmental properties are important for the self-discovery in Expeditionary Learning. It is also necessary for self-initiation under Roger's principle and is generally required in Kolb's model (Johns 1998). Therefore, the learning environment has to include these properties as a part of its characteristics to improve learner performance.

Experiential learning requires social interaction between the learners

Even when there is no direct provocation, the absence of any social interaction makes learning extremely difficult. Social interaction in learning contributes to motivation to learn and the development of interpersonal skills (Ministry of Education 1993). Expeditionary Learning suggests that social interaction helps articulating the value of friendship, trust and group actions (empathy and caring). Rogers and Kolb consider that social interaction exposes the learner to multiple perspectives on the subject learned (self-initiated and active experimentation). To promote the social interaction in learning, the learning environment must support the tasks that require team effort and collaboration. Also, it has to facilitate the cooperation between the learners involved in the assigned task.

Experiential learning requires feedback on the actions

Feedback is intrinsically linked to the learning process. When delivered in a constructive way, it can improve learning outcomes and enable learners to develop a deep approach to their learning (Chamber 2005). In Expeditionary Learning (solitude and reflection), feedback enables the learners to reflect and enhance their practice. In Rogers's principle, feedback allows the learners to evaluate their own achievement. In Kolb's model, feedback is used to reflect the consequences of actions. An effective learning environment needs to have a mechanism to provide feedback in a timely manner to help learners reflect on the skills they applied during the learning.

Experiential learning requires information to be presented in various forms

Mayer and Anderson (1997) found that students learned more from instruction that involves more than one type of media or representation (i.e. use of graphics in addition to textual data). While this is not a specific requirement for experiential learning, multiple representations on the content make the analysis more efficient (Eliam 2007). This is especially useful in the Kolb's active experimentation stage (Moon 2001). In this way, the learner can observe and assess the information more accurately. Therefore, it would be more advantageous to the learner if the learning environment is able to express the content in different forms.

Experiential learning needs to support the learners in planning for further experience

In a normal circumstance, learning does not take place through one or a few experiences. In addition, relying on a limited experience may lead to the formation of misconceptions (Karpov 2003). On the contrary, skills can be reinforced and enhanced if the learners have opportunities to repeat the experience until the desire knowledge is constructed (Beard and Wilson 2007). In Kolb's model, when the learning cycle is completed, the learners plan to continue a new cycle to gain further experience. Usually, the second cycle will represent learning at a higher level. Although this is not clearly mentioned in Rogers' principle and in Expeditionary Learning, it is of a rather ritual nature of experiential learning. An effective learning environment should be able to provide resources such as information or report that the learners can use to plan further learning activities.

5.2.5 Experiential Learning and Operations Management Curriculum

The interest in experiential learning techniques has been steadily growing, largely because of the need to integrate the development of real world skills and abilities to enrich the curriculum content. Yet this is imperative for operations management education whose focus is now on delivering the problems facing operations managers in the actual workplace and how managers acquire and transform their experiences (Luque and Machuca 2003). Experiential learning can be used in operations management and in related courses to develop a system view, develop problem solving skills, and to practice the integration and synthesis of concepts. In an experiential learning environment, students learn what tasks are needed to process an order and to produce and deliver the product to the customer. They learn, for example, how investments in infrastructure of implementation of different systems, procedures, and management approaches can affect lead times, on-time delivery and costs (Mehring 2000). By integrating experiential approach into operations management course, it could help the learner to develop more holistic views which improve the quality of managerial work (Kayes 2002). In addition, this approach is considered superior to the traditional method (Ruohomäki 2002).

5.3 Collaborative Learning as a Learning Strategy

Some learning theories that emphasise social genesis suggest that the learning accessed through experiential learning alone may not be sufficient to develop the requirements for expertise at work (Alavi 1994), since this kind of knowledge is often opaque, hidden or of a kind not readily accessible in the workplace (Vygotsky 1978). These theories suggest that learning can only be accomplished through the social process which occurs through interpersonal interactions in a cooperative context (Alavi 1994). This positions learning as the acquisition of developmental, socially collaborative, and culturally mediated knowledge (Hamada and Scott 2000). Based on this perspective, learning must be part of a social process, not a solitary activity.

In contrast with individual or traditional instructional methods, collaborative instructions involve cooperative procedures which promote student learning and achievement. This kind of learning is a social activity, embedded in ongoing domains of practice, and this activity, in turn, gives rise to new theoretical problems that drive learning to a new level of mental, affective, and behavioural responses and endeavours (Hamada and Scott 2000). This activity usually leads to emergent knowledge as the result of interaction of the understandings of those who contribute to its formation. It enhances learning by allowing learners to exercise, verify, and improve their mental models through discussions and information sharing during the problem-solving process (Alavi 1994). The learners in the collaborative learning environment are less likely to have irrelevant or distracting thoughts and are more likely to synthesise and integrate ideas and concepts (Alavi 1994).

Academics who implement this learning strategy believe that learners can develop better critical thinking skills when they share their ideas and listen to those of others (Gremler, Hoffman et al. 2000). Under this mode of learning, the instructors can assign more challenging and complex tasks. This is because members of work teams are usually exposed a variety of problem-solving strategies. This type of learning allows individuals to communicate technical information individually and collectively rather than confining it to their own abilities. The learners tend to generate high levels of information and alternative approaches to complex problems which lead to solutions, better comprehension and high-level thinking skills (Yazici 2004).

Collaborative learning also exposes learners to a work environment that resembles the one that they will encounter as professionals; learners' interpersonal communication and technical skills improve as they learn to help other members learn (Yazici 2004). Team-oriented learning environments allow learners to learn from colleagues with expertise and to help one another by working together, sharing information, and watching out for one another. These activities encouraged team members to participate in the learning process, take charge, and manage their work (Yazici 2004). These activities are an important mechanism for dealing with today's complex and rapidly-changing business environment. In addition, because work teams place greater responsibility on learners to manage their own learning, collaborative learning can develop self-directed learning skills. It increases learners' self-efficacy, learning goal orientation, and the intrinsic valuing of the learning task. Team members can monitor individual thinking, opinions, and beliefs and provide feedback for clarification and change (Alavi 1994). As a result, the learners are more likely to become intrinsically motivated and more engaged with the course material; this is crucial for effective learning.

Learners who follow in-class collaborative learning procedures and actively interact with each other are more satisfied with their learning experience and evaluate their courses more favourably than learners who are exposed to the traditional lecture method (Warschauer 1997). In their review of literature on college-level learning, Kulik and Kulik (1979) reach a similar conclusion. They report that learners who have exposure to collaborative methods had a more favourable evaluation of their classroom experience.

There are several theoretical models provide framework for understanding the collaborative learning. These models provide insight and understanding into the development of collaborative learning courses. For the interest of this research, three theoretical concepts and models are reviewed. These include Lev Vygotsky's zone of proximal development, Barbara Smith and Jean MacGregor's assumptions of learning, and Roger Johnson and David Johnson's elements of collaborative learning.

5.3.1 Lev Vygotsky's Zone of Proximal Development

The term 'zone of proximal development' is probably one of the most widely recognized and well-known ideas associated with Vygotsky's scientific production. The term now appears in most developmental and educational psychology researches. Within such area, the concept is used widely in studies about teaching and learning in many academic disciplines and professional areas, including nursing, psychoanalysis, psychotherapy, and occupational therapy (Kozulin, Gindis et al. 2003).

Zone of proximal development is the area where the learner cannot solve a problem alone, but can be successful under guidance or in collaboration with a more advanced peer. The zone of proximal development has three components, according to Dixon-Krauss (1996):

Social Interaction: teachers or more competent peer support learning through talk.

Students' Needs: teachers or peer provide support based on feedback from the learner as they are engaged in the learning task.

Variable Support: teachers or peer vary the amount of support they provide according to learner's demands.

5.3.2 Barbara Smith and Jean MacGregor's Assumptions of Learning

Collaborative learning is an educational approach to teaching and learning that involves groups of students working together to complete specific learning activities. There are several forms of collaborative learning that are practiced by teachers of different disciplinary backgrounds. According to (Smith and MacGregor 1992), this type of learning is commonly based on a set of five assumptions:

Learning is an active, constructive process: To learn new information, ideas, or skills, learners have to work actively with them in purposeful ways. They have to assimilate the information and relate this new knowledge to a framework of prior knowledge.

Learning depends on rich contexts: Instead of being observers on problems and solutions, learners have to become immediate practitioners. They have to actively engage in activities with peers in order to process and synthesize information.

Learners are diverse: Learners bring multiple perspectives to the classroom - diverse backgrounds, learning styles, experiences, and aspirations. They are beneficial when exposed to these diverse viewpoints.

Learning is inherently social: In collaborative learning, there is the social stimulation of mutual engagement in a common endeavour. This mutual exploration, meaning-making, and feedback often lead to better understanding on the part of learners, and to the creation of new understanding as well.

Learning has affective and subjective dimensions: In collaborative learning situations, students generally experience a shift in their intellectual development as they learn to articulate their own point of view and listen to the views of others.

5.3.3 Roger Johnson and David Johnson's Elements of Collaborative Learning

Collaborative or cooperative learning use small groups or teams in which peer interaction plays a key role in learning (Yazici 2004). It involves social or interpersonal processes by which a small group of learners work together to complete an academic problem-solving task designed to promote learning. This combines several elements of teaching and learning (Johnson, Johnson et al. 1998):

Positive interdependence: exists when the learners believe that they cannot succeed unless the other members of the group also succeed. In a problem-solving session, positive interdependence is structured by group members agreeing on the solution to each problem and fulfilling assigned responsibilities.

Face to face promotive interaction: exists when the learners explain to each other how to solve problems, discuss the concepts and strategies being learned, teach their knowledge to classmates, and explain the connections between present and past learning.

Individual accountability: exists when the learners help, assist, encourage, and support each other's learning. Individual accountability requires the teacher to ensure that the performance of each student is assessed and the results given back to the group so as to the individual. The group needs to know who needs more assistance in completing the assignment, and group members need to know they cannot completely depend on the effort of others.

Collaborative skills: these skills are necessary for the effectiveness of the group. The learners must have and use the leadership, decision-making, trust-building, communication, and conflict management skills. These skills have to be taught just as purposefully and precisely as academic skills are.

Group processing: involves a group discussion of how well members are achieving their goals and maintaining effective working relationships. Groups need to describe which member actions are and are not helpful and decide what behaviours should be continued or changed. Such processing enables learning groups to focus on group maintenance, facilitates the learning of collaborative skills, ensures that members receive feedback on their participation, and reminds learners to practice collaborative skills.

5.3.4 Implications of Collaborative Learning on a Learning Environment

To this research project, the collaborative learning models described above share common properties that can be used to define the properties of a learning environment as follows:

Collaborative learning requires active participation of the learners

In traditional learning, the learners are seldom required to respond with action when they learn something. Programmed learning takes the form of questions requiring the student to fill in a blank, unscramble a word or choose one of several possible answers. Each step along the way they must do something that helps embed what they have learned. However, if the learners are actively involved in learning activities, they are able to assert their skills, knowledge and right to choice and control (Marais and Bosman 2000). This strategy allows them to transfer the learning to situations they may encounter in their everyday lives and to the decisions and choices that they make. Active participation in learning is therefore significant in helping the learners to acquire knowledge through the learning process. All collaborative learning principles presented above requires active participation from the learner in completing the learning task. The learning environment has to facilitate the knowledge construction process by allowing the learner to work collaboratively on the learning activities.

Collaborative learning requires the learners to share a common goal

Collaborative learning is a learning method that uses social interaction as a means of knowledge building. Learners need to work in a group of two or more to achieve a common goal, while respecting each individual's contribution to the whole. This can only succeed when group members perceive that they are linked with each other in a way that one cannot succeed unless everyone succeeds (Roberts 2004). Although this characteristic is not obviously mentioned by Dixon-Krauss in his study of Vygotsky's concept, it is commonly found in the other collaborative models. Since the learners are tied together by joint participation in such learning, the learning environment must allow groups of learners to work and perform the learning task together.

Collaborative learning requires the interaction and communication between the learners

In collaborative learning, the learners need to work together to promote each other's success by sharing resources and helping each others. This suggests a critical element which relates to collaboration between the learners, the social interaction. In other words, it relates to process that have to do with getting to know each other, committing to social relationship, developing trust and belonging and building a sense of community (Bromme and Spada 2005).

All model discussed above point out that social interaction requires some forms of communication to stimulus the learning. This may include questions about the interplay among the learning tasks, the learner cues that inform teachers, and the type of supportive instruction needed to facilitate learning. An effective learning environment needs to encourage social interaction by providing efficient means of communication between the involved parties.

Collaborative learning needs contribution from each learner

In collaborative learning, individual group members create, acquire, and share unique knowledge and information. Individual members may influence groups to which they belong to learn. While groups learn for themselves as they work, individuals are learning continuously (Valerie and London 2008). Johnson and Johnson stress the important of individual accountability into one of the collaborative learning elements. This can be promoted by providing opportunities for the performance of individuals to be observed and evaluated by other (Johnson, Johnson et al. 1998). The learning environment must provide a tool for individual to explain their thinking or to demonstrate a skill that the team is assigned to practice.

5.3.5 Collaborative Learning and Operations Management Curriculum

Collaboration helps learners to relate operations management to other business functions. As part of a study conducted by Yazici (Yazici 2004), collaboration appears to facilitate the understanding of techniques and concepts in operations management. The results from this study show that students' understanding of operations management is influenced by all the collaborative learning activities. They gain more knowledge of operations management and have a good understanding of the context. They also believe that their ability to analyse, formulate, and solve problems and their strategic-thinking skills are improved by the use of collaborative learning. This indicates that collaborative learning enhances recognition, analysis, and formulation of operations management problems and related courses (Alavi 1994).

Public and private organisations are relying on teams to support institutional missions and improve organisational performance (Bolton 1999). As global teams emerge to adapt quickly to competitive changes, companies depend more on collaborative work environments (Harvey and Novicevic et al. 2001). This underlines a requirement for employees to communicate and work with each other more effectively than ever before. For global operations management, transferring the understanding of the system can be challenging. The collaborative learning environment provides the learners to recognise operations management problems and think strategically when determining which strategies should be implemented. Without a collaborative learning method, the learners may not have developed the critical-thinking and necessary skills. Collaborative class practices are therefore important in the learning of global operations management. They can enhance the learners' ability to apply knowledge to any management situation.

5.4 Coaching and Mentoring as a Learning Strategy

People adopt the behaviours and belief systems of some certain groups of people or cultures throughout their lives. That is, as one enters a new job, a new social group, or a new neighbourhood, one gradually begins to exhibit the appropriate behaviour, jargon, and mannerisms of that culture and to act in accordance with the cultural norms. Although collaborative learning situations could serve this purpose, it does not guarantee higher learning outcomes. This is because most learners have difficulty regulating their own learning behaviour (Kester and Paas 2005). Instead of being guided by their own independent efforts, learners need additional support to become reflective, critical, self-motivated, self-directed and self-disciplined (Zimmerman 2002). Coaching in the classroom can be a useful strategy in this case, both to monitor and assist in learners' development (Billett 2000).

Research based on educational models of experiential learning also suggests that team, peer-based experiential learning constitute an effective learning strategy only when instructors carefully guide the process (Schroeder 1993). This notion leads to the same conclusion that the learners need to be partnered with the instructor as they begin to learn a new task (Griffin 1995). This is because experiential knowledge is difficult or is impossible without direct guidance. Similarly, the development of the procedural capacity to complete workplace tasks can also be aided by the direct guidance of more experienced co-workers (Billett 2000). Orr (1996) supports this contention by demonstrating a case of a photocopier service company where workplace coaching is outlined. The skills and know-how are amassed by experienced photocopy repair technicians in order to proceed with their work. These are then used to train novice technicians. As heuristics are developed through work practice and overtime, the novice technicians require a more experienced co-worker to model their use, explain their purpose and assist novices with their use. In the eyes of experientialist, coaching is a useful strategy that can encourage the learners into knowledge-constructing and knowledge-reinforcing activities.

Coaching strategy offers several benefits for education. The coach helps to avoid missed opportunities for learning by monitoring learners' participation and recognising differences between learners' individual solutions (Connelley, Houghton et al. 2003). Since the learners often miss learning opportunities and get stuck at a certain level of proficiency, a coach can show them other possibilities, provide unobtrusive assistance and create potential learning experiences that will improve individual learner's development (Baker and Bielaczyc 1995). By coaching, learners receive instant feedback about their performance; this reinforces successes and helps them to correct any mistakes quickly (Phillips 1996). In universities with greater student diversity with respect to ethnicity, age, and family educational background, students may place greater value with more personal attention and feedback from the instructor, so coaching can be an extremely useful strategy (Schroeder 1993). Bolton (Bolton 1999) suggests that coaches enhance learner satisfaction and help students learn more from each other. Eighty-six percent of the students in this study claimed that the coach made a lot or a great deal of difference to their experience. A full 100% of students with a coach stated that they were able to transfer learning to another situation.

Coaching in the classroom allows the teacher to activate and accelerate student-centred learning (Kester and Paas 2005). This approach is consistent with substantial corporate training and development efforts that are designed to improve the productivity of self-directed teams. The provision of expert advice when it is required or sought is an essential element of the collaborative learning model. It is also part of the theoretical framework provided by Vygotsky (1978), who advocated help from a teacher or capable peer as a learner attempts to construct his or her own concepts in a social context. Instructors who consult to corporate teams can increase their classroom credibility and add real value to the learners by presenting the parallels between corporate teams, including difficulties influencing peers over whom they have no authority, limited time and resources for team development, conflicting priorities of team members, preferences to deal with task rather than personnel issues, and reluctance to give meaningful feedback to team members (Kreijins, Kirschner et al. 2002). When relevant opportunities for learning are found, the coach can guide the learners to practice collaborative skills, providing advance such as encouraging students to participate and to discuss their differences (Suthers and Santos 2001). This suggests a strong multiplier effect for such a simple implementation.

Most definitions of coaching refer to empowering people to make their own decisions, unleash their potential, enable learning, and improve performance (Grant and Cavanagh 2004). Successful coaching represents a shift from a command-and-control style based on motivation by situation insecurity, to a style that is based on partnership for achieving results and commitment through collaboration to accomplish new possibilities.

There are a number of model of this type of learning known as coaching model. They are generally started with a definable goal and proceed to methods of achieving that goal. Such models are likely to be used for basic coaching. The next section briefly review the John Whitmore's GROW and Page and Wosket's CLEAR model for this purpose. In addition to these two models, the coaching strategy that was defined by Ellinger et al. is also included as their approach is more applicable to management coaching (Passmore and Anagnos 2009).

5.4.1 John Whitmore's GROW Model

The GROW model developed by sir John Whitmore starts from his definition of coaching as 'unlocking a person's potential to maximize their performance'. The main concept of the model is to help a person to learn rather than teaching them. It enables the coach to examine the current situation for learner, to discus possible options and, finally, establish what action will be taken. The popularity and appeal of the model is that it provides a systematic, memorable framework that describes a rather complex process like executive coaching (Dembkowski, Eldridge et al. 2006). At the same time it is practical. The GROW model is consisted of:

G – establish the Goal: The coach and the learner develop agreement on specific outcomes and objectives – the goal for the coaching programme.

R – examine the Reality: The coach works with the learner to explore the reality of their current situation. In this stage the coach uses a range of techniques including inviting self-assessment, asking specific challenging questions and offering feedback.

O – consider all Options: The coach works with the learner to generate and choose between options for action that will move the learner closer to his goal.

W – confirm the Will to act: The coach works with the client to define an action plan and identifies potential obstacles and how to overcome them.

The first three stages are all designed to increase the learner's awareness of himself, his situation and possibilities for action. The final stage is all about evoking the learner's responsibility to take action.

5.4.2 Page and Wosket's CLEAR model

Page and Wosket have a useful five-stage model that shows supervision proceeding (Dembkowski, Eldridge et al. 2006). The model consists of:

Contracting: Coaching session start with establishing the learners' desired outcomes, understanding what needs to be covered and how the coach and learner process can be most valuable.

Listening: The coach helps the learner develop understanding of the situation in which he or she wants to affect a difference. In addition, the coach can help the learner hear themselves more fully, through reframing and making new connections in what has been shared.

Exploring: Through questioning, reflection and generation of new insight and awareness coach work with the learner to create different options for handling the relationship or issue.

Action: Having explored the various dynamics within the situation and developed various options for handling it, the learner chooses a way forward and agrees the first steps.

Review: Reviewing the actions that have been agreed. The coach also encourages feedback from the learner on what was helpful about the coaching process, what was difficult and what they would like to be different in future sessions.

The CLEAR model starts by discussing the 'contract'. This allows the ground rules to be set, so the learner has the opportunity to discuss how he or she would like to learn. There is then a big emphasis on listening, a key component of coaching. When the learner is being listening, he feel valued and feel more confident in committing to change. The review stage is also important, as it not only reviews the outcome of the coaching session but also reviews the effectiveness of the process. It involves a discussion of how useful the session was, and how to make it event more useful next time.

5.4.3 Ellinger and Bostrom's Effective Coaching Strategy

Ellinger and Bostrom (Ellinger, Ellinger et al. 2005) conducted a qualitative, critical incident study to investigate the different ways that exemplify how managers facilitate employees' learning. In particular, they wanted to determine the types of activities that contribute to a learning organization. The study asked managers to describe effective and ineffective critical incidents when they saw themselves to be facilitating their employees' learning. An incident was defined into empowering behaviours and facilitating behaviours: Empowering behaviour are those that appeared to encourage employees to assume more personal responsibility and accountability and power and authority for their actions and decisions. Facilitating behaviours are those that appeared to promote new levels of understanding and offer guidance and support to their employees to bring about learning and development. In summary, these behaviours are:

Empowering Behaviours:

- Setting goals, outlining expectations and communicating their importance to subordinates;
- Providing resources, information, and materials for subordinates and removing external factors and obstacles that may be impeding performance
- Encouraging employees to think through issues
- Holding back solutions, letting employees come up with their own idea

Facilitating Behaviours:

- Providing observational, reflective and constructive feedback to employees
- Seeking feedback from employees about their progress on the job
- Role-playing, personalising learning situations with examples, and using analogies and scenarios
- Broadening employee's perspectives by encouraging employees to take others' viewpoints

5.4.4 Implications of Coaching and Mentoring on a Learning Environment

Coaching requires the learning goal to be clarified

Goal setting in the coaching process is important because it will have the impact on the learning context. By setting clear goals, the learner enhances his ability to self-regulate as it increases motivation towards taking positive action to achieve specific aims, which resulted in persistence learning (Dembkowski, Eldridge et al. 2006). To set a specific goal, coaches work with the learner to elicit answer on the questions such as what does the learner need to accomplish, what are the resources and constrains will involve in the achievement of the goal, or when should this be accomplished. Experienced coaches always ensure that the goal is one which is of direct and personal relevance to the learner and that it has been initiated by him rather than being driven by external force such as his coach or his partner. Setting goal is one of the elements in all model discussed above. Therefore, a good learning environment needs to provide a support that helps the learner to clarify goal in a learning session.

Coaching needs to provide constructive feedback to the learner

The purpose of constructive feedback is to give the learners clear and precise information on what they have done, so they can use the information to make an improvement in their performance. Through the coaching approach, constructive feedback provides someone who has been coached with the opportunity to start the cycle of activity again, and continue their personal development in a structured and supported way (Hall and Simeral 2008). Constructive feedback is mentioned in all model presented above as it is a basic nature of coaching. Thus, a learning environment needs to create a positive learning climate by having a channel in delivering feedback or providing information on the learner actions.

Coaching needs to encourage feedback from the learner

When giving feedback, the coach must also seek feedback from the learners. This exchange helps the coach adapt and adjust the coaching session in a meaningful way that leads to a successful outcome. Ideally, the coach should seek feedback for the learners at different stages through the coaching. The coach should be asking the learners what changes they have noticed in their behaviours, attitude to work, relationship with the other learners, satisfaction and so on (Dembkowski, Eldridge et al. 2006).

The feedback from the learner is used for a more specific purpose in the coaching models discussed earlier. In the coaching strategy defined by Elliger and Bostrom, feedback is likely to reflect the performance of the learner. It can be used to determine whether the key deliverables agreed at the beginning are achieved. In

CLEAR model, during the review state, the coach needs to seek feedback from the learner to define and plan actions for future coaching session. For the GROW model, although not clearly specified in model, feedback is used in the Reality stage to recognise the learners' skills as the coach can provide useful resources that suit to there level. The learning environment that can supports feedback seeking would allow the coach to provide strong learning opportunities for the learners.

Coaching needs to offer learning resources and directions

Learning resources may include materials created for a given learning instruction project, as well as materials discovered incidental to such programmes. The use of learning resources helps the learners develop skills to become a self reliant and critical user of information resources (Brown and Smith 1996). With guidance and direction from a knowledgeable coach, the learners can create opportunity to best use the resources in a variety of situation.

One of the principal uses of coaching that can be implied from all the coaching model is to offer the learner the learning direction rather than merely transmits knowledge. Ellinger and Bostrom, however, specifically mention that providing resources along with guidance will enhance learning performance. Although this is not mentioned in the other two models, coaching strategy implies the use of wide variety of learning resources in its basic nature. In order to enhance the utilisation of the information resources and to clarify the learning procedures, a learning environment needs to allow the access to the learning resources as well as the guidance from the coach.

Coaching needs role-play in learning

Role-play is one method of learning. It asks the learners to imagine themselves in an assigned role and to play the part. It gives all of those involved an experience which is not too far from the actual situation. They can have good pre-prepared responses for the different eventualities that can arise. Role play activities can also be used to analyse problems from different perspectives, to spark brainstorming sessions, to experiment with different solutions to a problem, to develop team work, and help group problem solving (Downs 2002).

Role-play is widely implemented in experiential learning and in collaborative learning. For coaching, role-play gives learners an opportunity to draw on the information and demonstrate how well they understand the concepts and principles. During the session, the coach becomes an actor, trying to portray the constituent as accurately as possible. The coach can help the learner who has problems by encouraging him to play out possible scenarios. After the learner has completed the role play, feedback can be provided as usual.

Regarding the important of role-play activities in learning, Ellinger and Bostrom has mentioned as one element in the coaching strategy. Although the GROW and CLEAR model does not include role play, it can be used as a technique to facilitate learning. The learning environment needs to support role-play activities such as providing resources necessary for creating a role-play scenario.

5.4.5 Coaching and Operations Management Curriculum

Recent studies suggest that coaching interventions in business improves both the employees' level competences (Hannah 2004) and customer satisfactions (Kiger 2002). For operations management education, coaching can improve both managerial performances and job skills (Ellinger, Ellinger et al. 2005). This view is also supported by Phillips (1996) as he emphasises that coaching is the only way for people to learn the skills which lie behind specific incidents in management area. Under operations management context, coaching can be used as a technique in which the instructor observes the learners and provides hints, helps and feedback while they complete an operational task (Collins, Brown et al. 1991). This technique requires the instructor to engage learners as full partners in the learning process, with learners assuming primary responsibility for their own choices (Wright and Lovelock 1999). Bolton (1999) reports that under the guidance of an experienced coach, the learners often appreciate the willingness to experiment, alter behaviours, and strive for improved performance.

5.5 Visual Imagery as a Learning Strategy

Humans, like all primates, are visual creatures, and the human mind has evolved around the sense of vision. Humans receive 83% of their knowledge through seeing; 11% through hearing; 1.5% through touch; 3.5% through smelling, and other 1% through taste (Kroehnert 2000). This underlines the power of visual sensory in both delivery and receipt of information. It can therefore be argued that visual messages are superior at capturing and conveying learning material.

Visual information creates representation of the context and concept of subject matter. By mapping the underlying properties of objects and relationships into the visual properties, visual can reveal various aspects of the information, which consequently enhance learning (Rao and Sprague 1998). Visual cues can reduce the perceived of a low-analysable decision-making task and promote self efficacy that leads to increased performance in learning situation.

In instructional settings, animation and other types of graphics are used to depict the behaviour of phenomena such as meteorology, physics, or chemistry to reduce information complexity, augment cognitive processing, and facilitate comprehension (Andres 2004). The process of knowledge assimilation is made easier because visual messages are clear and imaginative; little brainpower is required to understand and act upon information. By including visual objects or images in the learning would have the following positive effects. It would minimise explanatory content by summarising distinctive features or procedures, facilitate interpretation by clarifying abstract concepts, facilitate comprehension by eliminating the need to translate text into imagery, and facilitate long term memory by creating a memorable mnemonic (Andres and Petersen 2002). These effects, in turn, can lighten the cognitive load when processing complex information.

Although various research has shown that the use of visual imagery is effective for learning associations, there is no model that provides a framework for creating a learning environment. However, some of the current research works in human-computer interaction has provided a useful guidance that can be used to determine the characteristics of the learning environment. Since the review has been extracted from technical papers, unlike the other learning models discussed earlier, the implication for the learning environment does not rest on the concept but on its practical implementation.

5.5.1 Implications of Visual Imagery Learning on a Learning Environment

Visual imagery learning needs visual representation

Visual learning tools are relied on visual properties such as object fidelity, colour shading, and animation that create visually understandable presentations of information (Russell 2003). By using such graphical marks and by linking or arranging them in space, a large number of objects and relationships can be shown in ways that can be quickly assimilated. In addition, people are more likely to remember pictures and picture-evoking words than abstract concepts; consequently, they would remember the message better (Kroehnert 2000).

Visual imagery learning should base on three dimensional graphics

Visualisation in learning can include two- or three-dimensional graphics and animations to support navigation, analysis and interaction (Rao and Sprague 1998). Animation is useful in providing learners who are less familiar with process to understand the technique and the results (Bell, Anderson et al. 1999). In addition, three-dimensional graphics can improve visualisation in learning. This is because three-dimensional environments can provide a level of visual realism and interactivity that is consistent with the real world. In this presentation environment, comprehension is dramatically enhanced because the visual working memory workspace immediately encodes spatial information and does not require any translation of verbal information into imagery (Barnes 1997).

5.5.2 Visual Imagery and Operations Management Curriculum

For operations management, while it may be fairly easy to see the performing of a service activity, it is more difficult to envision machining or other operation steps (Smith and Cox 1990). A discussion of physical evidence is much more vivid when the learners actually can observe it and instructors can elaborate on learners' observations (Gremler, Hoffman et al. 2000). A field trip to a factory would deliver this need (Smith and Cox 1990). By visiting an actual factory or service operations facility, students can actually see operations phenomena. As an alternative, visualisation can be applied in operations management contexts for reducing cognitive load through the provision of imagery and animation that capture physical form and motion (Andres 2004). Visual imagery can be used to depict physical models that represent abstract models defined in operations process (e.g. MRP, JIT, batch production and job shop production) (Mueller-Wittig, Quick et al. 2002). Video has been used in such application to bring real situations into the classroom. By this, the basis of a plant's existence would make much more sense. Many management educators who have used video as a teaching tool have been impressed with its ability to connect the learners with management concepts (Marx and Frost 1998). Visual imagery is very helpful in recreating a sense of the content of such environment.

5.6 Conclusion

This chapter proposes a new integrative approach based on several models and techniques of student-centred learning for optimising the effectiveness of the learning process for global operations management. The holistic model consists of four multidimensional learning components. This includes experiential learning where learning is seen as a continuous process grounded in experience, collaborative learning where learners work together on tasks, coaching and mentoring where the teacher stimulates the learning processes by observing and correcting the learners, and visual imagery learning strategy where the information is provided through images and animations. By combining these multidimensional learning approaches into a unified model, educators can overcome the inherent weaknesses in traditional instruction. These four components provide a generic architecture for the development of learning-based technologies, which will be discussed in the next chapter.

Chapter 6: The Role of Technology in Operations Management Learning

This chapter matches the specified attributes from the learning approaches discussed previously in Chapter 5 with the capabilities of current technologies that could be used to create a learning environment for operations management programmes. The technologies that will be discussed are: learning-based simulations, computer-mediated communication, intelligent agent, and virtual reality. The way in which these four technologies can be integrated into the virtual world system will also be described and discussed in the context of the learning.

6.1 The Role of Simulation Technology in Operations Management Learning

Since business schools have redesigned their degree programmes to be more competitive, many operations management courses have restructured their course materials, and introduced experiential learning approaches into their syllabi (Machuca and Luque 2003). As opposed to sole instructor lecturing, the participative style of instruction through case studies and games has been introduced into courses to enrich the students' understanding of the manager's role (Love and Boughton 1994). Such experiential applications have greatly facilitated the students' knowledge of workplace issues. Students who have not had prior experiences with operations systems can observe and investigate the operational and behavioural issues of the system in the classroom. Almost all graduate level of operations management courses now includes one such application in their curriculum (Chwif and Barretto 2003).

In order to gain a practical knowledge of the operations system, the material used in an operations management course requires a sufficiently complex sense of a real-world environment (Lainema and Hilmola 2005). To be sufficient, the course material needs to cover all key linear and dynamic aspects in the focused functional areas (Love and Boughton 1994). Although games and case studies can be used to convey systems concepts and approaches used by the operations manager, they cannot illustrate all of the dynamic interrelationships of a system (LaForge and McNichols 1989). In the case study approach, even though the instructor put a great effort to present the event under study as accurately as possible, much of the context and many variables in the real world are excluded (Saunders 1997). As a result, learners may acquire only some skills and may construct experience on the basis of a misconception (Cadotte 1995). Also, as most cases develop their story lines chronologically, it can give a misleading impression of how people actually discover and solve problems at work (Hartman 1992). This often fails to reflect the trade-offs demand by real industrial problems. Likewise, business games have been established to be used for education purposes but they are limited in the level of realism they could offer in operations (Micklich 1998). While a game approach may demonstrate the interrelationships, it only provides a static view at one particular point in time. It does not emphasise the dynamic aspects of the operations environment (Love and Boughton 1994). Increasing the richness of a business game raises a number of practical problems that affect the structure of the game. Business games can therefore at best provide the students with an appreciation of a business system, not with practitioner experience (Lainema 2004). In the same way, it is possible to argue that internship experience is more valuable because of the realism it offers to the learners. However, sending students to the field offers realism, but lack of control over content, context, and timing of the experience often results in problems (Lainema and Hilmola 2005). In addition, while internships provide excellent business operations experience, they have been slow to respond to the growing need for the context of globalisation (Alon and Cannon 2000).

The use of simulation to aid learning is common in operations management and related disciplines. In traditional operations management education, physical laboratories are sometimes required to demonstrate the logical procedures of a working operation. However, their expense allows them to cover only a small portion of the operations management spectrum (Billett 2000). Simulations are, therefore, often used to envision complex models of the work processes or production principles to enhance the understanding behind the principle of a topic being studied while avoiding the high equipment expenses (Greasley, Bennett et al. 2004). Apart from this, the best way to ensure the transfer of procedural skills is to train people on the job; in this case simulations are used as a training tool. Learners are expected to be able to transfer the skills and knowledge they have learned from simulated context to a variety of real life situations. For example, Smeds (1998) has designed an interactive enterprise simulation system that can illustrate sophisticated concepts of enterprise workflows and dynamic business processes. With this system the learners can interact directly with the enterprise model and experience the enterprise spaces and functioning of the enterprise from within. A holistic understanding of the enterprise system is created and the learners can gain experience and knowledge from the simulated enterprise world.

6.2 Simulation Technology and Experiential Learning Theory

By definition, a simulation is simply the imitation of a real life situation. It is a powerful tool that can be used to model the behaviour of almost any system (Chwif and Barretto 2003). The interrelationships among the elements are also built into the model. Then the model allows the computing device to capture the effect of the elements' actions on each other as a dynamic process. This allows a variety of 'what-it' questions concerning the real system to be investigated.

Simulation technology is a very effective student-based learning tool. It can be used as a learning tool for their visibility, reproducibility, safety and economy (Ruohomaki 1995). It can be applied to the teaching of facts, concepts and principles, or processes, and to train specific skills (Ruohomaki 1995).

In education simulation can be employed as 'a sequential decision-making exercise structured around a model of a business operations in which participants assume the role of managing the simulated business operations' (Greenlaw, Lowell et al. 1962). The use of simulation technology creates possibilities for learning that would have are unlikely to occur in a traditional educational setting. In relation to experiential learning simulation technology has several important characteristics:

Simulation provides the learner the opportunity to practice skill

Usually, simulation is based on a dynamic set of rules embodied in a computer program. With this scheme, simulation can be used to deal with situations and processes that demand flexibility in thinking. It can be employed to illustrate concepts of dynamic content and process so that different kinds of solutions can be tested and their probable consequences can be seen. These procedures typically generate a more detailed understanding on the part of the learners about the impact and outcomes (Graf and Kellogg 1990). With this technology, learners are allowed to practice decision making and the planning of alternative strategies in order to evaluate the outcome of their decisions (Chwif and Barretto 2003). The ambiguity in instruction can be substantially reduced by this means of learning.

Simulation is supportive and flexible

Simulation enables the learner to perceive practical situations. It is usually applied when the situation is too abstract, expensive or dangerous (Riis 1995). In a simulation session the participants are active learners who learn by trying things out and working with others. A wide range of conditions, parameters, and scenarios can be tested without fear of causing damage or endangering human life. This is particularly useful for enabling the learner to grasp the knowledge and build essential application skills, especially when it is infeasible to learn by doing in the real world (Ruohomaki 1995).

Simulation can promote social interaction between the learners

A simulation session is usually based on group interaction in a problem solving context. The group size and structure can be varied by the instructor depending on the objectives of the session. Learners can demonstrate, distribute and exchange knowledge with members in the group during and after the training session (Ruohomaki 1995). In addition to acquiring knowledge on the subject, this offers the learners the opportunities to learn about the social system.

Simulation provides feedback on the actions

When simulation technology is applied in the learning context, it can show learners how variables interact and affect performance (Gremler, Hoffman et al. 2000). Unlike a case study and other static traditional learning activities, simulation provides the dynamics and time-phasing characteristics (Seymour, Gallagher et al. 2002). This allows learners to visualise situations and to perceive changes as a consequence of their actions and choices (Galvao 2000).

Simulation allows information to be presented in various forms

Principally, a simulation can be seen as a multi-sensory media. Many simulator programmes provide graphical representations of the context being simulated. Some of them include complex animation sequences to demonstrate the dynamic flow pattern of the process in the simulation model. When different representations are present, experience are enriched and strengthened, resulting in a much deeper understanding of the learning context (Ruohomaki 1995).

Simulation supports the learners in planning for further experience

After a simulation session is completed the planning process can be initiated through discussions on the data generated by the simulation (Riis 1995). Further session may involve some modifications of the model parameters for optimising the efficiency of the process. Or, it may involve the revision of the original plan of operations. By engaging in the simulation session the learner can experience consequences of their decisions and develop an action plan to address the issues found in the previous session.

6.3 The Role of Computer-Mediated Communication in Operations Management Learning

Fundamentally, the computer applications based on computer-mediated communication in operations management have been developed to the support decision making process in operations. For example it has been employed to establish a group communication support system which has had different kinds of effect on groups and their decision processes (Pinsonneault and Kraemer, 1990). With the extended ability provided by this technology, the emphasis is shifting from a single decision maker to a group of decision makers which are connected to each other. The improvement is particularly significant in term of productivity, the time taken to reach a decision, the degree of participation, the degree of satisfaction and many other factors (Davison 2001).

The widespread use of this technology in operations management has had an influence on curriculum and pedagogy. Smeltzer (1986) found positive responses in analysing the reactions of management students on a variety of electronically mediated communication tools including video and computer conferencing. In his experiment, the students were comfortable with the technological tools and rated them stimulating just as in face-to-face meetings. In term of participation, a minority of respondents reported that the tools negatively affect their in-class activities such as questioning and thinking. However, all the students believed that the group cohesion is greater when mediated by the technology.

With the advent of internet-based service such as email and World Wide Web in 1994, universities have changed their pedagogical structure. Many of them use the technology to create a learning environment to reinforce cross-cultural communication for global studies. As in a more recent research conducted by Morse

(2003) on using computer-mediated classroom to facilitate cross-cultural teaching, the overall result indicates a higher quality and quantity of learning as well as a greater temporal and geographic convenience. This confirms the conclusions of much of the existent literature on using technology of computer mediated-communication as a learning tool.

6.4 Computer-mediated Communication and Collaborative Learning Theory

Computer-mediated communication (CMC) can be broadly defined as human communication via computer. As a tool in a learning environment, this technology involves interaction between two or more human users using computers to communicate and cooperate during the learning process. It offers great opportunities for learning and instruction especially when collaborative learning and the geographical effects of globalisation are taken into account. In the domain of collaborative learning, computer-mediated communication holds several important characteristics as follows:

CMC allows active participation of the learners

An online learning environment via computer-mediated communication allows learners to actively participate in the learning process without the constraints implied by location or time. This provides potential benefits to learners who have difficulties with participation in learning activities (e.g., physical or environmental constraints). People who are living in a different country can meet up online and share their cultural knowledge. Since cultural knowledge is deeply embedded within individual, intercultural cultural competence can be developed and cultural differences can become comprehensible (Crookall and Saunders 1989).

CMC can provide a sense of the common goal

The computer-mediated communication offers tools for promoting the collaborative learning through educational tasks (i.e. problem solving and case studies). With networked simulations the learners come to appreciate their interdependence and the need for mutual support. Team working abilities can be developed through the simulations which include persuading, co-operating with, listening to others, issuing and accepting commands (Weaver, Bowers et al. 1995). Also, this type of learning environment is effective for learning since it provides an environment for the participants to construct their own knowledge through their understanding in a community.

CMC supports the interaction and communication between the learners

Although the face-to-face is crucial for stimulating interaction among learners, the learning outcomes in an online environment is equal, if not superior to those gained in traditional classroom settings (Suthers and Santos 2001). Henri and Rigault (1996) suggest that electronic networking provides more intense communication than face-to-face groups since they enable the learners to express their views without social pressure. The study also concluded that these media can offer additional value to the networks and collaboration facilities since they can link schools with a broader community. Thus, using a computer-mediated collaborative environment to support collaborative learning has the potential to improve the quality of education.

CMC allows the contributions from each learner to be taken into account

In contrast to face-to-face discussions, computer-mediated communication such as textual chatting allows opportunities for learners to review and reflect on contributions posted into the system (Bouras, Psaltoulis et al. 2002). The group of learners can be encouraged to evaluate their own and others' writing and to provide feedback evaluation. In addition, such types of reflection on learning can make the learners aware of what is acceptable in terms of knowledge claims and how they should be expressed within a subject area (Hewings 2006).

6.4.1 The Role of Intelligent Agent in Operations Management Learning

The management of operations often involves seeking to resolve several goals such as increasing quality, flexibility and reducing costs. Various models based on mathematical principles have been developed to address the problems such as those for inventory maintenance and scheduling. Given the nature and complexity of problems faced in operations management artificial intelligence (AI) has been introduced into the area to cope with the problems. Up till now, various AI techniques such as expert systems, neural networks and generic algorithms are employed to improve the convenience in problem solving as well as enable new type of decision tasks.

In its wide rage of techniques being used, some even potentially enable the specialist knowledge to be embedded within an application tool, as of interest mainly to this research – the intelligent agent. By integrating intelligent agent into a model-based decision support system, it helps users select and formulate appropriate models. When allied with other types of system, it promises considerable potential benefits as a tool to facilitate operations management tasks.

In educational area, intelligent agent can be used as a component in computer-based training to develop intelligent tutoring systems that can interact and guide users according to their specific needs. Such system can provide a great deal of assistance and guidance to unskilled learner (i.e. operators in training or operations manager). But as of now, this technology is still in its infancy and requires more investigation further in operations management area.

6.5 Intelligent Agent and Coaching

In recent years, several computer applications have employed artificial intelligence techniques to enhance the learning. The functions such as natural language processing and expert systems are beginning to appear in mainstream academic applications. Natural language processing helps the system to interpret unstructured requests and allows learners to interact in a more human manner (Grishman 1994). The expert system acts as a specialist who provides the compliance advice and guidance needed by learners to perform their duties in learning (Jackson 1999). Many more of these intelligent functions have been integrated into computer applications to create a more effective learning environment.

One of the intelligent functions that are of great interest is intelligent agent. An intelligent agent is a computer programme that imitates human decision-making behaviours (Schleiffer 2005). It is used as an assistant in a broad range of applications to handle the need to respond to a request with useful information. It is often used to replace a human entity otherwise required by the learning process. For example, medical training simulators may use an intelligent agent as a virtual patient to allow medical students to demonstrate their skills in clinical practices such as paediatric diagnostics (Hubal, Deterding et al. 2003) and surgical training (Allagher, Ritter et al. 2005). As an interview training tool (Link, Armsby et al. 2002), the intelligent agent is used to simulate a telephone interview. In a manufacturing simulation, the intelligent agent demonstrates the human ergonomic issues that may affect the assembly line (Donald 1998). It provides a more efficient method for understanding the effects of operator sequencing on material flow. In each case, the processes experienced through intelligent agent approximate or parallel those that would be conducted by practitioners. The agents also encourage learners to apply the knowledge and skill which would be difficult to acquire from other sources. In the context of coaching, intelligent agent has several important characteristics:

Intelligent agent helps the learner to clarify objectives in a learning session

Similar to other computer-based training technologies, the intelligent agent usually comes with specific training knowledge for a particular domain. It can provide helpful directions on what is the major goal the learner needs to achieve and how to proceed with assigned learning tasks. An example of this characteristic can be found in “Andes”, the intelligent tutoring system for introductory college physics (Gertner and VanLehn 2000). “Andes” interacts with learners using coached problem solving in which the student and intelligent agent tutor are collaborating to solve problems. When a problem is first opened, a dialog contains a statement of the problem and a picture of situation is illustrated. At the lower part of the dialog contains hints and guidelines to help the learner to understand the goal of the problem.

Intelligent agent provides constructive feedback to the learner

Many types of feedback ranging from very simple to highly complex can be provided by an intelligent agent. In a very simple form, the colour feedback on the answer text – green for correct and red for incorrect can be generated using information from the learner’s actions. For a more complex form, the system can provide scaffolding guides in addition to informative feedback. Through these the learner can reflect on feedback to improve their learning performance.

Intelligent agent can seek feedback from the learner

In a more complex implementation the intelligent agent can be designed to actively seek feedback from the learner. In a distance learning application developed by (Jafari 2002), the agent goes beyond a simple concept by acting on behalf of a tutor. By performing a job as a tutor the intelligent agent assists the learner as much as a human tutor does. The goal is to follow the learner’s individual solution path from the problem solving actions and applies its production rules to evaluate the actions. With such algorithm the agent is able to recognise the learners’ strengths and weaknesses so as to provide useful resources that suit to there level.

Intelligent agent can provide learning resources

The most common goal of intelligent agent in learning applications is to provide the benefits of one-on-one instruction in automated way and in real time fashion. One of the techniques used is the tracing of the learner's actions and to provide individualised instruction in the problem solving context. If the student appears confused about the nature of the current problem state, the system will provide hints that lead the learner back to the correct solution path. For example, the hints can be a reminder of the current goal, a general description of how to achieve the goal, or a description of exactly what problem solving action to take. In addition, resources such as related documents may be provided along with the hints to assure success in problem solving.

Intelligent agent can role-play with the learner

The relationship between the learner and the agent is defined to be a pedagogical relationship, where the intelligent agent can monitor and evaluate the implementation of teaching interventions (e.g. provide help and feedback). In support of this feature, Laurel (1990) suggests that intelligent agents should have distinctive characters similar to actors in a play. For example, as part of a social studies program for studying the time period of the Civil War, there could be a historian agent, an explorer agent, and a politician agent to represent different point of view. She found that this representation allows the learners to use their ability to make accurate inferences about how a character is likely to think and make decision. In addition, the agent as a character invites conversational interaction and makes a more effective learning environment.

6.6 The Role of Virtual Reality in Operations Management Learning

Operations management is a large system, formed by many entities that interact in complex ways. These entities include the transition of raw materials and the flow of information through a series of stages that are exhibited by multipart systems (Coughlan and Coghlan 2002). Although a simulation can completely illustrate the sophisticated characteristics of such operations, learning can be exhausted by the large amount of data that the system generates. The complexity of implementing a system eventually causes problems for non-specialist learners and is usually subject to misinterpretation and ambiguity (Menga and Morisio 1990).

In order to respond to this issue, visualisation is employed to improve the understanding of simulation models. This is because visual information provides the highest bandwidth channel from the computer to the human (Riva 2003). When the simulation data is displayed using standard computer graphic techniques, many things become more visible. Visualisation provides an ability to comprehend huge amounts of data. It transforms abstract information into image in which pattern recognition can be easily identified (Zeltzer 1991). With an appropriate visualisation, errors and artifacts in the data are commonly revealed. It can be especially valuable in allowing the perception of patterns, resulting in quick insight into learning.

This is the main reason why virtual reality comes into play. Virtual reality technology can be employed to illustrate how the system works in a very meaningful way. It also allows the learner to get a better perspective than what could be achieved in 3D solutions. Many methods concerning in operations processes such as the arrangement of machines, material handling paths, and material handling devices could be designed and analysed. Potential problems including safety issues, bottle necks, and material handling activities can be revealed straightforwardly (Iqbal and Hashmi 2001; Mancini, Vigano et al. 2004).

6.7 Virtual Reality and Visual Learning

Under various forms of visualisation tool, including still pictures and animations, Virtual reality has been the subject of much interest recently (Burdea and Coiffet 2003). Virtual reality technology employs the capability of interactive three dimensions computer graphics to improve the presentation of data. Most of the current virtual reality technologies provide unique visual experience that is utterly authentic and highly interactive.

Virtual reality is a significant technological breakthrough with the massive potential to facilitate learning. It enables learners to handle massive amounts of information. (Winn 1993) identifies three kinds of experiences that are available in virtual reality which could prove useful and important in learning. First, it allows its user to interact with the events in virtual environment. Second, this technology can present information that is not available to human senses in a direct and clear manner. Third, by combining the first and second feature, this technology allows the representations of objects and events that have no physical form in the real world. Studies (Grantcharov 2002; Gallagher, Ritter et al. 2005) show that these unique properties of virtual reality allow its applications to support experiential, conceptual and discovery learning which is otherwise not possible.

The virtual reality environments are primarily visual and three-dimensional in nature. The visualisation can be displayed either on a computer screen or thorough special stereoscopic head-mounted display. As an educational tool, it is helping the learner to visualise highly abstract pictures of areas, locations, process or quantitative data. It is often used to illustrate the situation that is difficult or expensive to obtain.

The virtual reality learning environment is experiential and intuitive. It offers unique interactively and can be configured for individual learning styles. Learners are placed into a three-dimensional environment, making possible for them to interact with virtual objects in a manner similar to the way they would handle their real-world counterparts. Virtual reality provides two distinctive characteristics that important for learning: interaction and immersion (Dickey 2003). The interactive characteristic is assumed because this technology is not limited to passive visual representation but enables rich interactions from its user. The immersive characteristic allows the user to have the feeling of being in the world created by virtual reality. These characteristics allow natural interaction with information which is essential for effective learning.

6.8 The Need of Multifunctional Technology Based Solution

When the desired learning outcomes include the development of interpersonal and team skills, computer simulation is not the best experiential learning tool since it may not capable to deliver the sense of teamwork, especially when the learners are geographically dispersed. In addition, the facilitators often face difficulties managing simulations and staying in touch with their learners outside of the classroom and class times (Saunders 1997). As a result, the learners may not be able to compete and collaborate on teams effectively as the exercise intended to serve.

In order to implement collaborative learning strategies, the instructor may have to provide collaborative learning environment to ensure learning efficiency. However, applying collaborative learning techniques into the learning environment can be a problem for facilitators, who have to monitor and guide the learners (Suthers and Santos 2001). This is because it is very hard for a human facilitator to track many teams working at different times and in different places.

This raises a demand for an automated expert system as a delivery system to provide coaching during simulated exercises and providing the learners with helpful comments and feedback (Wai, Rahman et al. 2005). Having an intelligent agent within a simulation system to suggest alternatives when the learners are struggling would certainly provide a great benefit. In addition, since the agent normally represents as a human entity, it can enhance realism in training scenarios. Therefore, using intelligent agent technology could create an effective experiential learning environment and compensate for the limitations of simulation technology in education.

Virtual reality can also be included to simulate three-dimensional visual environments so that the user can interact with the exercise in a more effective manner. Complex environments such as operations that once seemed unrelated and difficult to understand can be made fairly simple with the representation generated by this technology. Collaboration between the learners can become more natural. Coaching through intelligent agent can become more effective. When these technologies are combined, it would lead to an expanding set of opportunities for learning.

6.9 Virtual World Technology – A Multifunctional Technology for Learning

Until recently, numerous computer training systems have been developed to address specific aspects of learning in global operations management. This sort of training system can be global financial operations, global operations in manufacturing, international marketing, or global human resource. Only a few of these systems have an architecture that allows different entities and different technologies from disparate domains to interact in a single application, in real time, and over large geographic distances (Calvin, Dickens et al. 1993). As computer technologies are improved, the computer system can be a context for learning through community-supported collaborative construction. The proliferation of the technologies provides opportunities to move beyond the creation of constructionist tools and activities to the creation of an integrated application, student-oriented, and knowledge society.

Virtual world technology is one of the emerging technologies that can be brought into classroom to enable a meaningful learning environment. The virtual world is a computer-based environment in which its users live and interact with others via avatars, a virtual representation of a user (Benford, Greenhalgh et al. 2001). This computer environment usually takes the form of a two- or three-dimensional space with multi-user capability. It appears similar to the real world with real world rules such as gravity, locomotion, topography, real-time actions, and communication (Dede 1995). This technology is now common in multiplayer online games where the individuals meet in a virtual environment, in a social context free from real-life constraints.

Many educational virtual worlds provide a real-time common meeting and working place (Prasolova-Førland and Divitini 2003). Under this type of information infrastructure, learners' collaborative interaction can occur across distance, among avatars. This creates two important cognitive factors: *telepresence* and *immersion*. *Telepresence* allows learners to create or recreate distant events as if they were together. It allows the learners to interact around a virtual object in a collaborative manner (Dede 1995). According to Escobar et al. (Escobar, Rendon et al. 2003), telepresense can improve the understanding attained by the learners who use telepresense technology. *Immersion* is a sense that a learner has of being in a virtual world. Immersion is a significant concept of virtual world design since it conveys the entire virtual experience. Immersion in a virtual world removes the boundary between the learner and the machine. When this happens, the experiences in the virtual world can be identical to experiences in the real world (Biocca and Delaney 1995). The knowledge the learners produce is therefore direct, personal, subjective and tacit. This allows learners to access the knowledge through their direct experience, which makes their knowledge more integral. Overall, telepresense and immersion enable the learning process to be more active and more effective for educational or professional development.

As the main interest of this research, virtual world technology can be used to create a single interface of disparate materials produced by several technologies. For simulation, an instantiation of some abstraction that only be accessible as numerical data is expressed more naturally under virtual worlds. For computer mediated-communication, 3D virtual worlds offer more communicative opportunities and provide an environment that supports constructivist learning by allowing for the emergence of knowledge-building communities (Dickey 2003). This has drawn the attention of higher education because they can provide learners and tutors with advanced interfacing capabilities and real-time communication support. For intelligent agent, rather than simply presenting facts, information, and knowledge to learners, an intelligent agent can provide both intellectual and psychosocial feedback, mimicking the types of interactions occurring in face-to-face constructivist learning (Dede 1995). For virtual reality, by containing facsimiles of real objects and their behaviour, it helps close the gap between experimental learning and information representation (Winn 1997). A uniform bundling of these technologies would help learners to develop an expertise that cannot be derived from a collection of dispersed technological tools.

River City - An Example of Virtual World Application for Education

Among numerous virtual world learning applications, River City appears to share many functional similarities with the proposed framework. In River City, virtual reality, computer-mediated communication technology and intelligent agent are combined to create a virtual world learning environment (Nelson, Ketelhut et al. 2005). River City's virtual world allows the learners to take control of their own learning, study topics of personal interest, and pursue their own learning objectives. The learners are populated the virtual city, along with computer-based intelligent agents acting as mentors and colleagues. By exploring the River City's world, the learners can observe patterns and discuss questions such as "Why are many more poor people than rich people getting sick?" They can also talk with intelligent agents as well as with other learners about the situation in River City. At the end, the learners can individualise their own learning style in order to apply critical thinking concepts to their academic situation.

6.10 Conclusion

Academics have described ways in which technologies can be used to support teaching and learning. Many guidelines and strategies can illuminate the ways of creating effective computer-based learning environment to improve the teaching-learning situation. Educators are now looking to learning technologies as an important means of delivering quality programmes to the learners.

Many innovations and applications of information technologies have been developed for supporting learning and teaching in past decade. These technologies may finally be able to play a key role in enabling learning to higher standards. According to various researches in recent years (Jain and McLean 2005; Peluchette and Rust 2005; Johnson, Bartholomew et al. 2006; Lean, Moizer et al. 2006) computer-based training modules have been accepted as an appropriate teaching and learning facility for global operations management education.

As for this chapter, four key technological tools are introduced with their applicability to a specific learning experience. Simulation technology can be used to promote experiential learning activities under a classroom environment. Networking technology can create collaborative learning environment in which geographical dispersed team of learners can get together. Intelligent agent technology can provide coaching support to the learners as they perform their learning responsibilities. Virtual reality can provide a virtual environment in three-dimensional form. These technologies can be combined into a virtual world, the technology that possesses all critical functional attribute of the four technologies.

As global operations management requires its practitioners to possess basic skills prior to actual business encounters, the learner must practice these skills in a multinational business environment if available. Virtual world could simulate such environment through telepresence. Distance learning networks can be expanded to allow learners and teachers to share worldwide learning environments. Through virtual participation in local and international activities, students can become active in the process of culture, and can understand more clearly the nature of global business management.

Chapter 7: Conceptual Design of the Virtual World Prototype

Virtual world is one of the emerging technologies that can create a meaningful learning environment in the classroom. This chapter provides a conceptual design of the virtual world prototype, which is intended to support instructions in global operations management. It starts with a reason for using a prototype as the specifications for software development. It then shows the design of technology models described in the previous chapter. In brief, the technology models include Mandrill simulation system, intelligent agents in Mandrill, the network communication system, and the virtual environment. When these technologies are integrated, learners' collaborative interactions under synthetic constructivist environments could take place across distance and would result in a richer global operations learning environment.

7.1 Virtual World Prototype and the Design Process

A prototype is an important part of the software development process. It serves as a concrete representation or a tangible artifact of an interactive system. For system designers, a prototype can be used to express ideas and reflect on them. This approach is more intuitive for an end user who is not an expert in the software development field. Hardware and software engineers often use prototypes to proof of ideas and to study the feasibility of a technical process. They can conduct scientific experiments and fine tune the system. For researchers, a prototype can be used to help the thinking, planning, experimenting and learning process while designing a system. Questions and doubts regarding certain issues of the design can be addressed by building and studying the prototype. For this research, different prototypes are developed to serves different roles including; communicating information and demonstrating ideas, helping thinking through the research processes, and testing and proofing concepts relating to the development.

7.1.1 Representation

According to Beaudouin-Lafon (2003), a prototype for software development can be distinguished into two basis forms of representation: offline and online. Offline prototypes are normally constructed through paper sketches or videos. They can be created quickly and securely with no technical knowledge required. The purpose is to examine a variety of design alternatives and to explore the design space. Online prototypes, on the other hand, usually include computer animations and programs written with computer languages. They require skilled programmers to implement advanced interaction and visualisation techniques. Although the cost of producing an online prototype is usually higher, it provides richer and wider parameters for experimentation.

This research utilises both forms of prototype. The offline prototypes are developed at the early stage of the research to explore different design alternatives as well as to refine the design criteria. Figure 7-1 illustrates the mockup 3D virtual environment of the Mandrill's spindle assembly cell. It is mainly used to present the basis of overall system architecture. Figure 7-2 depicts another version of the offline prototype. It provides a more detail of the system elements and functions. This version is mainly used in the research process to extend design possibilities before the development.

For the online form, several prototypes are developed to serve different requirements for different types of evaluation; some are specifically focusing on computer communication and some are for addressing the issues in the virtual environment. They also enable active involvement of users in the development phase to help avoiding unpromising design as well as discovering some usability problems. The details of online virtual world prototype are presented in the later sections within this chapter.

7.1.2 Level of Precision

One of the goals of creating prototypes is to present the structure of the system being built. By their nature, prototypes require details. A more detailed representation helps designer to accurately describe the system functions. A lower detailed representation of a prototype may result in miscommunication. For example, a verbal description of system environment such as 'the user walks and talks inside the virtual factory' may seriously misinform about what the user actually does in the system.

In order to prevent a potential miscommunication of information, this research utilises a high level of prototype. This means all technology within the virtual world can actually perform its essential functions. The simulation is conducted on the Mandrill simulator which fairly reflects necessary operations management functions.

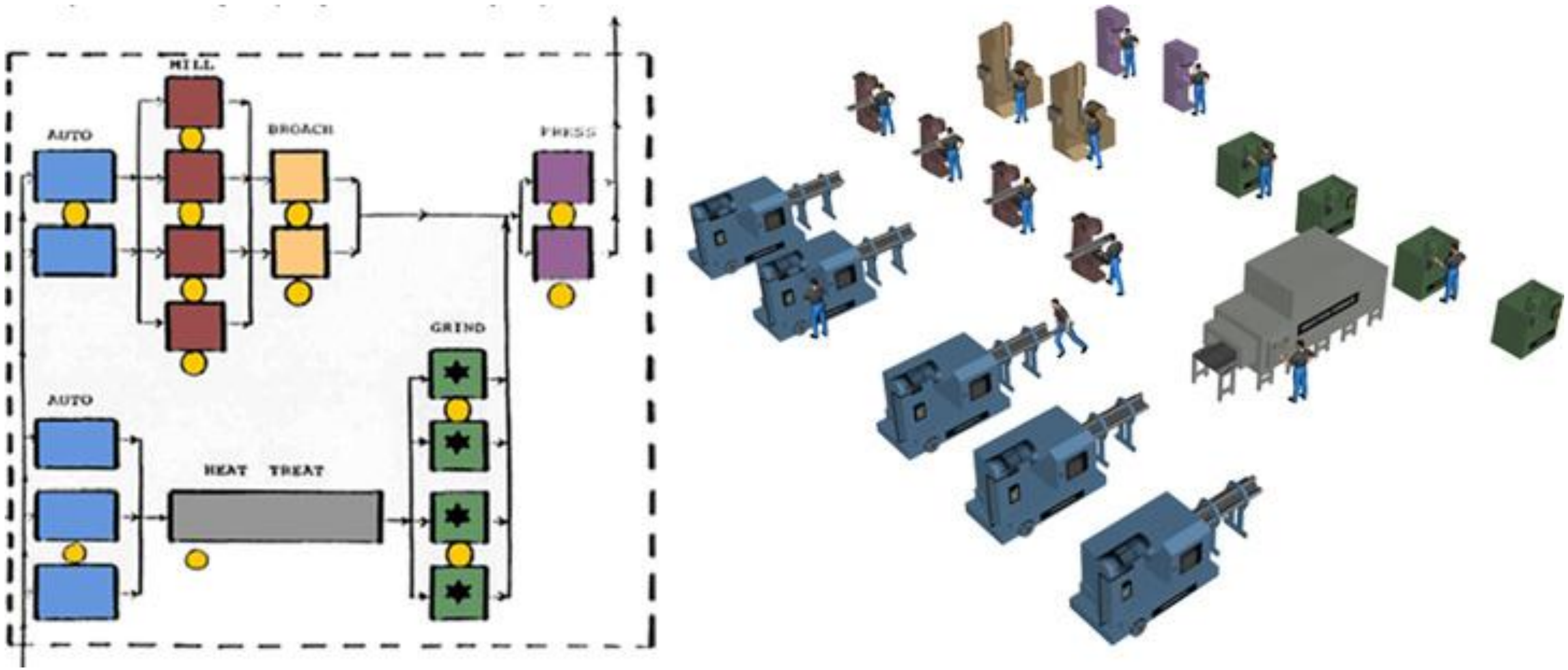


Figure 7-1: The Initial Factory Layout and the 3D Mock-Up of the Spindle Assembly Cell

Figure 7-2: Another mockup of the virtual world prototype

The network communication unit can serve remote communication over the internet, allowing the learning community to collaboratively construct knowledge. The intelligent agent can provide immediate feedbacks based on queries that learners are assumed to pose to the system. The virtual reality mode allows the user to navigate in 3D space. All of these technology elements are integrated to illustrate the technical basis of for the proposed system.

7.1.3 Interactivity

An important characteristic of software training systems is that they are interactive. The quality of interaction is tightly linked to the end users and a deep understanding of the system. A simulation system with virtual reality capabilities designed to create an operations model requires a different interaction that is designed for training, even though the technical basis is the same.

Basically, there are various levels of interaction. At one end, fixed prototypes, such as video clips or pre-rendered animations are non-interactive. The user cannot interact with the prototype, or at best pretend to interact with it. This type of prototype is often used to demonstrate scenarios. At the other end, open prototypes can support large sets of interactions. Such prototypes work like the real system and usually cover all the essential concepts. They allow system designers to test a wide range of examples of how users use the system. For this research, open prototypes are developed to gain the understanding of the system for both a researcher's and a user's perspective.

7.2 Virtual World Prototype

Figure 7-3 illustrates the early technical design of virtual world prototype. At this point of study, the prototype is designed to have only four major technologies (e.g. simulation, intelligent agent, computer mediated communication, and virtual reality) based on the predefined multidimensional learning model. However, more technologies are added to this design to ensure the interoperability of the system. The design detail of Virtual World prototype will be discussed in the next chapter.

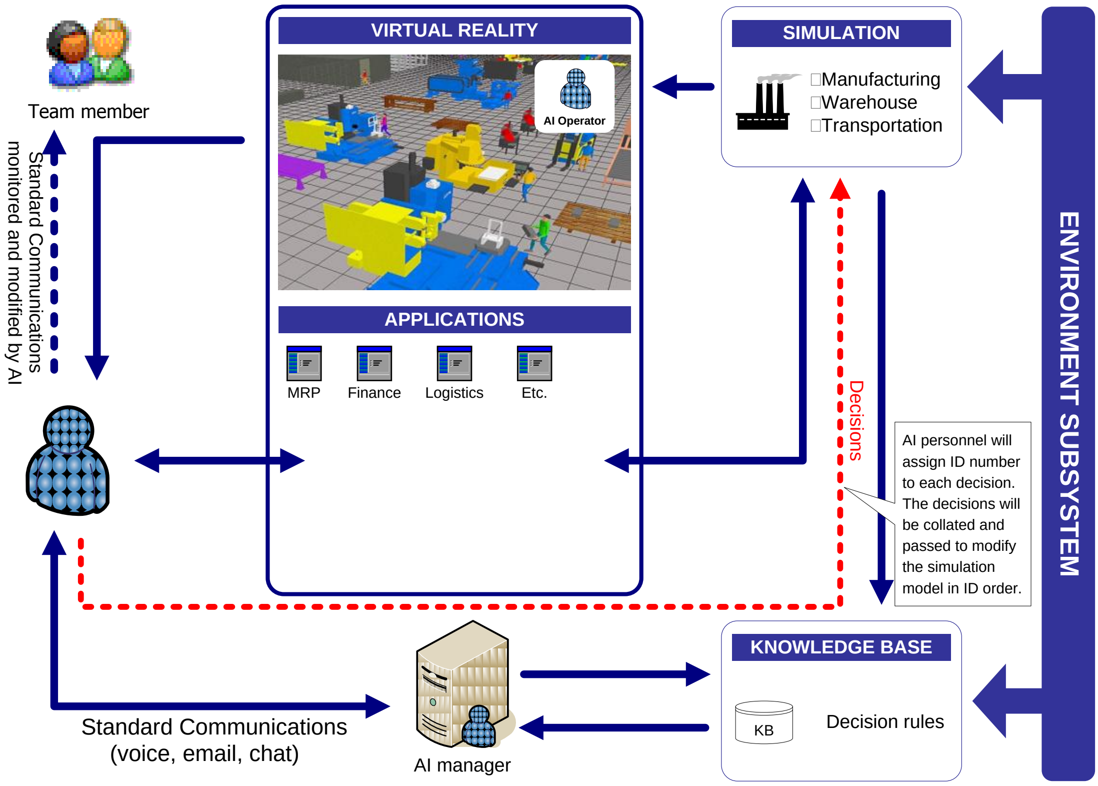


Figure 7-3: Early technical design of Virtual World prototype

7.2.1 Simulation Engine

The design of the virtual world to aid learning for global operations management is based on the "Mandrill System", a learning-based enterprise simulation system that was developed and designed by Love and Boughton (1994) to fulfill the need for experiential learning activities in Operations Strategies module at Aston University. The system uses advanced simulation techniques and computer networking technologies that can create a rich and dynamic business management environment. This system covers all key business functions and offers in-depth representation of manufacturing operations. All the major functions of the business are presented: operations, sales, purchasing, engineering, distribution, human resource, and finance. External customers and suppliers are also modelled. Details of all products, manufacturing methods, plant, personnel, suppliers, customers, sales histories and financial reports are provided. The wide range of functions supported and the level of detail means that more than 1000 documents are stored in the case knowledgebase.

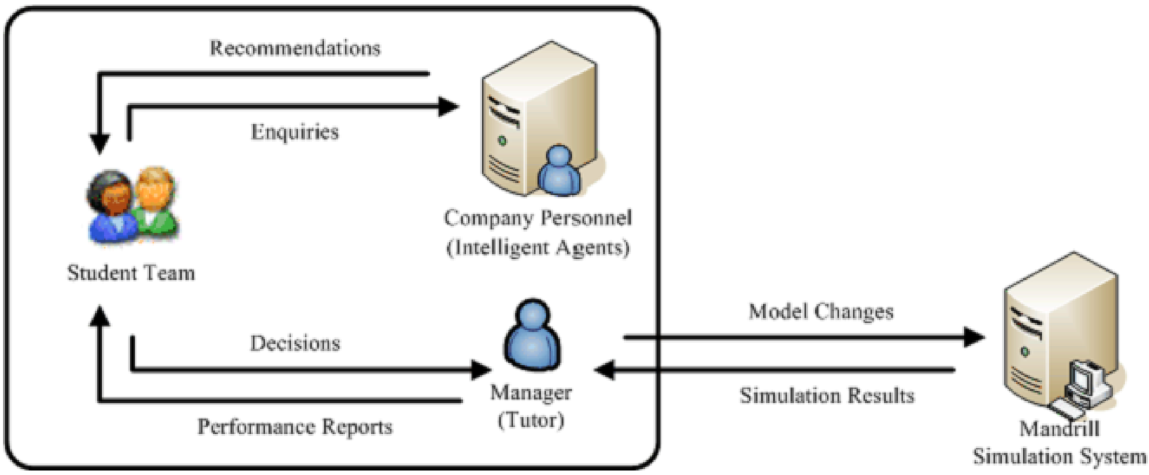


Figure 7-4: Mandrill Case Study Process

The class used the Mandrill simulation system to reflect the dynamic environment of a business enterprise. During the term, the learners were grouped into teams of four or five in order to practice using the system to make business decisions and solve business problems. This learning technique provides a chance for the learners to put the theory into practice and to see the consequences of their decision without risk of failure.

The exercise is a cycle of events (Figure 7-4). The typical cycle begins when the teams received the previous week's performance report. After analysing the report, the teams then send queries to company personnel to request further information about operational plans or actions. The queries can pertain to worker training arrangements, plant capability studies, or market forecasts. The system will then return the managerial plans, recommendations and related management documents to the team after processing the queries. Afterward, each team then forwards its decisions to the tutor, who has assumed the role of manager. The tutor will interpret the decisions, change the parameters of the simulation model, run simulation and send the performance report for the following week back to the team. According to the apparent features of Mandrill simulation system, it can serve as a baseline for the development of the Virtual World prototype.

7.2.2 Intelligent Agents

Intelligent agents perform three important functions in the Virtual World prototype. The first is to facilitate and accelerate the interaction between the learners and the case knowledgebase. The human-like nature of the system smoothes the interaction between the learners and the simulation system. The agents establish an emotionally safe and friendly learning environment in which learners can express their knowledge and creativity. In this way, the learner feels more comfortable making mistakes and is more willing to take risks in decision making, which has a positive impact on the learning process.

The next function of the agents is to enhance the experiential learning aspects in business management by increasing the realism in training scenarios. In Virtual World, the agents represent the company personnel engaged in business activities. They act as the factory manager, the finance manager, the personnel manager, the technical manager, the purchasing manager, the quality manager, the sales and marketing managers and the tutors. All of these virtual agents provide the learners with the understanding of how to handle issues that may arise in a real business environment. The learners can interact with the virtual managers, just as if they were communicating with real managers. Therefore, the need for complex material and the high cost of role-playing setup has been eliminated, and a more flexible learning environment has been created.

The third function of the intelligent agents is to help the tutor manage learning. Like the other agents in the system, learners can interact with the tutor through a computer interface. A human tutor's task has been reduced by the use of the autonomous agent that organises the learners' queries. In some circumstances, the agent is also a tutor, answering questions about operations management. This enables the learners to send a query and receive a reply in real time when the answer is available in the case knowledgebase. The tutor can also verify learning activity by monitoring interactivity with the agent. When there is no participation over a specific period, the tutor can send a message via the agent to notify the learners before taking action.

7.2.3 The Virtual Environment

In this study, virtual reality technology is employed to create a physical simulation environment for Mandrill's operations processes. One of the objectives is to enable the learners to interact intuitively with the simulation. By immersing the learners in a three-dimensional environment, they understand the concepts and principles behind the simulated operations in a more intuitive way. Several design and software engineering decisions are taken during the course of the research project to reach this goal. This section lists the important decisions and their rationales.

The meaning and relevance of a three-dimensional representation are important considerations for learning effectiveness. In general, the presentation of information in virtual environments can be clear or abstract, simple or complex, relevant or ornamental, and consistent or specialised (Gabbard 1997). Most of the virtual learning environments are based on the nature of the learning tasks. For instance, a simple and relevant world is desirable for business process management, while a medical simulation may require a more complex and ornamental representation. Other characteristics of information stem from the accuracy of representation. These characteristics, which reveal the degree to which the representation accurately represents the entity, are including such as rich or minimal, true to real-world physics or abstract, and dynamic or static.

It is assumed that a higher level of fidelity produces a better learning and training experience, and facilitates training transfer. However, it is not certain that better fidelity will improve learning since it may distract the learner from focusing on the subject that is to be learned. The more abstract representations, however, make fewer computational demands, and reduce visual clutter in the display. In general, simple fidelity that actually facilitates learning task may have much more utility than high-fidelity, true-to-life model (Wilson, Shepherd et al. 2004).

The Virtual World prototype represents machines, workpieces, and the rest of the virtual factory using geometric models. Its factory layout involves the arrangement of the machines and material handling path, and material handling devices involved in manufacturing a product. The artefacts inside the virtual world are represented with a moderate level of fidelity. Figure 7-5 is an example of the artefacts inside the Mandrill's virtual world, the Conomatic machine.

Photo of the Conomatic Machine   3D Model of the Conomatic Machine

Figure 7-5:An example of Conomatic machine in the Virtual World prototype

The Virtual World prototype is based on the spindle assembly cell of the Mandrill simulation. This cell is comprised of eighteen machines consisting of five conomatics, one induction furnace, four grinders, two pressing machines, two broaching machines, and four milling machines. There are thirteen directed operators and three supported operators working in a shift.

In the spindle assembly unit, an electronic truck transports steel bars from the warehouse to a conomatic machine. The operator then feeds the bars at the auto feed unit on the conomatic in which the bars are then parted off into gear spindles. They are then put onto a pallet and moved to the induction furnace for hardening. The hardened spindles are then transported to the grinder to remove abrasion and are brought to the assembly press when finished. Another set of bars is then placed into a large conomatic machine. The parted off workpieces are then cut and broached through the milling and broaching stations. They are then moved to the pressing unit for assembly. Afterwards, the finished workpieces are sent to the stockroom.

Inside the Virtual World prototype, 3D models of the operators and workstations show the interaction of all elements in the cell. The learners need to observe this interaction if they are to understand the system during the navigation. The following figure illustrates the working operations of the spindle assembly cell where the raw material entering into unit operations and unit processes are clearly identified.

Figure 7-6:Screenshot of working operations of the spindle assembly cell in the Virtual World prototype

User Representation

The technical term for representing a user in a virtual environment is “user embodiment”. This embodiment ranges from high fidelity where every sensory level of the user is supported by the system to low fidelity where the system may only support a single sensory level (e.g. visual). In an information- rich environment, a user can be depicting into many different levels such as lifelike appearance, text-only information, or application-specific information. Benford (1996) suggests that the embodiment should be limited to useful and relevant content, detail, and sensory representation.

In Virtual World prototype, users are represented by textual information in the messaging dialog and 3D avatars wearing formal suits with their name floating above. While the textual embodiment conveys the focus of user attention and communication, 3D representations convey basic communication cues such as position and orientation to promote a sense of presence within the environment.

Figure 7-7:User Embodiment in Virtual World prototype

Intelligent Agent Presentation

Another graphical element of Virtual World prototype is the virtual managers that are role-played by the intelligent agents. In the virtual environment, the agents may appear visually, textually, and aurally. Similar to user representation, agent presentation is not limited to a single form, but is dependent on context and user resources. In Virtual World prototype, human facial icons and 2D images are used to represent the intelligent agents. Each of the intelligent agents has its own identity, clearly distinguished by name and appearance. Though simple, this representation is sufficient for promoting a sense of embodiment for non-living objects.

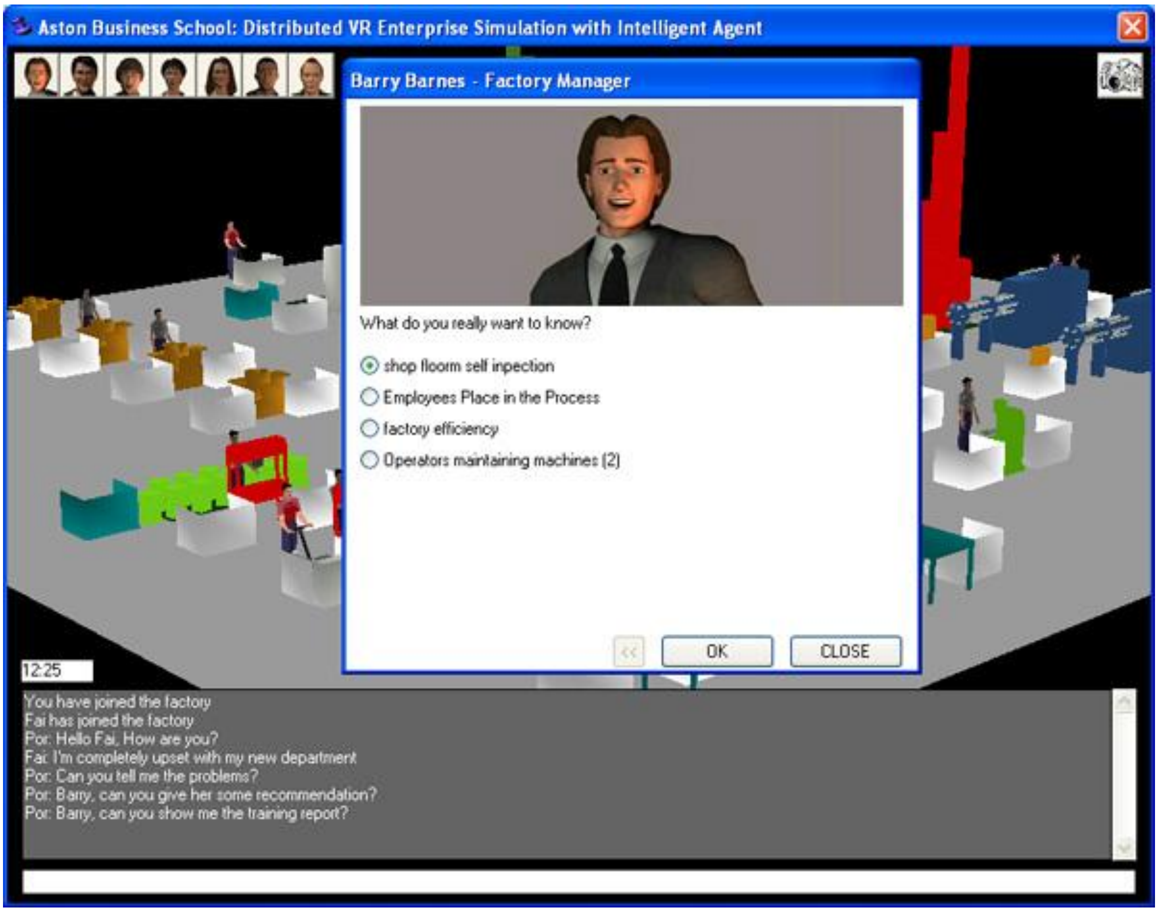


Figure 7-8: Barry Barnes a Virtual Factory Manager in the Virtual World prototype

7.3 Conclusion

Global operations management requires a well qualified and experienced manager to lead quality operations. Achieving this critical requirement brings out the wide range of paradigm shifts in learning and technological revolutions. The Virtual World prototype is one product of such revolution. On technological perspective, the Virtual World prototype derives the greatest possible benefit from various educational technologies (i.e. simulation, computer-mediated communication, artificial intelligent and virtual reality). In considering the value from learning perspective, the Virtual World prototype would provide opportunities for experiential learning and collaborative learning with coaching support under visual learning environment. As a matter of research fact, the Virtual World is supposed to be the best means in delivering a worthwhile globalisation experience.

Chapter 8: System Components of Virtual World Prototype

The purpose of this chapter is to describe the technical elements of the Virtual World prototype. The details include the review of major technical components and the coding concepts. Software tools and system libraries that are required for the interoperability are introduced and explained in the body of the chapter. Although the Virtual World prototype developed in this research is fairly unique, it can be expected to serve as a broad guideline for the development of other virtual world systems, especially those designed for training.

8.1 Virtual World Prototype

A virtual world system may technically be viewed as a distributed system with virtual reality interface. It creates a virtual space where users can virtually be together at the time they are using the system. This research utilises this feature to create a virtual environment for people to practice operations management. The distribution nature of the system allows people who are living in a different place or country to work together. By this, a truly international training environment can then be made possible through a computer desktop.

The virtual world simulates the operation of a small factory and allows a team of people who are physically distributed to interact with the factory and the personnel within it. The team can make decisions that change policies or practice in the virtual factory and can then see the impact of these on the factory's performance. They can interact with personnel in the factory to gain information about what is happening. At the same time the people in the team can communicate with one another too and are provided with a common virtual reality view of the simulated factory, even though they may be located around the world. The system has to provide and manage all these aspects.

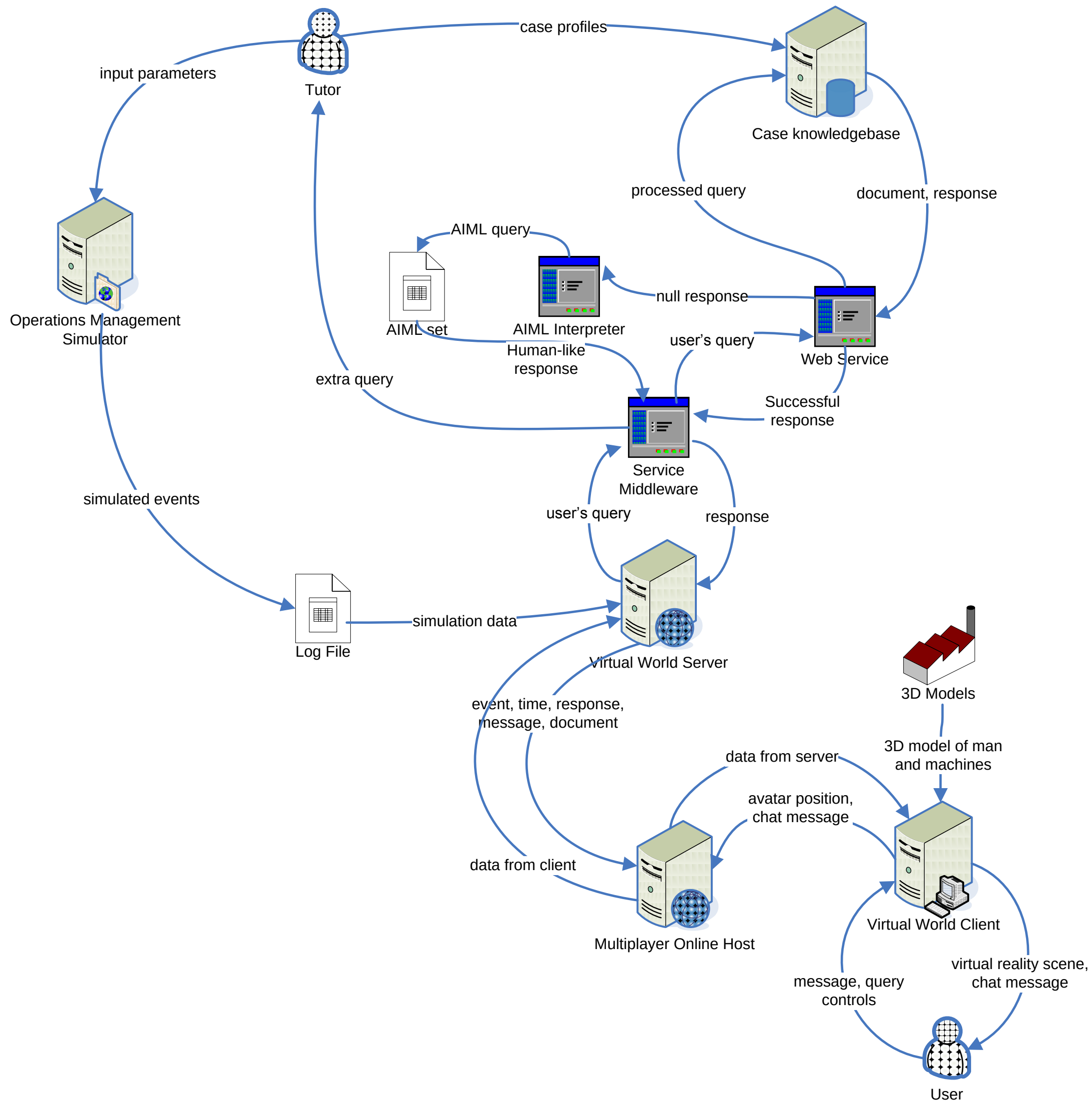


Figure 8-1: Schematic view of Virtual World prototype's architecture

Figure 8-1 illustrates how the Virtual World prototype works. A normal virtual world session requires a team of four to five learners to join into the system. The group leader who controls the session will start a pre-programmed scenario when the team is ready. Each member in the team will get the scene distributed from the leader. The session will continue until the scenario reaches to the predetermined point. During the on-going session, the members of the team can discuss the situation of the virtual factory. They could even visit the factories created by other teams to learn the different in management. Discussion on the different in policy can be made and other learners may read and respond to them. The different in operations such as the number of workers and machines can be seen as if they were on site visiting. They could even learn how to communicate with people in other cultures where English is not the major language. Many possibilities are yet to be explored.

On a holistic view, the Virtual World prototype is constituted of two major modules; the client that provides the user interface and the server that supply services and data. They are constructed by using different types of software tools including existing software modules, modifications of existing software and programs that were specially created. Economy of effort combined with the large scope of the system meant that re-use of existing technology and/or software was employed wherever possible.

8.2 Operations Management Simulator

The factory simulation engine in the Virtual World prototype utilises the ATOMS simulator which was developed by Love & Bridge in 1988. ATOMS is a powerful tool that can enable a learner to understand the operations of a factory. Like other factory simulators, ATOMS has been used to simulate various stochastic operations on a factory floor. One of its features that is beneficial to this research project is the ability to generate detailed log files containing each simulated event in the order of occurrence. These log files can then be processed to generate a virtual environment where the learner can actually see the manufacturing operations. Figure 8-2 shows an example of simulation events generated from ATOMS.

```
01:03  14:22 = UnLoad/Load - W/Station GRIND209 Batch 6 Qty 500 Oper GRIND_OPS
01:03  14:23 = JobStarted  - Batch 6 OP 3 W/Station GRIND209 Qty 10
01:03  14:26 = UnLoad/Load - W/Station GRIND210 Batch 6 Qty 500 Oper GRIND_OPS
01:03  14:26 = JobStarted  - Batch 6 OP 3 W/Station GRIND210 Qty 10
01:03  14:28 = UnLoad/Load - W/Station GRIND209 Batch 6 Qty 500 Oper GRIND_OPS
01:03  14:29 = JobStarted  - Batch 6 OP 3 W/Station GRIND209 Qty 10
01:03  14:30 = EndOPShift  - End Of Operator PRESS_OPS Shift Number 1
01:03  14:32 = UnLoad/Load - W/Station GRIND210 Batch 6 Qty 500 Oper GRIND_OPS
01:03  14:33 = JobStarted  - Batch 6 OP 3 W/Station GRIND210 Qty 10
01:03  14:34 = UnLoad/Load - W/Station CMATIC205 Batch 8 Qty 1500 Oper AUTO_OP_SP
01:03  14:34 = JobComplete - Batch 2 OP 3 W/Station BROACH217 Qty 494 Oper BROACH_OPS
01:03  14:34 = TranCalled  - Batch 2 OP 3 W/Centre PER-BROACH Tran TRUCK Oper MTRL_HDLRS
01:03  14:34 = JobStarted  - Batch 2 OP 3 W/Station BROACH217 Qty 500 Oper BROACH_OPS
01:03  14:34 = JobComplete - Batch 2 OP 3 W/Station BROACH218 Qty 497 Oper BROACH_OPS
01:03  14:34 = TranCalled  - Batch 2 OP 3 W/Centre PER-BROACH Tran TRUCK Oper MTRL_HDLRS
01:03  14:34 = JobStarted  - Batch 2 OP 3 W/Station BROACH218 Qty 500 Oper BROACH_OPS
01:03  14:34 = UnLoad/Load - W/Station GRIND209 Batch 6 Qty 500 Oper GRIND_OPS
01:03  14:35 = JobStarted  - Batch 6 OP 3 W/Station GRIND209 Qty 10
01:03  14:35 = JobStarted  - Batch 8 OP 1 W/Station CMATIC205 Qty 50
01:03  14:38 = UnLoad/Load - W/Station GRIND210 Batch 6 Qty 500 Oper GRIND_OPS
01:03  14:38 = UnLoad/Load - W/Station CMATIC204 Batch 8 Qty 1500 Oper AUTO_OP_SP
01:03  14:38 = UnLoad/Load - W/Station CMATIC211 Batch 4 Qty 1500 Oper AUTO_OP_GR
```

Figure 8-2: Simulation data generated by ATOMS

This research utilises an ATOMS model of one of the cells in the Mandrill operations game (Cell 12) since it fairly represents the nature of a typical manufacturing operation. The scenario of Cell 12 contains many conventional manufacturing activities such as material handling and several machine operations. It also includes events such as machine breakdown, batch production, absent of worker, and temporary job overloads. Also, with various types of machines and different kinds of operators present in cell 12 it helps increase the richness of virtual reality scene.

A log file generated by ATOMS consists of four main parts: time-in, time-out, event, and operational details. Time-in specifies the time when a particular event occurs. Time-out specifies the actual finish time of the event. They play an important role in controlling the sequence of the virtual reality. Event involves operation of the simulated factory. There are many types of event generated by ATOMS such as setting up machine, starting shift, job moving or loading material. These events are eventually translated into virtual reality scenes. Operational details mainly consist of objects such as machines and workers with their properties. Their task is to parameterise the 3D model in the Virtual World prototype.

In the Virtual World prototype system, data in a log file is transmitted to each Virtual World Client (see below) connecting in the same session. The Virtual World Server reads the log file line by line and sends out the event and operational details according to the detected time-stamps. Although this method requires a more complex algorithm in programming than sending the whole log file to each client, it ensures that the scene of the Virtual World is synchronised. For example if a job loading event is sent, every user would see an operator loads materials into a machine through the virtual reality scene created by the Virtual World Client. The group can then discuss the situation under the definite timeframe which may help raising productivity in learning.

8.3 Intelligent Agents

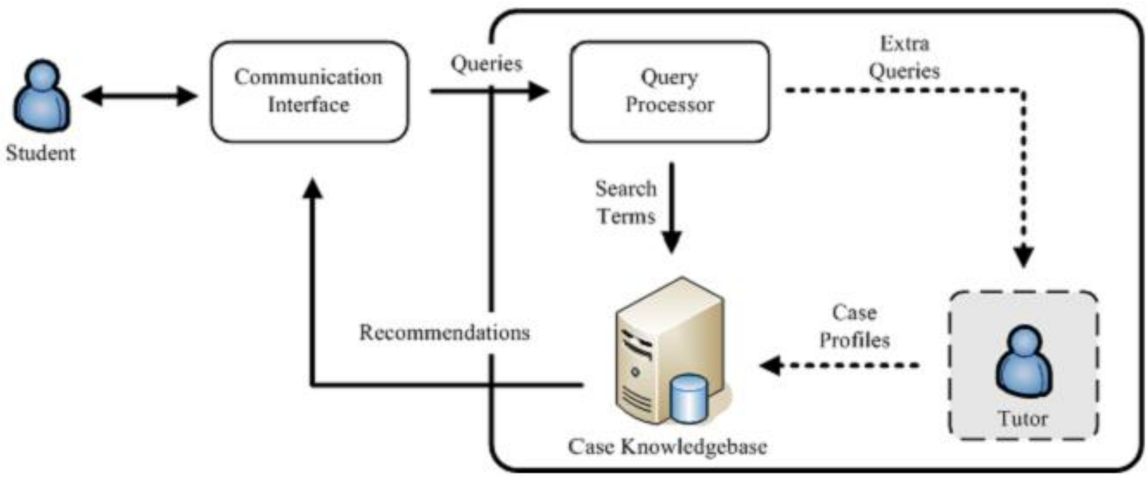


Figure 8-2: Operating model of the Intelligent Agents

Figure 8-2 depicts the intelligent agent architecture in the virtual world system. Among the components of the architecture are the query processor and the case knowledgebase. The query processor receives queries from the communication interface and translates them into a set of computer search terms. This process is done by parsing the words in the passage and scoring them according to the degree of relevance. The case knowledgebase then accepts the search terms and retrieves recommendations regard to the query requested. The recommendations may also contain links to the most relevant documents residing on the knowledgebase. The system also keep track of the knowledgebase by taking advantage of the structure inherent in the architecture since it has been designed to provide a mechanism for the tutor to create and modify the information in the knowledgebase. Hence, the tutor can create case profiles for other courses, while synchronically updating the case knowledgebase in order to respond to a similar question that may be encountered later on. The learners are therefore assured that the system is both timely and accurate.

8.3.1 The Communication Interface

The communication interface that enables the learner to exchange information with intelligent agents is available in many forms and settings. These include a regular email or web client to send and receive messages and attachments to and from the system. In the virtual world, intelligent agents are represented as 3D live conversational partners with a high degree of interactive capability. This type of interface can enhance the learning experience in addition to serving as a user interface.

Also, in the application for the module currently teaching in Aston University, the communication interface is a web client system. The web interface allows the learner to access both background case information and module-specific support materials that relate to the business tasks involved in the simulation. With this type of interface, any learner with a valid account can communicate with the agents without the need for training or special software. This method also amplifies the degree of realism since the communication method is similar to the way people work.

Regardless of the form of communication interface for the system, the core user functions are the same. The interface allows the learner to submit enquiries and decisions to the intelligent agents. However, the query may be addressed to the tutor when a request is for information that does not exist in the case knowledgebase, or when a specific enquiry is made. Such query will be considered as an extra query and will be forwarded directly to the tutor. The interface makes this process almost transparent to the learner except that the learner may experience some delay in obtaining a reply.

8.3.2 Natural Language Processing

As mentioned earlier, a learner would use a web enquiry service forward the requests for decision and the requests for simulation model execution to the agents. The system is designed to process these requests as they are received in a freeform natural language. Natural language processing allows the learner to communicate with the intelligent agents in much the same way as people communicate with company personnel. Thus, in contrast to the conventional computer commands or scripts, this greatly improves the learning experience.

To date, natural language applications for computer-supported instruction are widely used across disciplines. This is because the learner learns more than from conventional classroom materials (Anderson, Corbett et al. 1995). Also, as a human computer interface, natural language can accelerate the interaction between the learner and the system (Johnson 2004). This is also one of the factors that fosters learning and helps learners to build knowledge(Chi, Siler et al. 2001). The natural language system therefore provides a potential benefit, not only in terms of learning, but also in terms of interaction.

There are many topics in natural language processing disciplines. Among these topics are text understanding and machine learning. The query processor built into this system is based on their subset, word scoring, which processes a body of enquiry texts and translates them into computer search terms, so that it can be analysed by the case knowledgebase. In addition, there are several types of word scoring schemes, ranging from standard to more elaborate. The simplest method scores the presence or absence of query words from a document, whereas the most complicated method applies a semantic tree structure that assigns a high score word to a more specific synonym. The query processor built in this system is manipulated on a combined strategy which employs a statistical model of keywords and number occurrence of query words in a subject heading and a body text to determine the degree of relevance. The case knowledgebase will then return the highest-scoring documents.

The query processor is developed by IBM Lotus Notes, an integrated software programme for developing web-based applications. Its system core is based on the Notes high-end enterprise search system architecture. Through Lotus Notes platform migration, it allows broad scalability for functioning across information resources, including text files, relational databases, and other proprietary formats. The requirements for development are to construct the word scoring properties using a configuration form provided by the Notes system. The weights corresponding to the terms are divided into three parts following a heuristic ratio of 5:3:9, which sequentially correlate with the terms in the subject heading, body text and the query words that appear in both sources. The weights of these portions are then averaged to determine the relevancy for the information in the case knowledgebase.

The query processor also includes a thesaurus function which dramatically enhances the keyword searching. Thus, general association among thesaurus terms can be captured from the case knowledgebase. Furthermore, the processor also utilises the word variants command to expand the validated terms that are presented in a different order or in different forms. For example, when the search statement includes a term such as “losing time”, the system will be able to recognise it as “lost time”. So, this improves the ability of the system to match query and the information in knowledgebase and also sometimes improves precision at low recall levels by promoting relevant document to high rank.

8.3.3 The Human Elements

The technical systems of intelligent agents in Mandrill have adopted a human-centred approach. For more than five years, the system has developed the case knowledgebase by examining every query submitted from the learners and by analysing knowledge representation of the domain. However, it still requires more effort in knowledgebase development to automate all aspects of tutoring process. Therefore, in order to optimise operations, human elements are necessary to create the best result.

Fortunately, Artificial Intelligence has developed several approaches. Mixed-initiative Intelligence, for example, integrates a human element into the machine’s problem-solving process. While the machine possesses a great strength in storing and retrieving massive amount of information, humans have a high logical reasoning capability. The benefit is in the combination of knowledge and reasoning, so that the results are better than what either can achieve alone (Meier, Melis et al. 2004).

The Mandrill system consists of two human elements, both of which are essential for the system to operate: the student and the tutor. The student is the system end-user who interacts with the agents in order to receive information or to make a decision. The student investigates the recommendations returned from the system to ensure that they are relevant and applicable to the current simulation model.

Although the agents can respond to most of the requests, some students may require a more specific answer. When this happens, the agent will pass the query to the human tutor who is playing the part of a moderator controlling the backend system. The tutor will then manually process the query and update the case profile to the case knowledgebase.

8.3.4 The Communication System

The communication system combines process support with a task structure mechanism. The process support mechanism is provided through an electronic communication infrastructure, via electronic messaging capabilities through the internetworking communication. The task structure mechanism refers to the information and computational infrastructure that connects the case knowledgebase and computational modules. These two mechanisms increase the effectiveness or efficiency of interacting groups, either by increasing learning participation and active involvement in knowledge construction, or by preventing the difficulties commonly encountered in group learning such as social pressure or information overload.

The communication system in Virtual World prototype has been designed to handle a variety of interrelated approaches to education and training services. For educational role and game playing approaches, the communication system enables multiple users to perform a variety of interdependent tasks. For problem-based learning approaches, the system allows teams of learners to collaborate in problem solving and facilitate teachers or expert in monitoring roles. For learning community approaches based on social-constructivist principles, the system provides the learning environment that stimulates collaboration for sharing of knowledge and resources.

The system also facilitates peer coaching where the learners are supporting each other. These approaches create an innovative pedagogical model and content that are adapted to learning styles of the learners.

Communication among the learners at each networked virtual world station is based on asynchronous text-based communication. Text-based communication promotes the exchange of ideas, the sharing of multiple perspectives, and the creation of interpersonal distance, resulting in an equalising effect on participation. In addition, researchers such as Garrison et al. (Garrison, Anderson et al. 1999) suggests that written communication is closely connected with critical thinking, since the reflective and explicit nature of the writing encourages rigor in thinking and communicating. Further, the time delay and permanence of text-based communication allow the learners to reflect on earlier stated information. This can actually be preferable to oral communication when the objective is higher-order cognitive learning.

8.4 Case Knowledgebase

The central brain of an intelligent agent is its knowledgebase. Generally, a knowledgebase is typically a free-form collection of data which may be of various formats, such as text, pictures, hypertext links, or multimedia objects. It is not as structured as the traditional database which consists of tables made up of rows and columns. The Mandrill's decision history from the teaching course can be viewed as a knowledgebase by this term.

The case knowledgebase is a central repository of manufacturing information that can be used to guide the learner throughout the Mandrill case study (Love and Boughton 1994). It contains several representation schemes such as production rules, control strategies, procedure descriptions and other manufacturing related information. The organisation of knowledgebase allows knowledge reusability which provides valuable benefits when knowledge is required in different situations.

There are totally seven sets of decision history. Each of them is playing an important role in developing an intelligent agent though unique searching algorithms. If the pattern of the words from the users matches with the patterns in the system, the Virtual World client will send a query through the web service. The content of the decision history is then retrieved and sent back to the client if the system does find a match in the decision history. If nothing is returned, the AIML program will generate a response message using it own set of knowledge. This process is completely transparent from the user's perspective.

The knowledgebase is based on the types of intelligent agent. This includes almost all manufacturing functions, from technical to marketing. Intelligent agents use the information from the knowledgebase to simulate human reasoning to generate response entities for a requested query as well as to give advices in some certain circumstances. In a simplified analogy, this service is substantially similar to the service provided by the traditional expert systems. The distinction is that intelligent agents can monitor, collaborate and respond to the changes in the simulation model. In short, this expert system capability can extend the ability of an intelligent agent to play a more active educational role

In this implementation the Mandrill system was extended to provide a web service that could respond to queries sent programmatically by the Virtual World system. If the pattern of the words from the users matches with the patterns in the system, the Virtual World client will send a query through the web service. The content from the memo history is then retrieved and sent back to the Virtual World client by the server. If the system does not find a match in the knowledgebase (see chapter 10 for the performance reviews) the AIML program will generate a response message using it own set of knowledge. This process is completely transparent from the user's perspective.

8.5 Web Service and Service Middleware

One of the challenges in developing the Virtual World prototype is how to create an auto-generated human like message. The users can be fascinated by the response from virtual people. This can be achieved through Artificial Intelligent Markup Language technology (AIML). AIML technology was designed as an XML dialect for creating natural language agent. It was released under an open source license with free AIML knowledge sets. There are also free or open source AIML interpreters available in many computer languages.

The Virtual World prototype integrates the free C# version of AIML interpreter and the basic AIML knowledge sets to the service middleware. This integration helps increase a sense of human-like response during a conversation with the intelligent agents. If a null response is sent from the web service or there is no proper response from the knowledgebase repository, the AIML will generate a message to the Virtual World client with its own knowledge sets. This situation is more often found when the user enters greeting words into the system. If this happens the AIML will simply return a phrase like “I don’t understand the question” or “Can you ask the question in a different way” back to the user. This helps smoothing out the conversation.

For this system, a web service may be perceived as an application interface which can be accessed over the internet. It is primarily designed to support the interoperability of different system on different locations. For the Virtual World prototype, a web service provides two important functions: get a response to an enquiry and retrieve a document on a request. The first function simply returns the content from the decision history. It takes the phrase of words from the Virtual World Client and sends them directly to the knowledgebase repository. If there is a response from the repository, this function will return the response to the Virtual World client. The second function is designed to transfer resources such as documents and numerical data from the repository to the client when they are needed. At the client side, the resources may be converted into textual data and presented directly to the user. The user can use these resources to find information during the learning session.

The middleware is developed using C# programming language. It is required to provide a bridge for the client and the web service. The reason for using middleware rather than developing an embedded function is the technical limitations imposed by the software tool. The main software tool that is part of the Virtual World prototype does not allow any direct communication with the web service. However, it can communicate through the service middleware. In this sense, the service middleware is designed to be a communication tool between the web service and the virtual world client.

8.6 Virtual World Server

The Virtual World server is the data distribution manager of the Virtual World system. It provides several system tasks at a time. The main tasks include managing user connections, controlling communication, and distributing the virtual reality scenes to each client.

When a new user has joined into a simulation session, the virtual world client will report the event to the virtual world server. The server then assigns an online flag to each client, letting them know when a new user has joined into the session. By the same token, the server will assign an offline flag to each client if a user is disconnected. Through this service, the user in each client will recognise the present of other users.

After a certain number of users have joined into a session, they will start a synchronous communication and collaboration with each other through text-based chatting. The Virtual World server centralises the distribution of the chat messages from each client, ensuring effective communication and interaction between the users. In the same way as controlling chat messages from users, the server also monitors the responses that come from the intelligent agents. When the web service delivers a response message through the service middleware, the server will spread it to each client. This enables the discussion both from the users and the agents to be proceeded along the simulation session.

Another major task is to synchronise the virtual reality scene in each client. The process is initiated when the Virtual World server reads a log file and sends out the operational details to the clients. The client then interprets the message from the server and translates them into a virtual reality scene. Along with the simulation states, the message also contains the position of the avatars in the scene. A user can point the destination where his avatar should be moved to. A message containing x, y coordinates is then sent to the server and distributed to each client. By interpreting the messages at the client side, the virtual reality scene populated by users' avatars is synchronically displayed at every client.

8.7 Multiplayer Online Object Host

Virtual World Server is developed using Jamagic, a JavaScript based tool designed for creating 3D application. Jamagic contains several 3D graphical utilities as well as an advanced coding interface that comes with a number of programmable components. It provides a networking component called Multiplayer Online Object which can handle several types of simultaneous communication from a large number of users. The server employs this component to enable the communication within the Virtual World system.

The communication is started when the Virtual World server connects to a Multiplayer Online Object host. In the same way as conventional internet hosting services, the Multiplayer Online Object host returns data on request. The host listens to the request and responses back by using a specific rule defined for each channel. For example, if the request comes from channel 2 where the x, y position of an avatar is stored, the message will be transmitted to every client to update the avatar's position. However, if the request is from channel 5 in which the message from the Web Service is stored, the host will only communicate with the server. The Virtual World system consists of ten channels:

- Channel 0: target x, y of an avatar
- Channel 1: chat message
- Channel 2: current x, y position of an avatar
- Channel 3: simulation events from Virtual World server
- Channel 4: simulation time from Virtual World server
- Channel 5: web service functions
- Channel 6: contents from knowledgebase repository
- Channel 7: extra message from Virtual World server
- Channel 8: query from the user
- Channel 9: documents from knowledgebase repository

8.8 Virtual World Client

The Virtual World client plays a major task in the Virtual World system. It interprets textual data from the system into a visual, virtual reality, form. For example, if an operational detail such as "moving materials between stations" is sent to the clients, it is displayed as a man driving a forklift truck moving materials from one station to another. If a message comes from the case knowledgebase, each client in the system will depict a message with 3D graphic of a manager in the virtual factory. Several computing techniques and tools are required to deliver this requirement.

In broad sense, Virtual World client is constructed as a 3D environment application. Similar to others, the client is built up by welding together the 3D components (e.g. cameras, objects, textures, materials and lights). Typically, a programmer needs to develop a customised 3D engine to handle these 3D components. However, this research utilises the 3D graphical components from Jamagic since it helps accelerating the development. For example, rather than calculating a metric transformation of a camera in a 3D world, Jamagic provides a set of programmable objects that ease such calculation. By providing inputs such as angle and position of a camera, the 3D world is then projected to the user.

Jamagic can import various types of 3D model produced by other tools. This research uses Blender, an open source 3D content creation suit for creating 3D models (i.e. people and machines in the virtual factory). The models created from Blender are then converted into a usable format through Accutrans, a 3D converter program. After the conversion, the 3D models are scaled into a correct proportion by the editor that comes with Jamagic package.

For the agents, a set of pre-rendered 3D graphics is designed and created using a software package called Poser. This software package can depict the human figure with photo-realistic quality. The graphics produced by Poser are imported as images and placed into the Virtual World system to enhance the immersion experience.

Table 8-1 summarises the components and tools in the development of Virtual World prototype

Components	System Role	System Used	Original Author/Tools
Virtual World Architecture	Determines functionality, major components and interfaces	New	Designed by T.S.
Intelligent Agent Architecture	Provides human-like responses to user's query	New	Designed by T.S.
Factory Simulator	Simulates factory operations. The log file generated from ATOMS is directly used as the input for virtual reality	ATOMS discrete event factory simulator	Developed by Love & Bridge, later enhancements by Love
Case Knowledgebase	Contains several representational schemes such as production rules, procedure descriptions and other manufacturing related information	Mandrill's knowledgebase can accept natural language responses that come from students via standard web user interface.	Developed by Love, in Lotus Note
Knowledgebase Web Service	This is an online application interface which is designed to support the interoperability between the Virtual World system and the Case Knowledgebase	New	Developed by Love, in Delphi
Service Middleware	Serves as a bridge between the web service and the Virtual World prototype.	New	Developed by T.S. in C#

AIML Interpreter	Creates human-like responses when nothing is returned from the Case Knowledgebase	New	Developed by T.S. in C# on a shared library file from Program# project
Virtual World Server	Distributes its data among the clients on the network. It acts as a control centre for the entire virtual world system	New	Developed by T.S. in Jamagic
Multiplayer Online Host	Provides multi-player communication services. Employs the Multiplayer Online Object protocol	New	Developed by T.S. in Jamagic
Virtual World Client	Translates the data from the server into a 3D scene. Manages all the user's interface & all virtual reality aspects.	New	Developed by T.S. in Jamagic, 3D objects are modelled in Blender and Poser

8.9 Conclusion

The Virtual World prototype is comprised of various components that require different type of tools and techniques for the development. For this research, the development is conducted on top of an existing system which has been employed in a real teaching course. According to this requirement, the system is specifically designed to have some level of interoperability between the components. Different virtual world projects may require different components for a virtual world system. However, the framework presented in this chapter may serve as a broad guideline for the development of the other projects.

Chapter 9: Logical View of the System Components

The purpose of this chapter is to explain how each component in the virtual world performs its task. The logic flow in the components is simplified and presented in a form of diagram. This mode of presentation provides an abstract view of a system which ignores some system details. Full details of the information can be extracted from the source code provided in the CD-ROM. Other virtual world project may find this chapter useful as a style guideline for developing functions and interfaces.

9.1 System Model

A system model is an intuitive way of describing how data is processed by a system. It simplifies and picks out the most salient characteristics about the entity being represented. This type of presentation can be used to show the principal activities and deliverables involved in a process. It contributes directly to the identification of operations on these components.

In general, a system model is based on computational concepts such as objects or functions. Nodes in the model represent entities in the system such as processes, functions or types. Links represent relations between these design entities such as calls, uses and so on. These representations altogether can show how system exchanges information.

9.2 ATOMS Simulator

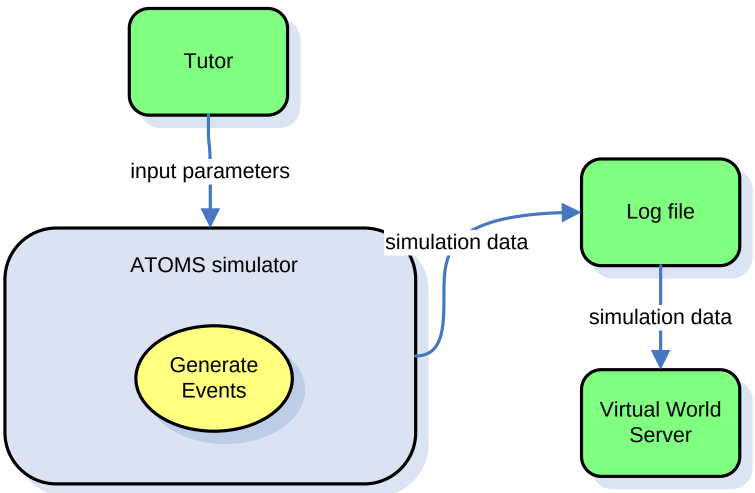


Figure 9-1: Logical View of ATOMS Simulator

Virtual world prototype takes a log file produced by ATOM simulation system. Since ATOM is developed by external developers as a complete system, it is treated as a black-box module that supplies operations to the system. In this diagram, numerical data that represent the working environment of Cell 12 are supplied as inputs. Simulation states are generated as a text file which can be used directly with the virtual world system. (see the Appendix for the numerical data that represents cell 12 operations)

9.3 Case Knowledgebase

Case knowledgebase is also produced by external developers. Since the system environment is covered by commercial standard, the system functions are assumed to have sufficient quality for virtual world prototype. However, the performance of the knowledgebase is vitally important for the quality of intelligent agent. Therefore, a separate evaluation is conducted to measure the performance of the system. The methods and results of the evaluation can be found in the next chapter.

9.4 Web Service and Service Middleware

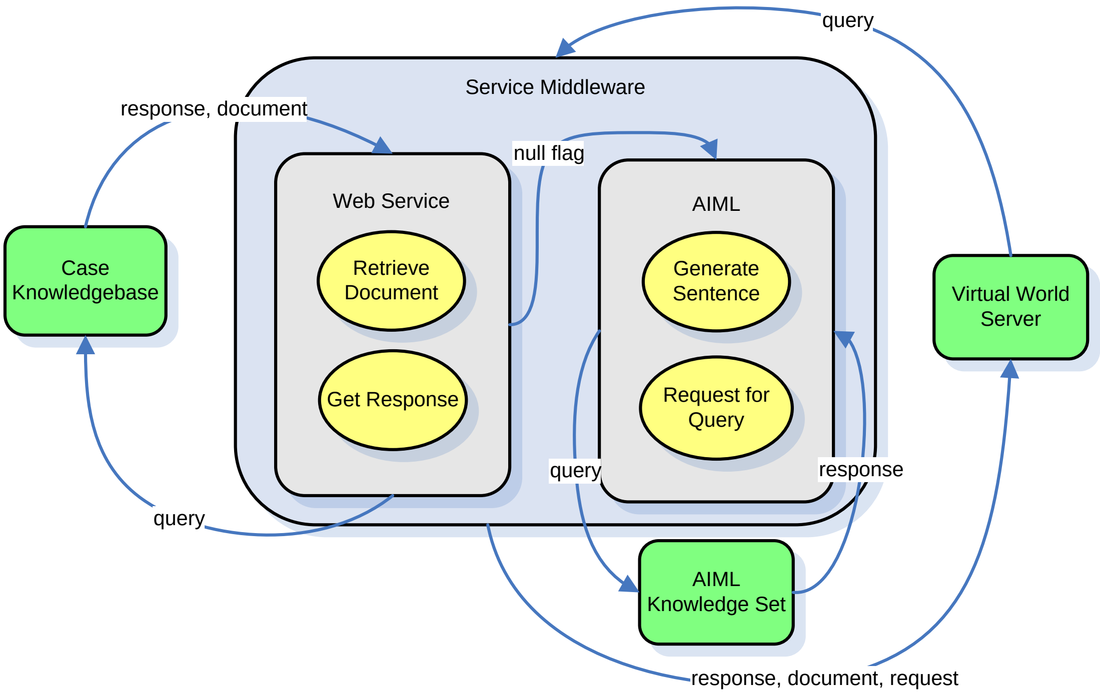


Figure 9-2: Logical view of service middleware and related components

The web service and service middleware is an integration of technical components that provides a computing response in a human-like manner. The process is started when the virtual world server transfers a query from its client to the service middleware. The middleware then forwards a request to the case knowledgebase and waits for a response.

There are four types of response that may be returned from the case knowledgebase. The first one is a list of subjects that may contain a legitimate answer. This type of response is needed for seeking clarification from the user if more than a single answer is possible. The second type of response is the answer to the query. It can be displayed directly in the virtual world client. The third type a document file. A document from the case knowledge base is converted into textual format which can then be displayed in the virtual world client. The last type of response is a flag indicating a null result. This normally occurs when the query such as greeting words is sent into the system. When the null flag is sent, AIML is set to operate.

AIML contains an expansible set of knowledge files. When the null flag is sent, the AIML module will find the best answer that match the query. The virtual world prototype includes more than 10,000 sets of knowledge which would cover all day-to-day conversation. If the AIML module fails to match up the query with its knowledge set, it will generate a sentence requesting a user to pose the question in a different way.

9.5 Multiplayer Host

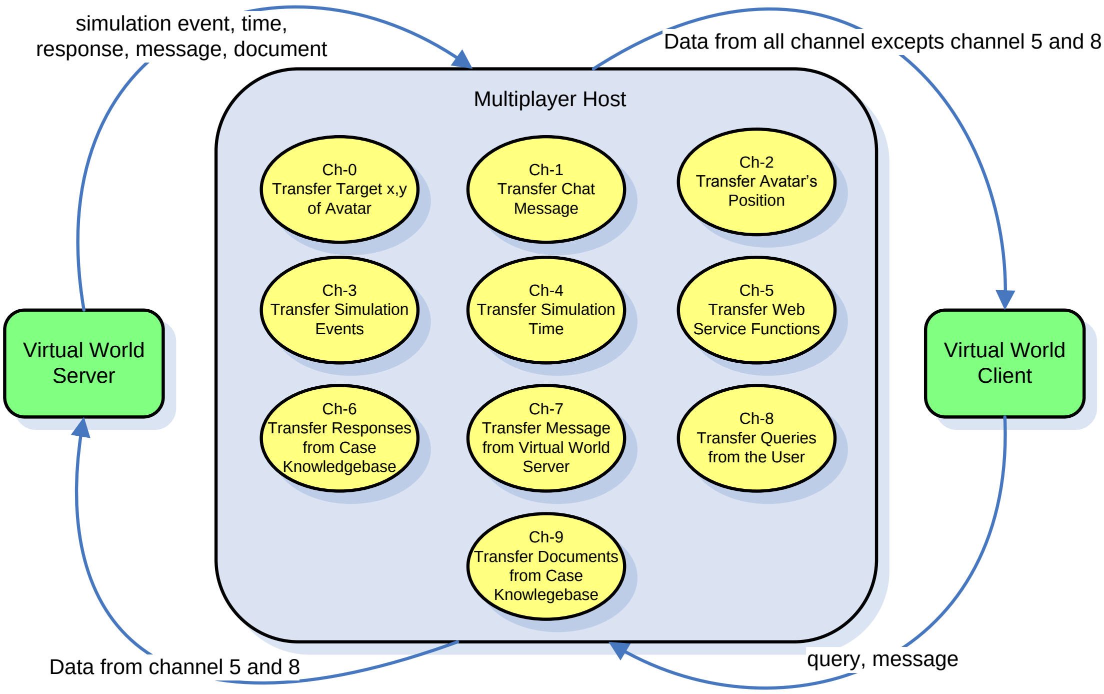


Figure 9-3: Logical view of multiplayer host

Communications in virtual world are transmitted through abstract channels defined in multiplayer host. There are ten channels that serve communication tasks between the virtual world server and its clients. When a user determines a new position of an avatar, the target coordination numbers are sent through channel 0. Every virtual world client in the same session will update the avatar's position according to the numbers that are transmitted from this channel. Channel 1 is for transmitting chat messages. The data transmitted in this channel will be displayed in the chat window in each virtual world client. For channel 2, its purpose is similar to channel 0. However, instead of target position, the current position of an avatar is transmitted whenever requested by other clients. Channel 3 and 4 are used to transmit simulation data to the virtual world client to construct a virtual reality scene. The rests are to facilitate communication between virtual world system and the intelligent agents. The function of each channel will be mentioned in detail in the virtual world server and client section.

9.6 Virtual World Server

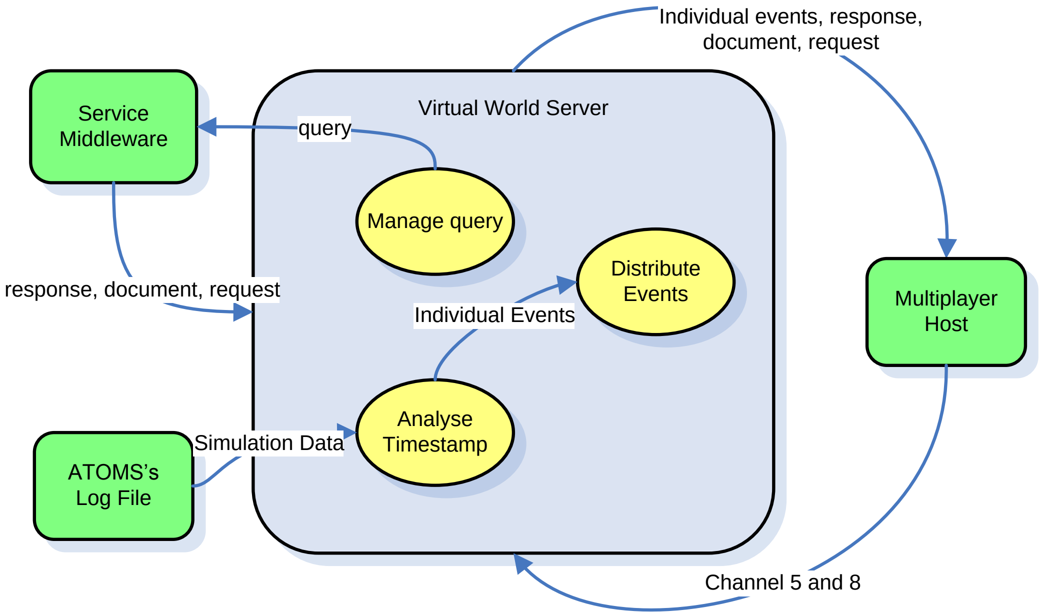


Figure 9-4: Logical view of virtual world server

Virtual world server separates the collection of events into an individual one by using the timestamps on each event. When the time in the system clock is reached, an event is distributed to its client. This process is automatically done using an internal clock system. The clock can be adjusted to satisfy synchonisation requirements.

Another major function is to control the communication within the virtual world system. Each message that is sent to the server is classified in to channels. Most of the messages are sent back to virtual world client (i.e. chat message, position of an avatar, and simulation events). System messages such as a query to an intelligent agent are forwarded to the service middleware for further processing.

Virtual world server accepts commands from the multiplayer host when it is transmitted through channel 5 and 8. When the data is received from channel 5, the server will send a special command to the web service routine, requesting for response to the user's query. If the data is received from channel 8, it will send a request for a document from the case knowledgebase.

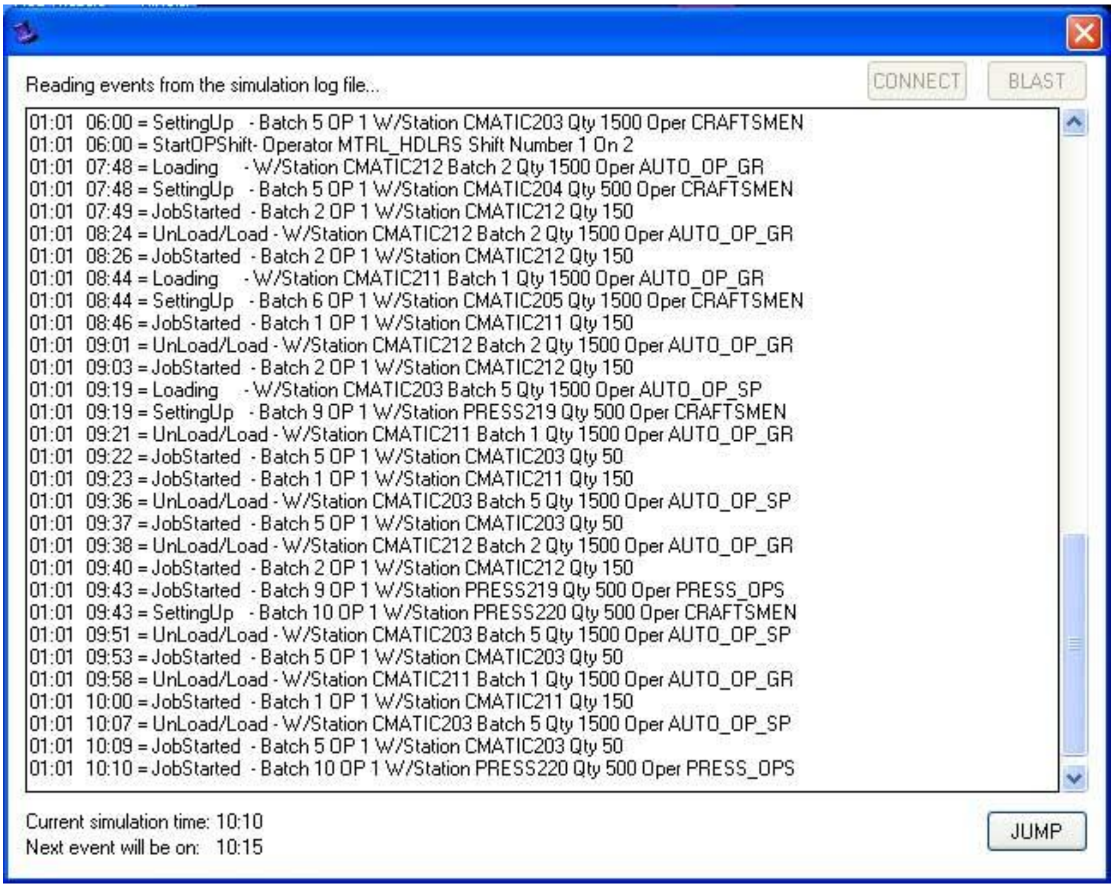


Figure 9-5: User interface of virtual world server

The user interface of virtual world server consists of an event window, status bars, and control buttons. The event window shows the current simulation state from the log file. The display is moved up when a new event is read into the system. The status bars at the bottom of the screen reports the current event that is being transmitted. There are three buttons that provide the basic controls over the virtual world. The ‘connect’ button establishes the connection with the multiplayer host. The ‘blast’ button distributes the event to every virtual world client connecting to the server. The ‘jump’ button forces the next simulation event to be sent to virtual world clients.

9.7 Virtual World Client

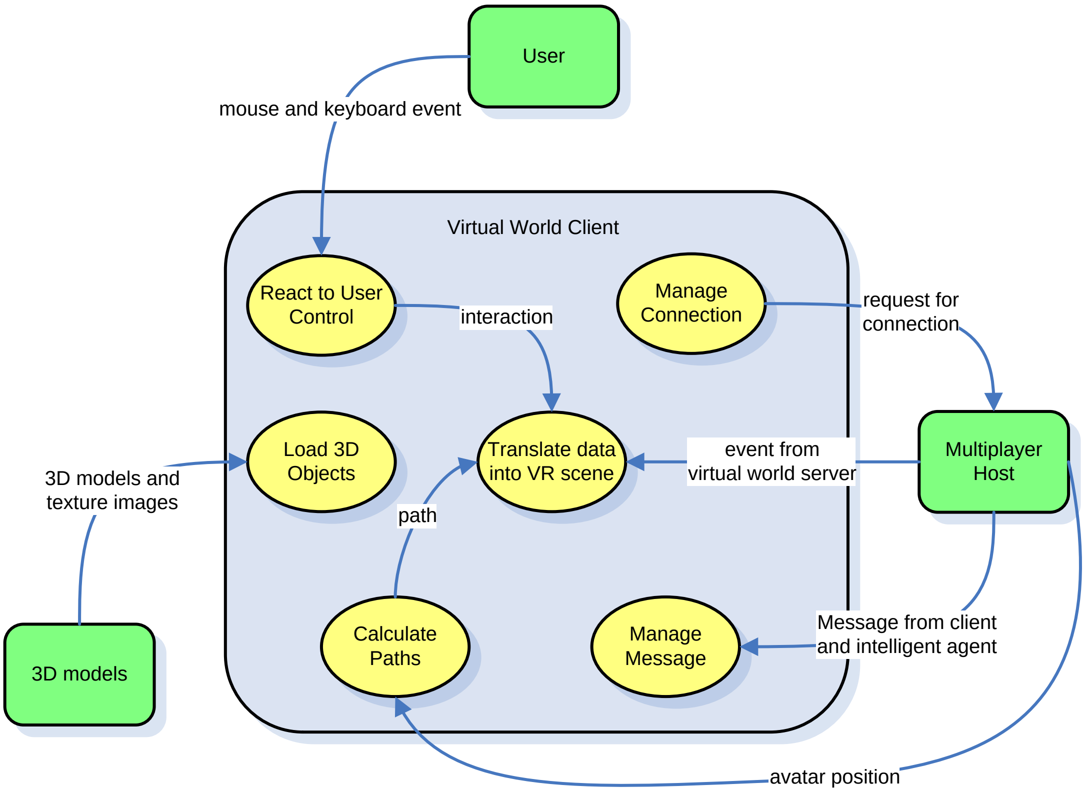


Figure 9-6: Logical flow of virtual world client

Virtual world client is a complex piece of software that is developed by around 6,000 source lines of code. It is constructed by using different type of programming techniques such as network programming, artificial intelligent programming, and 3D programming, all in a single application.

Virtual world client is initialised by loading 3D objects into its memory. These 3D objects include world, cameras, points, and artifacts. The world is a term commonly used in 3D application to describe a 3D environment. For virtual world prototype, the world is projected outward by two cameras. The first camera provides an isometric view of the virtual world. A user can adjust his view and position of the 3D world by changing the angle and the position of the camera. The camera can be moved under mouse controls such as clicking and dragging. The second camera is designed to provide a walk-through view. With this view, the camera acts as the eyes of an avatar. A user can use the arrow keys on a keyboard to move his avatar to see different views of the virtual factory. The two cameras are linked to a 3D point. When a point is added in a 3D virtual environment, it provides a reference of a position. The camera defines it position by referring to the distance between the point and itself.

Zooming means decreasing and increasing the distance from the point. Rotating the view means orbiting around the point. This technique significantly eases programming complexities.

The rest of the 3D objects are artifacts, which are the object that are visible to the user. They are the light source, blobs, and sprites. The light source provides a direct source of illumination. The virtual reality scene cannot be visible without a light source. Blobs are 3D plains that can embed textual data or images on themselves to provide information. The virtual world client employs blobs to represent the states of machine (e.g. machine is working, broken, and being repaired). Sprites are 3D objects that populate the scene. They are machines, workers, forklift trucks, user's avatars and all other props. The scene is created by composing these 3D objects and projected outward to the user through the cameras.

Sprites in the virtual world are composed of several polygon meshes and texture images. A polygon mesh is a collection of edges, vertices and faces that shape a model. A texture image provides the appearance of the model's surface. Textures are mapped on the model to make it looks real. The resolution or the quality is highly dependent on the details of its shape and texture. However, higher resolution will need a greater computing performance to render a scene. For the virtual world prototype, the sprites are designed to optimise for performance. With this design, the virtual world client can be working any recent computer.

Since each server has a unique simulation profile, the apparent of virtual factory will also be unique. The 3D scene is built based on an event sent from the virtual world server (through the multiplayer host). Some events simply change the state of 3D objects in the scene. The other may produce a complex animation sequences. For example, a simulation event such as setting up a machine will produce an animation of a worker who is busy working on a machine. When an event related to job moving is sent, the worker will walk from one machine to others. This simple concept requires a specific artificial intelligent module called path finding to create the outcome.

The primary task of path finding module is to find the route between two points. A virtual worker needs this module to calculate a way to walk, so that it can avoid other 3D sprites such as machines and user's avatar. This study employs A*

Algorithm since it is fairly flexible and can be used in a wide range of contexts. This algorithm gives scores to the path by calculating the path cost. An object will follow the lowest score path until the goal is reached. (see Pathfindingobjectv3.8.3dd in the CD-ROM for more details)

In addition to object moving from a point to another point, animations are also performed by the movements of a 3D object. In contrast with 2D animation where a sequence of images represents the movement, 3D animation uses a technique called interpolation. Interpolation can be handled many ways to create different kinds of movement transitions. This technique varies from a relatively simple type such as the resizing or the rotating of an object, to a more advanced one such as rigging and binding the object. The virtual world client applies the rigging technique to produce the animation.

Rigging is the process of setting up the controls on a 3d model to allow it to move and by animated. In most cases, a skeleton is required to set up a rig. A skeleton comprises a hierarchy of joints that disperse throughout the model. The joints act as a structure on which animation can take place. Animation for all virtual human (i.e. avatar and worker) is manipulated by rigging technique.

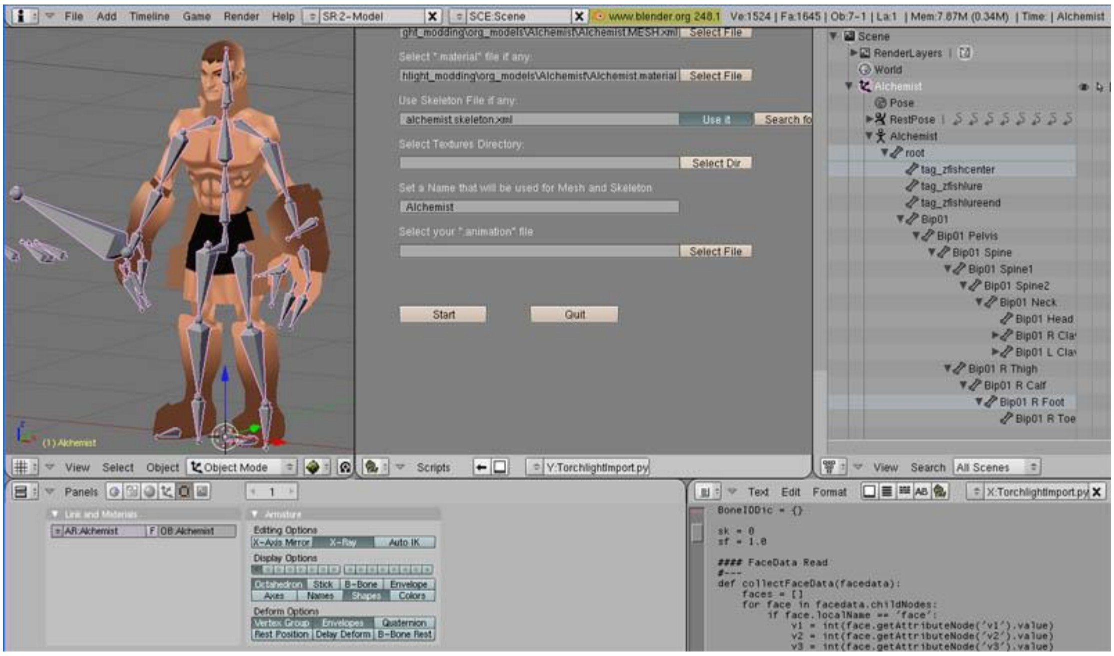


Figure 9-7: Rigging technique in virtual human modelling

When the initialisation process has been completed, a user will select a server he wants to join. The virtual world client is designed to provide at most thirty concurrent connections in a simulation session. In many cases, too many connections will result in system hanging or failing. This is necessary to prevent such damage. Therefore, if a team of five students is set, up to six teams are allows to be joining into the same session.

Users in the same server can communicate with others who are connecting at the same time. Messages can be transferred via the interface provided, through a channel of the multiplayer host. They will be displayed in a shared chat window. When a simulation data is received, the client will update the scene based on the data. Since all clients in the same session will receive the same set of data, the scene will be synchronously updated. These features, when brought together, allow the user to discuss an event that occurs during the session.

As mentioned earlier in the multiplayer host section, there are ten channels being used for the virtual world system. All but channel 5 and 8 are involved with the virtual world client. Different actions are produced according to the number of channels:

- Channel 0: moves an avatar to the target location
- Channel 1: displays a chat message in the shared chat window
- Channel 2: creates an avatar at the target location
- Channel 3: translates the data into a virtual reality scene
- Channel 4: updates the simulation time
- Channel 5: not available
- Channel 6: displays the intelligent agent dialog box
- Channel 7: displays an extra message from server in the shared chat window
- Channel 8: not available
- Channel 9: displays the document received from intelligent agent

The user interface of virtual world client contains a shared chat window, a virtual reality window, a collection of intelligent agent command buttons and a button to capture the virtual reality scene. The user can send a message by typing in the text filed. When the Enter key is pressed, the message is delivered to every member who is connecting with the same server. This feature facilitates meaningful communication between users.

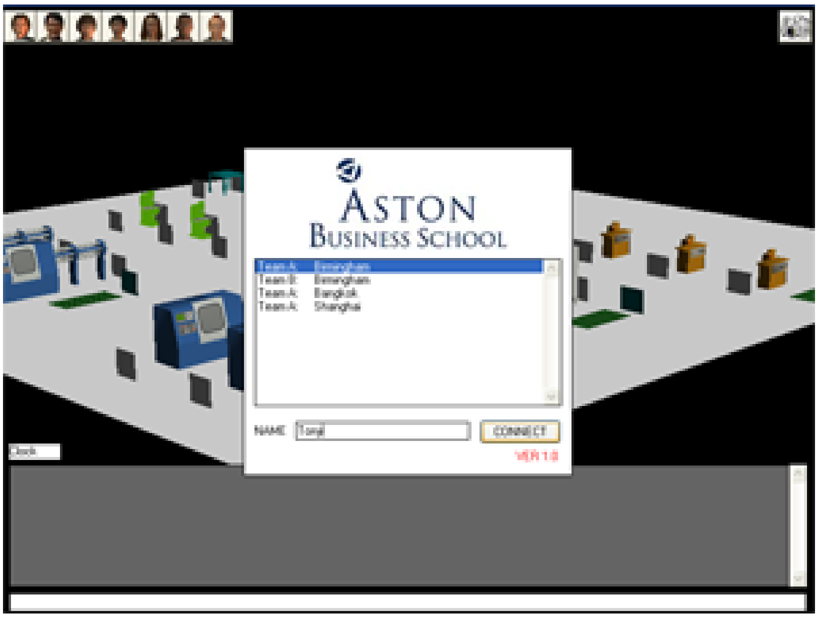
Figure 9-8: Screenshot of virtual world client

The virtual reality window presents the operations of a factory in the virtual world. A user can rotate, zoom, or move the scene to see the operations being discussed. If the user places his mouse on a 3D object for a while, the data of the object is then presented to the user. For example, if the mouse is placed on the raw material queuing for the process, the quantity is then displayed on the screen. In the same way, if the user wants to observe what operations are currently performing by a virtual worker, he can see the information by getting through this process.

The collection of buttons on the top left of the virtual world client is for accessing the intelligent agents. A user can press a button to call up a dialog box containing responses from the agents. When a response is returned from an intelligent agent, a button is flashed rapidly to notice the user. The user can press the button to view the response or see a document returned from the agent.

There is also a button with a camera icon on the top right of the client. This button provides a function to capture the virtual reality scene. This function greatly benefits the user for creating a document. The image captured can then be pasted directly into a word processor.

9.8 Example of the Working Environment of the Virtual World Prototype



The user has to select a channel before getting into the factory. Members from the same team normally select the same channel, unless they plan to visit other teams. This feature enables a creative activity such as international field trip to be done easily. Multinational team can also be formed using this feature.

After logging in to the factory, the user is represented by an avatar (a type of graphical representation of a user). This kind of user representation can enhance learning since users normally feel like they are really standing in the factory.

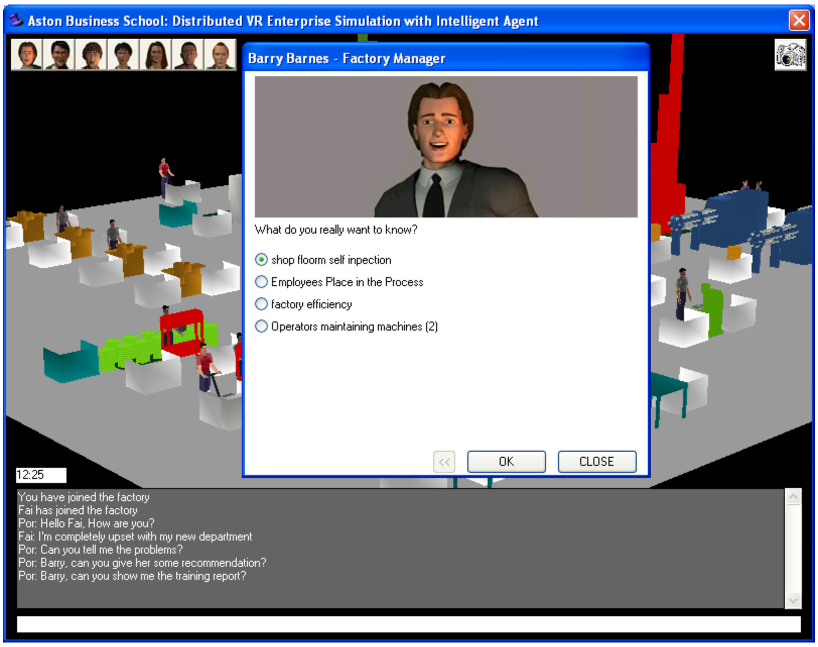
When the team members or other users have successfully logged in to the virtual world, their avatars appear.

The user can communicate with each other by typing text. The text is appeared to every user who is in the same channel. Through this feature, the user can share the idea and knowledge with each other.

The Virtual World server controls all of the object and events in the virtual world. The way the machine works, the way the operator acts, machine breakdown, everything is controlled by the server.

The Virtual World client interprets the data received from the Virtual World server and translates them into graphics. For example, the number of raw material is translated into blocks as illustrated in the above figure. If there is an issue in the process, the user can detect it easily.

Graphical representation of information is more likely to develop a better understanding. Even user who has less experience in manufacturing system can understand what is going on in the factory.



With the help from intelligent agents, the process of learning can even be performed more smoothly.

Chapter 10: Preliminary Investigation of Virtual World Prototype

The goal of this chapter is to evaluate the potential of the Mandrill Virtual World as a learning environment for global operations management. The context of the evaluation is covering two broad topics, the evaluation of the performance of the intelligent agents and the preliminary investigation of Mandrill Virtual World. The intelligent agent is one of the four core technologies that play a key role in articulating and transferring knowledge to the learners. Since its performance has a direct influence on the learning process, it needs a critical evaluation. The chapter begins with an investigation of the performance of intelligent agents using a number of quantitative measurement methods from the information retrieval discipline. It then describes a series of aspects, referring to the performance characteristics of the Mandrill Virtual World. These preliminary investigations indicate that virtual world technology can support learning about global operation management.

10.1 Performance Evaluation of the Intelligent Agents

This evaluation examines the efficiency of autonomous agents in their managerial tasks. In this evaluation, a test collection of 35 queries and 567 responses is developed. The queries are based on judgement sampling technique from 308 queries that were sent to the system by final-year students in previous academic years. The relevance of each response is judged by a tutor with considerable experience in teaching this module.

Several quantitative measurement methods in the information retrieval discipline are applied here to demonstrate the performance and effectiveness of the agents. The evaluation metrics are precision, recall, specificity, efficiency and fallout (Hersh 1995). Precision is the fraction of information retrieved which is relevant to the query. Precision is applied in this evaluation to measure the accuracy ratio of intelligent agents in returning relevant information from the case knowledgebase. Higher degree of precision means the information returned is usually more useful to the student. Likewise, recall is the fraction of the relevant information retrieved over the number of relevant information in the entire knowledgebase. It determines the performance of the intelligent agents in discovering and passing relevant information to the student. The degree of recall is lower if the agents overlook some of the relevant information, leaving the student unaware that more is available. Specificity, however, is used to measure the system's ability to reject irrelevant information. It refers to the proportion of non-retrieved information among all irrelevant information. Specificity is involved in the experiment when the query takes the form of non-systematic or natural language expression. Further, efficiency is applied to see how well the agent recognises the information that is deemed relevant to the query. The relationship between recall and precision is normally not very straightforward in the information retrieval system. Efficiency can be used to measures the indirect relationship between the two. If the degree of efficiency is high, it means the agents perform well. Lastly, fallout is another parameter of performance evaluation. Fallout is the fraction of the irrelevant information retrieved among the irrelevant information in the entire knowledgebase. In this evaluation, fallout is applied to measure the tendency for the agents to choose incorrect information as the amount of information increases. Lower degree of fallout means the agents produce fewer errors when retrieving information. Table 9-1 presents the quantitative results of the analysis conducted on the intelligent agents in the Mandrill System.

Intelligent Agent Roles	Precision	Recall	Specificity	Efficiency	Fallout
Technical Manager	37.90	53.67	97.86	51.53	2.14
Factory Manager	56.67	90.00	96.15	86.15	3.85
Finance Manager	69.67	80.00	93.16	73.16	6.84
Personnel Manager	26.44	50.56	96.68	47.24	3.31
Purchasing Manager	46.00	60.00	97.54	57.54	2.46
Quality Manager	43.33	45.71	99.25	44.96	0.75
Sales & Marketing Manager	60.00	80.00	98.78	78.78	1.22
Average	**48.57**	**65.71**	**97.06**	**62.77**	**2.94**

Table 10-1:The effectiveness of the intelligent agents under the precision, recall, specificity, efficiency and fallout ratio

There are 35 queries in the test set. These responses are generated automatically by seven agents, which are logically divided by function in a manufacturing system. All of these agents can derive relevant information at approximately 48.57% of precision and 65.71% of recall on average. In relation to this, the degree of overall efficiency they could achieve is 62.77%. In other words, when five responses are returned from the agents, two or three of them will have been able to process the request.

Furthermore, the agents can reject irrelevant information at approximately 97.06% of specificity with only 2.94% of fallout. This means that most of the inapplicable documents will not be returned to the students. Note that in this experiment, the samples selected for investigation include the queries that have expression errors commonly produced by the students. These errors include misspellings, incorrect punctuation and inappropriate entry of queries. The results displayed in the performance metric are therefore close to what would be achieved in practice.

10.2 Preliminary Evaluation of Virtual World Usability

This study constitutes a first step in evaluating the potential of the virtual world technology as a learning environment. Considering the immature state of this technology, this assessment will focus on the potential usefulness of the system. By considering both the technological diversities and multidimensional modes of learning, several technical, orientation, cognitive, pedagogical, and other aspects are included in this evaluation. The technical aspect is concerned with technical usability issues regarding the system environment in term of hardware and software and with the efficient design of the user interface. The orientation aspect focuses on the relationship between the learner and the virtual learning environment. This includes the competence of navigating within 3D space, the degree of presence and immersion, and the expression of comfort or discomfort in an environment. The affective aspect is centred on the level of engagement, preference, and confidence in completing the assigned task. The cognitive aspect is involved with the learners' attitude and internal concepts based on experience and feelings while using the virtual world. The pedagogical aspect concerns ability to construct the knowledge in the context of collaboration among learners.

The preliminary study sessions are conducted with 20 Thai participants from a combination of business educational backgrounds. Five of them are graduates of engineering programmes and who possess a good knowledge and experience in production and operations management, another ten participants are graduates of business schools, while the remaining five have degrees in areas such as law, medicine, and computer science, but they also have a basic knowledge of business management. Around half of the participants graduated from universities in western countries in which English was the language of instruction; the other half can communicate in English but have problems expressing complex concepts. All of them have considerable experience with online communication environments in using instant messaging applications and with 3D virtual environments in playing computer games. The participants were divided into four groups of five, on the basis of their background knowledge.

The experiments were split into two successive sessions in which the two groups were presented with the paper based Mandrill case study in the first session; follow by the virtual world in the second session. The other two groups were assigned in reverse. The paper based Mandrill case study comprises of the process performance sheets of the spindle assembly cell and plant documentations illustrating the organisation structure, factory layout and process descriptions. The same performance sheets were provided to the participants when they were in virtual world session but the plant documentations were omitted.

The participants were instructed to develop a collaborative scenario in managing the operations through role playing as international managers using English as a means of communication. In the experiment session, they were asked to provide strategic decisions based on aspects of global operations management. The decision guidelines and a decision form were provided at the beginning of the session to help the participants to identify the area in which they were to make a decision. In the paper-based session, the participants were assembled in the same room, while in the virtual world session, they collaborated remotely from separate locations. The participants were given 30 minutes in each session to complete the collaborative task. The evaluation includes reading documents, observing and analysing the operations process, and making decisions. After completing the experimental sessions, the participants were asked to fill in the questionnaire, describing their experience with these two learning approaches.

In collecting information on both student response and system usability, this evaluation used three information gathering techniques. First, an opinion survey was created on a structured questionnaire. Second, informal observations from the investigator were conducted throughout each experiment sessions. Last, the quality of decisions made by the participants. These data sources revealed different facets of the process.

The 20 participants completed an opinion survey comparing their experience in the virtual world environment to the traditional Mandrill case study. The questions were designed to elicit reactions based on the theoretical framework. Two types of question were asked: open ended and Likert-type items along a 7-point scale. The 7-point Likert scale is selected to obtain more variability in responses. Higher scores indicate greater likeability of the training environment. Below are the quantitative results from the participants.

Questions	**Case Study**		**Virtual World**	
	$\bar{X}$	s	$\bar{X}$	s
To what extent did you sense the global operations atmosphere during the experiment? (1: Low 7: High)	3.05	1.43	5.95	0.69
With what degree of ease were you able to understand the concept of global operations? (1: Difficult 7: Easy)	2.95	1.54	5.50	1.15
How completely were you able to investigate or explore the global operations processes? (1: Incomplete 7: Complete)	2.45	1.32	5.55	0.89
With what degree of ease were you able to critically analyse or identify the issues in the global operations processes? (1: Difficult 7: Easy)	3.20	1.47	5.55	1.39
How sufficiently were the training processes correspondences to reality? (1: Insufficient 7: Sufficient)	2.40	1.14	6.00	1.12
To what extent did you learn new techniques that enable you to improve your performance for global operations management? (1: Low 7: High)	3.20	1.11	6.00	1.34
How productively were you able to formulate the decision about global operations? (1: Low 7: High)	3.55	1.28	5.55	1.15
To what extent did you feel confident in expressing ideas regarded on global operations? (1: Low 7: High)	3.30	1.22	5.85	1.27
How much preferable to the training methods would you like to practice the global operations training? (1: Low 7: High)	2.40	1.27	6.35	1.42
Do you agree that without Virtual World technology, studying global operations management is highly difficult if not impossible? (1: Disagree 7: Agree)	$\bar{X}$ 5.85		s 1.04	

Table 10-2: Quantitative Results from the Survey

The survey also asked an open-ended question about virtual world technology. The answers to this question are reviewed and summarised in the following sections.

10.2.1 Technical Aspects of the Virtual World Prototype

Although the technical issues concerning the use of Mandrill Virtual World were not the primary focus of this study, numerous observations were made during the experiment sessions. As a result of the informal observation, the integration between simulated data and the system was highly consistent. The participants had no difficulty in learning how to use the interface to complete the task assigned. Their susceptibility to simulation sickness and physical fatigue was not presented. However, the participants enquired a more detailed animation of the machines as well as a more realistic graphic presentation for the whole virtual environment. Participants did not report any message delay on the communication site. They had no difficulty in using text messaging technology to communicate with each others while completing the collaborative task. Additional features such as the use of voice as a means for communication was needed. For the intelligent agents, although the performance described in the previous section looks highly promising, most of the participants were dissatisfied with the agents' responses. However, the interaction between the agents and the participants was highly natural. Based on overall technical acceptability from the evaluation, the current virtual world system can be justified as technically feasible to support collaborative learning and training for global operations management.

10.2.2 Orientation Aspects of the Virtual World Prototype

The orientation aspect focuses on the relationship between the user and the virtual environment. A good orientation can optimise the instructional effectiveness and increase user acceptance (Zaphiris and Zacharia 2006). Informal observations revealed that the participants had no difficulty with the virtual environment when the simulation was running. They also behaved as if they were managing a factory instead of working with a computer programme. Collaboration among students was very successful, and resulted in strong group bonding. On the survey side, the raw average is relatively high on the sense of being in a global atmosphere, nearly two times of the same sense perceived in the traditional case study. Regardless of whether the sense provided is accurate, this result indicates a significant potential of the virtual world in providing an international economic working environment. In terms of navigation, the participants were able to investigate or explore the operations processes more completely with the virtual world than with the case study. This response has confirmed the fact that the graphical representation allows easier interpretation of the business process (Lindemann 2003).

10.2.3 Affective Aspects of the Virtual World Prototype

Affective factors such as encompassing interaction and engagement are among the most important educational benefits of virtual reality and associated technologies.

The more degree of interaction and engagement generally lead to a better performance on learning. As expected, responses to survey questions showed that the virtual world was ranked high amongst the training preferences. The virtual world averaged 6.35 out of 7 when the participants were asked which training methods they preferred. At the same time, the case study was not their favourite method. The participants also felt more confident when expressing the ideas in the virtual world. They agreed that without the virtual world, studying global operations management would be very difficult. Moreover, during the investigations, all participants were extremely motivated by the technology. They showed extraordinary eagerness to enter the virtual world, even after the experimental session ended.

10.2.4 Cognitive Aspect of the Virtual World Prototype

Technological aspects affect the way in which the virtual world could support training and learning. However, the cognitive aspects are more relevant to the learning process. Although the Mandrill simulation system does not include aspects for global operation (i.e. government policies, natural resources, and other international infrastructures), the understanding of global operations management was established in the virtual world. For the preliminary investigations, a sound strategic plan for international operations such as "involving staff for collaborative culture building and decision making" was established by the participants. The other responses such as "The labours should be trained to use the machine properly and learn how to maintain the machine which makes a machine to last longer and perform well", while not directly related to the global operations, are imperative for managing the operations. The participant rated 5.5 points for the degree of simplicity to comprehend the concept of global operations. In addition, they agreed that conducting analysis and identifying the issues is simpler in the virtual world than it is with the case study. They also thought that formulating the decision about global operations under the virtual world is more productive than in the case study.

10.2.5 Pedagogical Aspect of the Virtual World Prototype

On the pedagogical aspect, the participants believed that they learned more techniques for managing global operations with the virtual world. This might be because they could better understand the concept when it was represented in a virtual environment. On the observation side, the participants demonstrated rapid comprehension of complex concepts and skills. They reported that they gained more understanding of multicultural working environment by working with their virtual international co-workers. They also agreed that the use of intelligent agent in the environment was pedagogically effective with regards to collaborative role playing. In general, they agreed that virtual world technology provided a successful learning experience.

10.3 Conclusion

These studies offer only preliminary observations in using virtual world technology to support learning in global operations management. They may serve, however, as a base for further exploration of design issues in virtual learning environments for education. In this study, the virtual world is comprehensively evaluated under different aspects of learning. On the technical front, the virtual world technology prohibits its use in learning how to manage the global operations, both efficiently and economically. On the educational front, the virtual world can be used to support learning process in such a way that they become cognitive partners with the learners, instead of just serving as mere devices to deliver traditional instruction. This indicates that perhaps the virtual world may approximate a natural medium to support learning in global operations management and in related areas.

Chapter 11: Conclusion and Further Research Directions

The research has described the global challenges for business firms which prompts paradigm shifts in business management. The needs for training to prepare the future manager to handle the variety of issues that have emerged from these shifts have been thoroughly discussed. Several issues pertaining to teaching and learning in the context of global operations management have been examined. A novel learning model which emphasises multidimensional learning approaches has been designed to deal with the issues. Information-based technologies that provide support for the learning model have been introduced. A unique learning tool based on these technologies, the virtual world, has been designed and a working prototype has been created. A set of preliminary experiments has been conducted. This concluding chapter begins with a review of the previous chapters and follows by the main conclusions. The chapter continues with a discussion of the limitations of the research. The research outcomes and the contributions are then described. The chapter then closes with recommendations for further research.

11.1 Research Summary

Business globalisation is now a force that is unlikely to be reversed. The effect of globalisation on economic revolution is more than a proliferation of factories and machines; it is a transformation of business operations, processes and systems. As globalisation continues, it exposes firms and economies to a great deal of uncertainty. This uncertainty can complicate the planning and the making of decisions. Different strategies and operations practices have emerged to ensure global competitiveness and profitability.

As new forms of business emerge, resources and capabilities have shifted away from physical and financial resources and towards the creative use of intangible properties. These intangible properties derive mainly from knowledge assets, which have become essential ingredients of business success. This fact translates human capital into a key competitive advantage for any business. Improving international competitiveness by enhancing the performance of a global manager is therefore critical to the successful management of global business operations.

Along with increasing internationalisation and globalisation of the world economy, the preparation and training of the global manager has received considerable attention. The central concern of education and training thus focus on the improvement of learning training aids and instructional methods to meet business needs. However, despite this crucial realisation, the traditional way of teaching operations management is still inefficient.

In the traditional classroom, instruction is accomplished through a teacher lecturing and students taking tests. Given its simplicity and the ease of execution of the traditional classroom methods, their utility for enhancing thinking appears limited when referring to real world situations. Many researchers suggest that this occurs because academics and practitioners' views of operations management are widely divergent. In order to ensure that the programmes meet the industry needs and job prospects, it is necessary to reshape the operations management curriculum.

The curriculum intended to serve industry must balance technical skills with professional skills so as to give learners a detailed understanding of day-to-day operations. The learning must therefore be student-centred. Student-centred curricula have already been introduced: experiential learning where learning is seen as a continuous process grounded in experience, collaborative learning where learners work together on tasks, coaching and mentoring where the teacher stimulates the learning processes by carefully observing and correcting the learners as they proceed with the skill, and visual imagery learning strategy where the information in learning are provided through images and animations. By combining these multidimensional learning approaches into a unified model, educators will be able to avoid the pitfalls of traditional instruction.

In order to improve the teaching-learning situation, educators hope to find technologies that can solve the problems associated with delivering quality programmes to learners. Educational simulation applications have been utilised to meet numerous experiential learning objectives. Computer-mediated communication technology has been introduced to enhance collaborative learning. Intelligent agents have served as specialists to provide the compliance advice and guidance that many learners need. Virtual reality has entered the classroom to visualise aspects of real and conceptual world, resulting in quick insight into the learning context.

Until recently, computer training systems have addressed specific aspects of learning in global operations management. Only a few have been designed with an architecture that allows different entities and different technologies from disparate domains to interact in a single application, in real time, and over large distances. The virtual world is one of the emerging technologies that can be brought into classroom to create such a learning environment. By incorporating collaboratively-evolved virtual worlds into different technologies, this could expand the capabilities of each learning package, resulting in a better learning environment.

The research has concentrated on the conceptual design and prototype development of Mandrill Virtual World to enhance global business operations learning experience. It has implemented a series of studies to determine the right balance among industrial requirements, pedagogical methods, and applied technologies. The preliminary investigation was conducted on both the performance of the intelligent agent technology and the viability of the virtual world to confirm its usability.

11.2 Conclusions

The thesis sought relationships among linked and overlapping literatures to discover relationships and promising opportunities. As a basis for this study, the literature from international and global operations management, international human resource management, psychology of learning, and technology supported learning environments was reviewed. The following facts were established:

- With the advance of globalisation, business is crossing national boundaries, posing many new challenges to the area of operations management.
- The preparation and training of cross-border operations manager is becoming essential to competitive advantage under the pressure of globalisation.
- The conventional forms of teaching and learning in operations management cannot produce the skills and knowledge required in this type of manager.
- Multidimensional learning process that integrates the four approaches of student-centred learning (experiential, cooperative, coaching and mentoring, and visual imagery) enables more effective learning in a course on global operations management.

- The explosion of information and communication technologies offers an effective way to create computer-based learning environments.
- Virtual world technology allows different entities and technologies from disparate domains to create a more meaningful learning environment.
- When this technology is applied in global operations management, it opens vast new possibilities for enhancing learning.

The first part of this thesis illustrated the change in operations solutions caused by globalisation and the increasingly important role of global managers. Despite an extensive literature review on both global operations management and international human resource management, it asserted that global business restructuring is not possible in the absence of qualified personnel. Only a small amount of research has examined this crucial relationship. It also highlights the importance of training by focusing on the teaching and learning needed by global operations managers. Moreover, it identified current learning methods and proposed a learning model designed specifically to cultivate the skill of global operations manager. At the subsequent parts, it discussed various forms of technology-mediated learning in connection with the learning model have. The first prototype that allows seamless integration of the learning technologies in the field of global operations management was invented in this study. Preliminary investigations were conducted to determine the performance of the prototype.

11.3 Future Research Directions

With reference to the development and missing gaps, there are several possible research directions which can be considered. As this research constitutes only a preliminary investigation of virtual world technology, more investigations are clearly needed in order to establish a framework for understanding the performance of this technology on aspects of learning global operations management. Further research can be conducted to determine learning performance of the technology by comparing different systems of learning (e.g. conventional learning, technology-enhanced learning, and the virtual world) to determine the real efficiency of the virtual world in learning support. Additional research may also be conducted in real world settings where there may be considerable variability with respect to cognitive, social, personality, and physical functioning. This variability is even more dramatic when the experience of different gender, cultural, and ethnic groups is compared. Although this does not mean there are inconsistencies in the learning model proposed in this research, it does suggest that generalisations should always be viewed with caution. Apart from this, there may be other and better methods of improving the learning model. For example, a modified model may include human aspects whereby affective and emotional factors can be the key for effective learning. This model can be directly applied to the existing model to improve the attitude and mental ability of the learners. In addition, both primary and secondary research based on traditional learning issues would be imperative for the construction of a more robust learning model.

From a technological perspective, there is a considerable spectrum of possibilities for adapting technology to support learning. Based on the existing technological framework, a more realistic simulation for global business operations that provides global factors such as government policies, geographic distance information, and attributes of international economy, would enrich the learning experience. A simulation technology could be combined with the technological framework to promote learning. On a communication site, communicating using voice could expand learning opportunities, simply by connecting voice over IP solution at the virtual world client. A text-to-speech system could also be applied without redesigning the major parts of the technology. As for the intelligent agent, a more robust algorithm that could understand each stage of simulation would dramatically increase the potential of the virtual world. Other techniques such as neural computation and machine learning can also be considered necessary. For virtual reality, as this technology becomes more prevalent and economical, a more realistic representation (e.g. animation and virtual models) could be applied to create a more supportive learning environment. A more advanced interface input mechanisms and interface presentation components such as virtual gloves and head mounted displays could also be applied to increase the degree of immersion.

Although this study focuses on the applicability of virtual world in operations management, the technology could also be extended into many areas. For example, a language training centre may use virtual world to mock-up a scenario that allows people to practice their language skills. If a more advanced natural language technology is employed, the learner can even speak with intelligent agents through a microphone and the agent can respond back via synthesis voice. As another example, a cooking school may create a virtual restaurant where intelligent agents play roles of staffs and customers. Recipes may be modelled into a form suitable for processing and the agents may use them to review the cooking skills. Chef around the world may also join into the system to share their cooking techniques. Or, in another different area, a consultant company may find the technology useful in its work on future policies. Its clients can get into the system and perceive changes, detect potential threats, and determining the effectiveness without taking any risks. The possibility of using virtual world technology is seemingly endless.

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Appendices

Example of Simulation Events from Mandrill Simulator

The data below are generated from the Mandrill simulator. Virtual world client translates these data into 3D graphics. These data are streaming from a Virtual World Server to every client that is connecting in the same channel. This means each client can perceive the same environment no matter where they are.

01:02 06:00 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:00 = JobStarted - Batch 2 OP 1 W/Station CMATIC211 Qty 150
01:02 06:00 = UnLoad/Load - W/Station CMATIC212 Batch 2 Qty 1500 Oper AUTO_OP_GR
01:02 06:02 = JobStarted - Batch 6 OP 1 W/Station CMATIC203 Qty 50
01:02 06:02 = UnLoad/Load - W/Station CMATIC204 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:03 = JobStarted - Batch 2 OP 1 W/Station CMATIC212 Qty 150
01:02 06:04 = JobStarted - Batch 6 OP 1 W/Station CMATIC204 Qty 50
01:02 06:04 = UnLoad/Load - W/Station CMATIC205 Batch 6 Qty 500 Oper AUTO_OP_SP
01:02 06:06 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:06 = JobMoving - Transport TRUCK Batch 17 OP 1 W/Centre PRESS-12TN
01:02 06:06 = JobMoving - Transport TRUCK Batch 5 OP 3 W/Centre GRIND
01:02 06:06 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:06 = JobArrived - Batch 17 OP 2 At W/Centre INSPECTION Oper MTRL_HDLRS
01:02 06:06 = JobStarted - Batch 17 OP 2 W/Station INSP002 Qty 494 Oper INSPECTORS
01:02 06:06 = TranCalled - Batch 5 OP 3 W/Centre GRIND Tran TRUCK Oper MTRL_HDLRS
01:02 06:06 = TranCalled - Batch 5 OP 3 W/Centre GRIND Tran TRUCK Oper MTRL_HDLRS
01:02 06:07 = JobStarted - Batch 6 OP 1 W/Station CMATIC205 Qty 50
01:02 06:12 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:12 = JobMoving - Transport TRUCK Batch 5 OP 3 W/Centre GRIND
01:02 06:12 = JobMoving - Transport TRUCK Batch 5 OP 3 W/Centre GRIND
01:02 06:12 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:16 = UnLoad/Load - W/Station CMATIC203 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:18 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:19 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:19 = JobStarted - Batch 6 OP 1 W/Station CMATIC203 Qty 50
01:02 06:21 = UnLoad/Load - W/Station CMATIC205 Batch 6 Qty 500 Oper AUTO_OP_SP
01:02 06:22 = JobStarted - Batch 6 OP 1 W/Station CMATIC205 Qty 50
01:02 06:22 = UnLoad/Load - W/Station CMATIC204 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:23 = JobStarted - Batch 6 OP 1 W/Station CMATIC204 Qty 50
01:02 06:24 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:25 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:30 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:31 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:33 = UnLoad/Load - W/Station CMATIC203 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:34 = JobStarted - Batch 6 OP 1 W/Station CMATIC203 Qty 50
01:02 06:35 = UnLoad/Load - W/Station CMATIC211 Batch 2 Qty 1500 Oper AUTO_OP_GR
01:02 06:36 = UnLoad/Load - W/Station CMATIC205 Batch 6 Qty 500 Oper AUTO_OP_SP
01:02 06:36 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:37 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:37 = JobStarted - Batch 6 OP 1 W/Station CMATIC205 Qty 50
01:02 06:37 = JobStarted - Batch 2 OP 1 W/Station CMATIC211 Qty 150
01:02 06:38 = UnLoad/Load - W/Station CMATIC212 Batch 2 Qty 1500 Oper AUTO_OP_GR
01:02 06:39 = JobStarted - Batch 2 OP 1 W/Station CMATIC212 Qty 150
01:02 06:40 = UnLoad/Load - W/Station CMATIC204 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:42 = JobStarted - Batch 6 OP 1 W/Station CMATIC204 Qty 50
01:02 06:42 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:43 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:48 = UnLoad/Load - W/Station CMATIC203 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:48 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:49 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:50 = JobStarted - Batch 6 OP 1 W/Station CMATIC203 Qty 50
01:02 06:50 = UnLoad/Load - W/Station CMATIC205 Batch 6 Qty 500 Oper AUTO_OP_SP
01:02 06:53 = JobStarted - Batch 6 OP 1 W/Station CMATIC205 Qty 50
01:02 06:54 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 06:55 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 06:58 = UnLoad/Load - W/Station CMATIC204 Batch 6 Qty 1500 Oper AUTO_OP_SP
01:02 06:59 = JobComplete - Batch 17 OP 2 W/Station INSP002 Qty 485 Oper INSPECTORS
01:02 06:59 = TranCalled - Batch 17 OP 2 W/Centre INSPECTION Tran TRUCK Oper MTRL_HDLRS
01:02 07:00 = UnLoad/Load - W/Station GRIND209 Batch 5 Qty 491 Oper GRIND_OPS
01:02 07:00 = JobStarted - Batch 6 OP 1 W/Station CMATIC204 Qty 50
01:02 07:01 = JobStarted - Batch 5 OP 3 W/Station GRIND209 Qty 10
01:02 07:04 = UnLoad/Load - W/Station CMATIC203 Batch 6 Qty 1500 Oper AUTO_OP_SP

Evaluation Sets

The evaluation sets are consisted of the case study of Mandrill's spindle assembly cell, decision form, Mandrill Virtual World programmes, and the questionnaire.

The case study consists of five documents, all for the participant

- Organisation structure
- Layout of spindle assembly module
- Process description of assembly module
- Cell level data of assembly module
- Performance assessment of assembly module

The decision form is consists of three documents

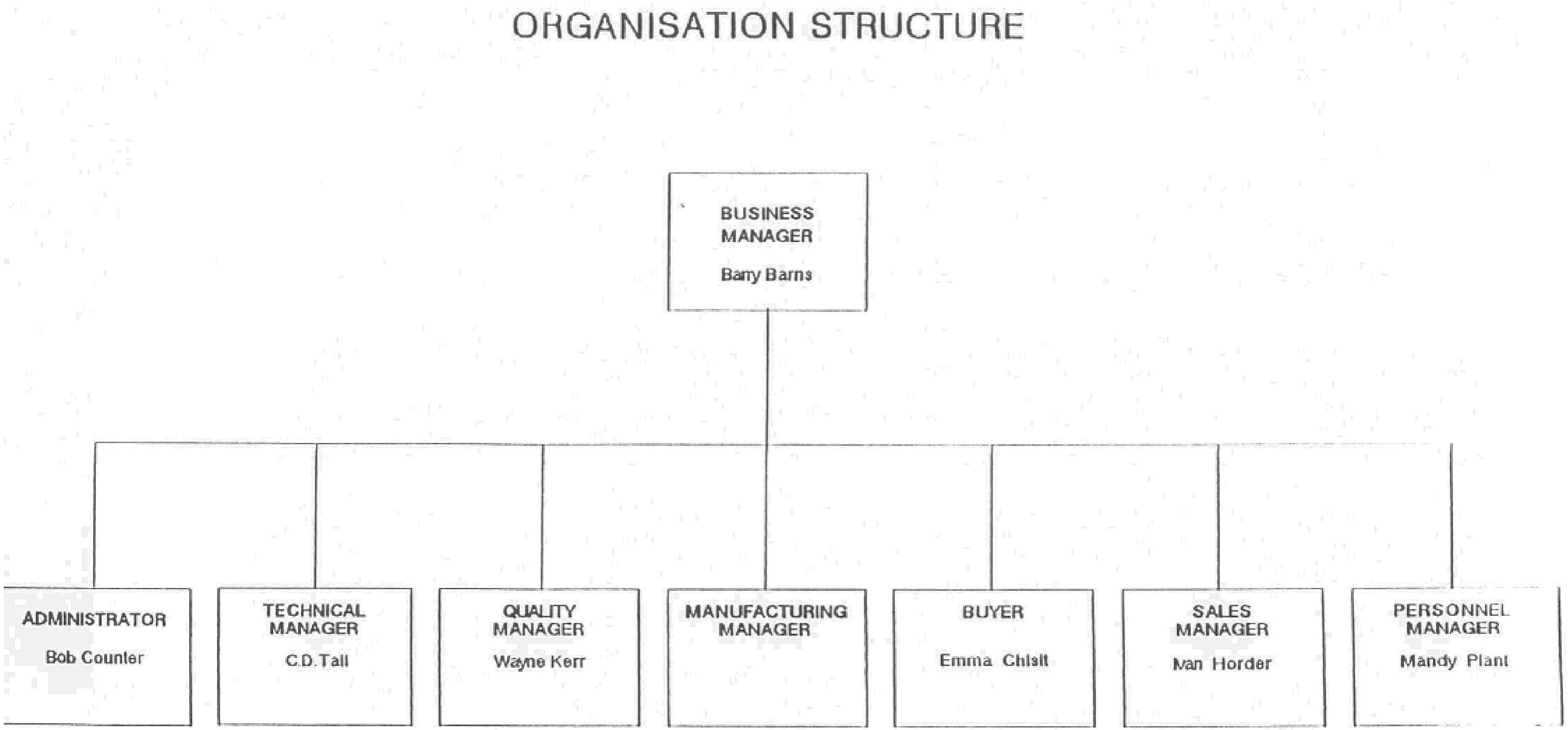
- Decision form (for the participant)
- Decision examples (for the evaluator)
- Decision guideline (for the evaluator)

The Mandrill Virtual World programmes consist of three main applications. The programmes and related files are available in the CD-ROM attached with this thesis

- Mandrill Virtual World Client (for the participant)
- Mandrill Virtual World Server (for the evaluator)
- Intelligent Agent Web Service (for the evaluator)

The questionnaire consists of one page document

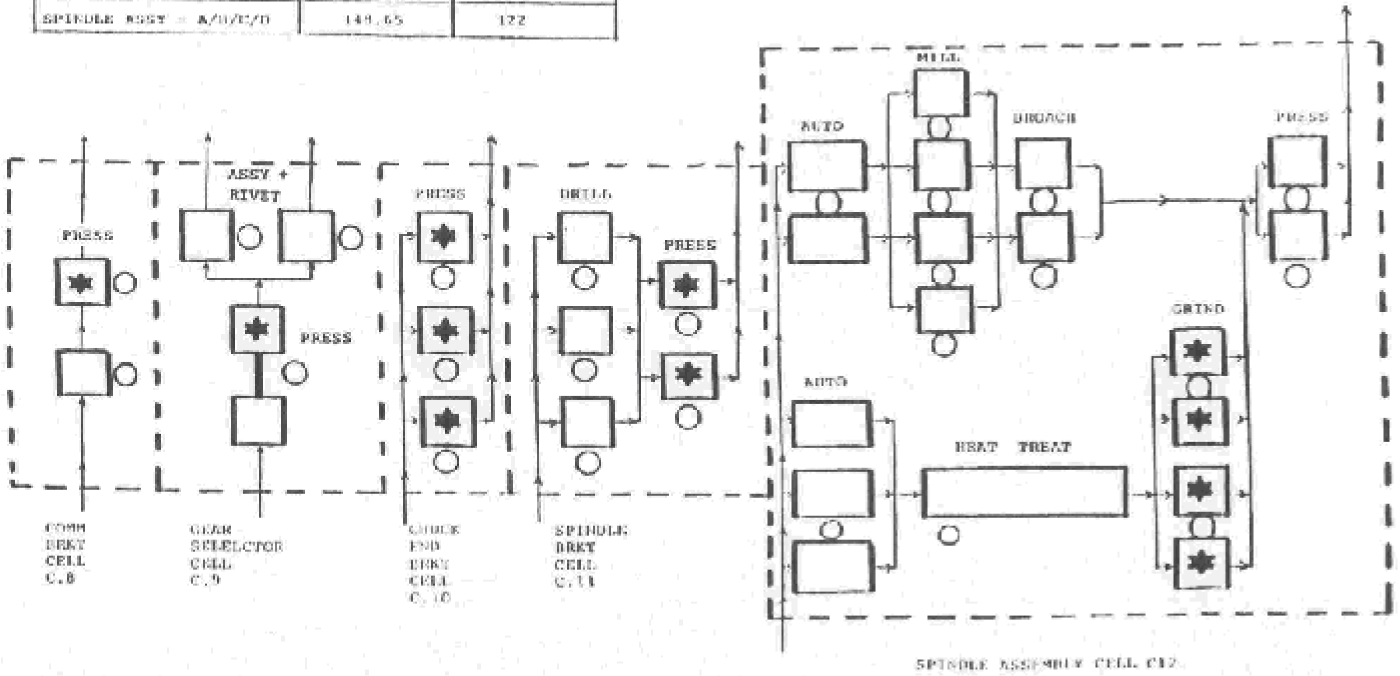
Organisation Structure



Layout of Spindle Assembly Module

SUB-ASSEMBLY MODULE

	CUMULATIVE CELL STD TIME (MIN PER 100)	BOTTLENECK CAP/HR/MC ✱
COMM. BRKT - A/B/C/D	24.38	474
GEAR SEL - A/B/C/D	27.56	695
CH. END BRKT - A/B/C/D	13.05	352
SPINDLE BRKT - A/B/C/D	55.92	262
SPINDLE ASSY - A/B/C/D	148.65	122



Process Description of Assembly Module

SPINDLE ASSEMBLY CELL

Transport bars of steel from stores to Auto. -lathe.	Electric truck moving approx. 11 pulling carrier that has 30 bars o on it. Each bar = 50 spindles (all model Model A: = 12mm dia. B: = 14mm dia. C: = 16mm dia. D: = 18mm dia.
Operator feeds bars of steel into rear of headstock (auto feed unit) on Conomatic.	Plant nos. 203 - 205. Manpower 1 man for 3 machines.
N.B. Operations are: 1. Drill hole & tap (for chuck). 2. Turn (rough) bearing area. 3. Turn 10m/m from front face to finished dia. 4. Turn (rough) gear/bearing area. 5. Part off (which includes producing conical shape to the end of the bar).	
Tool changes, and material handling are within standard time.	
Parted off pieces fall into a chute that targets the gear spindle into a pallet.	
Patrol inspection.	Frequency 1 per mc. per hour.
Move to Induction furnace.	By hand batch size 1,500.
Operator places gear spindle into a chute that feeds induction furnace.	Plant no. 206. Chute takes 50 spindles at a time. Process time is 15 minutes
N.B. Hardening of spindle is in bearing area (chuck end) and all smaller dia. areas.	
Remove from chute that receives hardened spindles, and place in work tin.	Batch size 1,500.
Move to grinders.	By hand.

Fit spindle to grinder collet. N.B. faces to be ground: all bearing areas.	Plant nos. 207 - 210. Manpower 1 man for 2 machines.
Patrol inspection.	Frequency 1 per mc. per hour.
Place into pallets and move to assembly press.	Batch size 1,500., by hand.
Transport steel bar from stores to large conomatic.	Electric truck moving 110 metres appro pulling carrier with 10 bars on it. Bar are 1830mm long and 150 gears are cut out of each bar. Model A: 40mm dia. B: 45mm dia. C: 50mm dia. D: 55mm dia.
Load bars to Auto feed on Conomatic.	Plant nos. 211 - 212.
Operations are: 1. Drill. 2. Ream. 3. Turn face (hammer cam gear end - this includes boss for cam gear and also recess that controls cam gear i/dia.). 4. Turn outside dia. 5. Part off (includes boss at ch. end). 6. Turned parts fall into chute that directs them into a pallet.	Manpower 1 man for two machines. Batch size 1,500.
Patrol inspection.	Frequency 1 per machine per hour.
Move to Gear Cutting mcs.	Electric truck moving approx. 3 metres
Operator locates gear blank on machine. Blank is gripped in collet on outside diameter. N.B. Gear cutter only cuts one form at a time. Blank is rotated 15 times so that 16 cams are formed.	Plant nos. 213 - 216.
Remove from gear mill and place in pallets.	Batches size 1,500.

Patrol inspection.	Frequency 1 per machine per hour.
Move gear blanks to Broach.	Electric truck approx. 3 metres movement.
Locate gear blank in broach.	Plant no. 217 and 218.
N.B. Operation of broach is: a) Vertical standing broach. b) Blank locates in first 12mm of broach bore. c) Hydraulic press forces blank down broach. d) Completely broached blank falls in wire mesh chute, where continuous broaching fluid washes swarf off gear.	
Patrol inspection.	Frequency 1 per mc. per hour.
Operator places gears in pallet, which is moved to assembly press.	Batch size 1,500. Electric truck moving approx. 3 metres
Gear spindles from grinders to press gear from broach to press.	Plant nos. 219 - 220.
Operator locates spindle in press, then locates gear into spindle.	
Press gear into position.	
N.B. Gear is a drive fit into spindle.	
Remove assembly from press and place into pallets.	
Bench inspection - views general form, diameter of shaft at bearing areas.	Frequency 100%.
Pallets are transported to I.P.S.	Electric truck moving approx. 75 metre

Cell Level Data of Spindle Assembly Module

CELL LEVEL DATA	NO 12
~~	SP.ASSY
	=======
number of shifts	2
shift length (hrs)	37.5
number of operator stations	13
no. of direct ops. - shift 1	15
- shift 2	15
- shift 3	0
- total	30
budget number of directs	31
operator performance rating (%)	89
average misc. labour losses (%)	8
absenteeism (%)	10
total overtime (hrs)	0
av. attendance hours - directs	33.75
number of machines	18
no. of m/cs at bottleneck operation	4
machine efficiency (%)-bottleneck	99
machine downtime (%)-bottleneck	12.33
av m/c available hrs per shift/week	37.5
mc cap/hr at bottleneck - prod A	121.58
- prod B	121.58
- prod C	121.58
- prod D	121.58
bott.mc stdtm (min/100) - prod A	49.35
- prod B	49.35
- prod C	49.35
- prod D	49.35
mc group stdtm(min/100) - prod A	148.65
(cumulative) - prod B	148.65
- prod C	148.65
- prod D	148.65
actual unit scrap rate (%) - prod A	3.965
- prod B	3.607
- prod C	4.083
- prod D	4.130

Performance Assessment of Spindle Assembly Module

PERFORMANCE ASSESSMENT

PRODUCTION	SPINDLE ASSY
ISSUES - A	5500
ISSUES - B	7000
ISSUES - C	4000
ISSUES - D	9100
	25600
TOTAL PRODUCTION - A	3671
TOTAL PRODUCTION - B	7200
TOTAL PRODUCTION - C	4170
TOTAL PRODUCTION - D	8481
	23522
GOOD PRODUCTION - A	3526
GOOD PRODUCTION - B	6940
GOOD PRODUCTION - C	4000
GOOD PRODUCTION - D	8131
	22597
SCRAP COST (#/1000 GOOD)	37.34
SCRAP PARTS/MILLION (TOTAL)	39325
LABOUR UTILISATION	
NO OF DIRECT OPERATORS	30.00
AVERAGE ATTENDANCE HOURS	33.75
OP. PERF. RATING	89.00
ABSENTEEISM %	10.00
TOT. OVERTIME HOURS	0.00
EFFECTIVE HOURS	654.80
WAITING WORK (HRS)	276.70
OTHER LOST TIME (HRS)	81.00
TOTAL DIRECT HOURS	1012.50
WORK IN PROGRESS	
KITS IN PROGRESS - A	3327
KITS IN PROGRESS - B	5217
KITS IN PROGRESS - C	5485
KITS IN PROGRESS - D	6434

CELL NO.	CELL DESC.	ITEM	PROD.	CATEGORY	STORES LEVEL (UNITS)	IDEAL STORES LEVEL (UNITS)	WIP LEVEL (UNITS)	STORES COST (#/100)	STORES VALUE (#)	WIP VALUE (#)	TOTAL INVENTORY VALUE (#)
12	SPNDL ASSY	KITS	A	KTS	4238	7639	3327	8.0	339	266	605
	SPNDL ASSY	KITS	B	KTS	37219	36777	5217	8.5	3164	443	3607
	SPNDL ASSY	KITS	C	KTS	33109	33948	5485	9.0	2980	494	3473
	SPNDL ASSY	KITS	D	KTS	29737	31858	6434	9.5	2825	611	3436

Decision Form

Mandrill Operations Simulation

Mandrill Decisions			
		Week	
General Decisions Continued			
Objective	Description of Action(s)	Implementation Instructions	Anticipated Result

General Notes

Decision Examples

Mandrill Decisions			Team	
			Week	

Production Programme	*Module A (Field Coil)*	*Module B (Armature)*	*Module C (Sub-Assembly)*	*Module D (Drill Assembly)*
Product A				
Product B				
Product C				
Product D				

General Decisions

Objective	Description of Action(s)	Implementation Instructions	Anticipated Result
carpenterr Improve quality of ordered parts	The purchasing manager should speak to our suppliers in order to make sure that the components that we order are delivered with the correct levels of quality that we require from a purchased part.	Emma Christ and her department should contact our suppliers and ensure that they improve their pre-delivery inspection checks. The supplier should be made aware that we are not happy with the current levels of quality in the parts that we are currently receiving. They should be aware that if they fail to deliver the component with the correct levels of quality, we will be forced to look to other suppliers. Emma Christ should use her professional links with these companies in order to	The suppliers should improve the predelivery checks that they make on their products. This will mean that the parts should be of the quality required in order to fit these into our drills. This should give us some more confidence in the quality of the final product and will therefore help towards our main strategic aims.

		maintain a degree of persuasion and at the same time retaining their support in improving the quality issues.	
carpenterr To reduce the levels of absence within the Mandrill factory	An absence policy should be implemented. This should be organised by the Personel department. It should be passed down to every level in the factory.	Mandy Plant should organise for the effective implementation of the Absence Policy and procedure. This is the one as written by Mike Eccles. Steps to implementing the policy should begin immediately. All levels of personel should be briefed about the procedure and supervisors should ensure that this policy is maintained throughout the factory.	It is hoped that an absence policy together with a full description of the disciplinary procedures will help to reduce the absenteeism in the factory. This will mean that there will be more confidence in the forecast demand that we place on each cell. The quantities of such demands are based on calculations that include an assumption about the levels of attendance. It is therefore mportant to ensure that the Mandrill factory has the highest levels of attendance possible. This will install confidence in the production levels that will be achieved.
carpenterr Ensure that all supervisors are aware of the disciplinary procedures in place in the factory.	Mandy Plant should ensure that all supervisors and managers within the factory are briefed about the disciplinary procedures within th mandrill factory.	Mandy Plant is to ensure that all managers and supervisors within the factory are fully aware of the disciplinary procedures that are in place within the factory. They should be made aware that a	It is hoped that by being fully aware and refreshed about the disciplinary procedures will mean that all levels of quality and production will be raised. This will continue in order to work in a factory where there is

		knowledge of the disciplinary procedure is something that forms part of their job role. They are responsible for the management of the people within the cells within their control. They should be able to use such procedures or policies or tools in order to help them achieve the high levels of attendance and high standards of manufacturing quality that are essential in order to provide a quality product to the custome in the quickest time and at the right price.	the highest levels of production to the highest quality within the factory.
carpenterr 5S in Module A	A 5S activity should be carried out in module A.	The supervisors in cell A should implement a 5S activity in line with the training that they received last week. The supervisors should ensure that production across each of the cells in the module is maintained and that the required demand is met by each cell.	It will take a few weeks in order to have all members of staff across the factory to be trained in the principles of 5S. For this reason it is important to implement the principles within each cell as soon as all members of the module have been trained. This is possible as each module is independent of the next. This should help to improve the working conditions within the factory in order for further

			improvements to be made.
mennickej Implementation of 5S in module B	Staff of module B should be trained in 5S techniques	Training should begin on the first day of the week. 1 training session to be carried out each day except one day that contains 2 sessions. The schedule of the training sessions is up to the supervisors but must be carried out within the production time without affecting the target production. The calculations show that this is feasible. Therefore, the supervisors should produce a training schedule in order to maintain production especially keeping the bottleneck machines running by training people of different cells at a time and reallocating people to the bottlenecks within the cells where necessary. Furthermore, by reallocating people between cells the manpower shortfall in cells 3, 6 and 7 is compensated by shuffling people from other cells to these cells. All in all the manpower should therefore be	All memebers of cells 3 to 7 will be trained in the principles of 5S and the technique is implemented in this module. This will have the effect of introducing general performance improvements and product quality. But most importantly the operator performance should increase significantly and the misc labour losses should decrease. Less machine downtime will give a greater machine capacity. The general working conditions and working environment will also be improved. This will reduce scrap, improve operator motivation.

Decision Guideline

The decision of the following strategic problems should be based on global business aspect

Technical - What actions would you recommend to improve machine capability?
Factory - What actions would you recommend to increase productivity?
Finance - What actions would you recommend to decrease costs, manage fund?
Personnel - What actions would you recommend to enhance employee quality, satisfaction?
Quality - What actions would you recommend to reduce scrap rate, factory maintenance?
Marketing/Sales - What actions would you recommend to increase sales, stimulate demand?

Questionnaire

To what extent did you sense the global operations atmosphere during the experiment?	Case Study	Low 1 2 3 4 5 6 7 High
	Virtual World	Low 1 2 3 4 5 6 7 High
With what degree of ease were you able to understand the concept of global operations?	Case Study	Difficult 1 2 3 4 5 6 7 Easy
	Virtual World	Difficult 1 2 3 4 5 6 7 Easy
How completely were you able to investigate or explore the global operations processes?	Case Study	Incomplete 1 2 3 4 5 6 7 Complete
	Virtual World	Incomplete 1 2 3 4 5 6 7 Complete
With what degree of ease were you able to critically analyse or identify the issues in the global operations processes?	Case Study	Difficult 1 2 3 4 5 6 7 Easy
	Virtual World	Difficult 1 2 3 4 5 6 7 Easy
How sufficiently were the training processes correspondences to reality?	Case Study	Insufficient 1 2 3 4 5 6 7 Sufficient
	Virtual World	Insufficient 1 2 3 4 5 6 7 Sufficient
To what extent did you learn new techniques that enable you to improve your performance for global operations management?	Case Study	Low 1 2 3 4 5 6 7 High
	Virtual World	Low 1 2 3 4 5 6 7 High
How productively were you able to formulate the decision about global operations?	Case Study	Low 1 2 3 4 5 6 7 High
	Virtual World	Low 1 2 3 4 5 6 7 High
To what extent did you feel confident in expressing ideas regarded on global operations?	Case Study	Low 1 2 3 4 5 6 7 High
	Virtual World	Low 1 2 3 4 5 6 7 High
How much preferable to the training methods would you like to practice the global operations training?	Case Study	Low 1 2 3 4 5 6 7 High
	Virtual World	Low 1 2 3 4 5 6 7 High
Do you agree that without Virtual World technology, studying global operations management is highly difficult if not impossible?	Disagree 1 2 3 4 5 6 7 Agree	

Do you have any experience or academic background in the field of experiment? (leave blank if no applicable)

☐ Business Management ☐ Production/Operations Management ☐ International Operations Management
☐ Other related______________________________

Do you have any other comments regarded with the virtual world technology for global operations management?

Aston University

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Electronic Material

The CD-ROM attached with this thesis contains:

- Digital video illustrating the process of Mandrill Virtual World
- Compiled version of the Mandrill Virtual World Server
- Compiled version of the Mandrill Virtual World Client
- Compiled version of the Web Service
- Source code of the Mandrill Virtual World Server written in Jamagic
- Source code of the Mandrill Virtual World Client written in Jamagic
- Source code of the Intelligent Agent Web Service written in C#
- 3D models of the artifacts in Mandrill Virtual World in 3DS format
- Complete event list of Spinder Assembly Cell generated from Mandrill Simulator