VIRTUAL LEARNING PROCESS ENVIRONMENT (VLPE): A BPM-BASED LEARNING PROCESS MANAGEMENT ARCHITECTURE

BY

AYODEJI ADESINA (B.ENG.)
(ayodeji.adesina2@mail.dcu.ie)

A Thesis submitted in Partial Fulfilment of the requirement for the Degree of

Doctor of Philosophy
(Electronic Engineering)

Supervised by Dr. Derek Molloy

School of Electronic Engineering
Dublin City University

March 2013

Abstract

E-learning systems have significantly impacted the way that learning takes place within universities, particularly in providing self-learning support and flexibility of course delivery. Virtual Learning Environments help facilitate the management of educational courses for students, in particular by assisting course designers and thriving in the management of the learning itself. Current literature has shown that pedagogical modelling and learning process management facilitation are inadequate. In particular, quantitative information on the process of learning that is needed to perform real time or reflective monitoring and statistical analysis of students' learning processes performance is deficient. Therefore, for a course designer, pedagogical evaluation and reform decisions can be difficult. This thesis presents an alternative e-learning systems architecture - Virtual Learning Process Environment (VLPE) - that uses the Business Process Management (BPM) conceptual framework to design an architecture that addresses the critical quantitative learning process information gaps associated with the conventional VLE frameworks. Within VLPE, course designers can model desired education pedagogies in the form of learning process workflows using an intuitive graphical flow diagram user-interface. Automated agents associated with BPM frameworks are employed to capture quantitative learning information from the learning process workflow. Consequently, course designers are able to monitor, analyse and re-evaluate in real time the effectiveness of their chosen pedagogy using live interactive learning process dashboards. Once a course delivery is complete the collated quantitative information can also be used to make major revisions to pedagogy design for the next iteration of the course. An additional contribution of this work is that this new architecture facilitates individual students in monitoring and analysing their own learning performances in comparison to their peers in a real time anonymous manner through a personal analytics learning process dashboard. A case scenario of the quantitative statistical analysis of a cohort of learners (10 participants in size) is presented. The analytical results of their learning processes, performances and progressions on a short Mathematics course over a five-week period are also presented in order to demonstrate that the proposed framework can significantly help to advance learning analytics and the visualisation of real time learning data.

Acknowledgements

I am deeply grateful to my supervisor, Dr. Derek Molloy, whose encouragement, guidance and support from the beginning of this research to the level that has enabled me to develop an understanding of this research. I would like to express my gratitude for his patience throughout the writing of this thesis. I have benefited from all series of discussions with him and his advices have given me an invaluable insight and skill on technical writing, too. I would also like to thank Dr. Robert Sadleir for his support and constructive comments during the group weekly meeting.

I wish to offer a special thanks to David Molloy who, over the course of this study, has always been more than willing to offer assistance and many helpful discussions on the various topics within this research. I am grateful for his patience, attention and exceptional work ethic.

I have totally enjoyed doing my PhD over the past three and a half years and my time working with the Centre for Image Processing and Analysis (CIPA) has been a valuable and remarkable experience. For this I would like to express my sincere gratitude to my fellow research colleagues for their friendship, co-operation and understanding; Patricia, Min, Sha, Tian, Xiong and all other members of the CIPA group - Thank you all for making the group an enjoyable one to work with.

I wish to also thank my dearest wife, Abimbola, for her love, patience and supports. Her encouragement always inspires and brings out the best in me. I wish to extend my profound gratitude to my entire family, particulary my Mum and Aunty, Comfort and Grace, for their belief in me and my work. Thank you all, for you all have been my strength over the course of this study.

Acknowledgements are also due to IRCSET, the Irish Research Council for Science, Engineering and Technology for funding my PhD studies.

Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: ____________________ ID No.: 54162327

Candidate

Date: ____________________

Author's Publications

The following publications stem from this research. All publications are full length papers and each describes a particular aspect of this research.

- Adesina, A. and Molloy, D. (2012b). Virtual learning process environment: Cohort analytics for learning and learning processes. *Proceedings of International Conference on e-Education and e-Learning, ICEEEL.* Amsterdam, Netherlands. Accepted for a journal publication with the International Journal of Social and Human Sciences (Vol. 6. 2012)

- Adesina, A. and Molloy, D. (2012a). Virtual learning environment versus virtual learning process environment. *IADIS International Conference e-Learning, part of the IADIS Multi Conference on Computer Science and Information Systems (MCCSIS 2012).* Lisbon, Portugal

- Adesina, A. and Molloy, D. (2011a). A business process management based virtual learning environment: Customised learning paths. *Proceedings of 3rd International Conference on Computer Supported Education (CSEDU 2011).* Noordwijkerhout, Netherlands

- Adesina, A. and Molloy, D. (2011b). A business process management based virtual learning environment: The human interaction management system. *Proceedings of the Red-Conference: Universita della Svizzera italiana, Lugano (Ascona, Switzerland).* [ISBN: 978-88-6101-010-9]

- Adesina, A. and Molloy, D. (2010). Capturing and monitoring of learning process through a business process management (BPM) framework. *3rd International Symposium for Engineering Education.* University College Cork, Ireland

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

The adoption and use of Information and Communication Technologies (ICT) in education have helped to shape the way teaching and learning is managed. However, the use of ICT within the educational framework does not automatically result in a better teaching and learning process (Dellit 2002, Gold 2001). The educational value and benefit of ICT, within an educational setting, is largely dependent on the way it is used or harnessed (Dellit 2002, Hedaya and Collins 1999). Within the academic environment, e-learning is one of the most significant products that has emerged from the use of ICT in recent years (Chen et al. 2009). It is one of the ways in which ICT is used to synthesis many activities needed to deliver and/or improve teaching and learning processes.

E-learning has in no doubt had a profound effect on the way training and education is delivered for both industrial and academic environments. However, the cultures of learning in these environments are not the same. Academic environments are more formalised, generic, and entrenched in a traditional pedagogy (i.e., direct instruction, delivering course materials, project allocations, quizzes, continuous assessments, exams etc) and, to a greater extent, with explicit learning outcomes (Tynjala and paive Hakkinen 2005). Also, the engagement of many higher institutions with distance learning has led to a blended pedagogy that still instils an element of a traditional pedagogical approach (e.g., the provision of course materials). Conversely, learning within the industry or workplace is often directly related to organisational issues, non-generic, generally informal and learning outcomes are often implicit (Billett 2002, Eraut 2007, Gherardi 2001, Tynjala and paive Hakkinen 2005).

Within the academic environment, an education pedagogical structure is paramount and for any e-learning system to have meaningful educational value, neither the pedagogy that underpins it nor the technology that facilitates it can be detached from its implementation (Nichols 2008). Therefore, the role of technology in the management of learning and teaching should be seen as a platform to realising sound education pedagogy. Compromising education pedagogical structure due to technological deficits would be detrimental to the expected learning outcomes, even though it is arguable that technology can influence the course or shape of such pedagogy. Despite the adoption and many successes of e-learning within the academic environment, it has not resolved many issues that still surround learning, especially, learning with the aid of computer resources and the Internet (Weller 2006).

In the traditional classroom environment, lecturers - although bound by time constraints - are naturally predisposed to a more flexible pedagogy (Matuga 2001). Many factors can influence changes in a pedagogical approach. Learners' responses to questions and/or ability to remember what they learned in previous class sessions can influence pedagogical shift (i.e., a shift from a behaviourist-oriented pedagogy, where learners passively received lectures to a constructivist-oriented pedagogy, where learners are actively solving problems and constructing their own knowledge). Based on learners' responses, lecturers may expand on a topic, change learning content, emphasis on a broader participation in class discussions, and/or adopt a new formative approach based on their pedagogical tendency.

In an asynchronous e-learning environment, where structured course materials are delivered to online undergraduate learners, Virtual Learning Environments (VLEs) such as Moodle, WebCT/Blackboard etc. provide the platform for which many third-level online courses can be delivered (Weller 2007). In contrast to the classroom environment, behavioural learning processes and learning styles are difficult to measure within the current VLEs (Hung 2008). Today, online learning is becoming a viable alternative to learning in a traditional classroom (Zhang et al. 2004). Nevertheless, there are some significant advantages and disadvantages to both environments. Some of these are shown in Figure 1.1. Managing

	Traditional Classroom Learning	E-Learning
Advantages	• Immediate feedback • Being familiar to both instructors and students • Motivating students • Cultivation of a social community	• Learner-centered and self-paced • Time and location flexibility • Cost-effective for learners • Potentially available to global audience • Unlimited access to knowledge • Archival capability for knowledge reuse and sharing
Disadvantages	• Instructor-centered • Time and location constraints • More expensive to deliver	• Lack of immediate feedback in asynchronous e-learning • Increased preparation time for the instructor • Not comfortable to some people • Potentially more frustration, anxiety, and confusion

Figure 1.1: Traditional classroom learning vs. e-learning.
Source: (Zhang et al. 2004)

a very large cohort of learners (100 learners for example) simultaneously in a classroom can be challenging. However, in a traditional classroom real time interaction and observation is possible. In an e-learning environment, it is difficult to perform continuous analysis of the cohort's behavioural tendency, therefore, real time pedagogical decisions can also be difficult to make (Levinsen and Orngreen 2003). More often than not, accounts of competency or desired learning outcomes are often apparent to lecturers during a summative process; and the areas of difficulties faced by the cohort are often blurred as continuous learning process information in a real time manner are not available (Levinsen 2006). In fact, according to Hung (2008), the basic data provide by VLEs about learners' activities are: the frequency of login; visit history; message post on the discussion board. However, if lecturers are afforded the necessary learning process information that could provide the means to observe, monitor, track and analyse learners' online learning behaviours continuously, then lecturers' runtime pedagogical approaches might be dynamic (i.e., customised assessment, prompt feedback, and more personalised attention) as needed (Kelly and Nanjiani 2004).

Therefore, it is necessary to devise a new flexible framework in such a way that would serve as a model for learning process management. Such flexible framework must be adaptive and responsive to pedagogical changes. It needs to provide a learning analytical means beyond the summative process, in such a way that would allow behavioural learning processes of the cohort of learners - right from the inception of the teaching and learning process - to be continuously monitored and analysed until completion (Neuhauser 2002, Levinsen and Orngreen 2003). E-learning systems based on this framework will be productive and will save time for the management of a cohort learning process by the course designers (Levinsen and Orngreen 2003). Course designers will be able to monitor, analyse and evaluate the effectiveness of their chosen pedagogy using live interactive learning process dashboards.

Definitions of Participants' Roles in Learning Environments

The titles of the roles of the participants of both the "traditional classroom" and "online" learning environments that are mentioned throughout in this thesis are defined as follow:

Course designer - This is a person who designs, prepares and co-ordinates a course, paying special attention to the development of suitable materials, activities and assessments that are related to learning goals and objectives. Course designer can design courses in a structural and hierarchical way that includes modules, topics, lessons and assessments. The pedagogical role of a course designer involves organising the topics particularly as topics, sub-topics, sub-subtopics, etc. These hierarchical structures are equivalent to the Learning Objects. Course designer monitors and analyse critically the effect and impact of the course on the overall learning outcomes of the learners.

Lecturer - This is a person that has a pedagogical role to teach a course. Formative assessment is part of the lecturer's tasks as it is part of teaching. Lecturers involve in both a supportive and evaluative roles for their courses - formulating strategies for learning. Lecturer monitors learners' flow of progress from the beginning to the end of learners' learning processes - given guides, ideals and constructive suggestions. Lecturer accesses the learners' project.

A lecturer can also assume a role of a course designer: he/she can develop an effective course and pedagogy; and, teach the same course that he/she has developed. Once a course is in session, depending on the learning process stage a lecturer can serve as a course facilitator.

Tutor - This is a person that is employed to assist in teaching/tutoring a course. Tutor has a pedagogical role to assist learners to understand a concept and to help address questions that might arise in the course of learners' learning processes. Tutor can also monitor, guide and supervise learners' academic work.

Learner - This is a person who actively participates in a course study for the purpose of gaining knowledge in a particular field of study. Learner's knowledge gain is measured on a set of defined learning outcomes.

1.1 Motivation

Thanks to the advances in ICT, the significant impact of e-learning in the 21st century education system cannot be overemphasised. However, the future demand and sustainability of online education will be driven by continuous improvements to the existing methods, tools and technologies that would bring about educational value for all of the e-learning stakeholders - learners, course designers, educational institutions, content providers, technology providers, accreditation bodies, employers etc. (Wagner et al. 2006). With much attention on course content management and lesser attention on learning process management within the current VLEs, there is a need to extend VLEs beyond their current functionalities to ensure their future relevance in meeting the emerging challenges in e-learning.

Course designers and learners expectations in technology supported education systems have increased with the advances in ICT. Today it is not enough to simply account for how many learners attended or completed a course in an online environment. Course designers want metrics that are related to learning objectives/outcomes. They need statistics that will help them to quickly see trends and act on these trends for continuous course improvement (asynchronously or synchronously) (Vatrapu et al. 2011, Brooks et al. 2011, Crawford et al. 2008). Hence, the need to manage the process of learning, with e-learning content/materials; e-learning participants (learners, tutors/mentors, lecturer etc.); and, e-learning tools (e-mailing, chat-room, discussion board, YouTube[1], Slideshare[2] etc.) forming an integral part of the whole learning process management. The orchestration of the interactions between these objects based on sound, flexible and adaptive education pedagogy in an automated manner can be difficult within the current e-learning systems (Tynjala and paive Hakkinen 2005). The employment of automated agents to perform complex and time consuming tasks such as data mining for learning process analysis, can enhance the effectiveness and robustness of any e-learning system, in the absence of which the intricacies of learning processes can be difficult to manage. Agents are useful in distributed or centralised systems for various tasks such as data mining, information processing and information notification etc.

The research presented in this thesis argues for the need to manage learning not just through learning content management that is often associated with the conventional e-learning systems; but more importantly through the management of the process of learning itself with an emphasis on sound, flexible and adaptive online pedagogy. Following this line

[1] www.youtube.com
[2] www.slideshare.net

of reasoning, this thesis also presents a new architectural framework for an e-learning system that is based on the Business Process Management (BPM) conceptual framework. The new e-learning architectural framework focuses on learning process management through the modelling of a learning process workflow around structured course materials based on a desired pedagogy.

In the enterprise domain, BPM refers to: mapping of processes with the strategic objectives of the organisational plans and goals; construction of process architectures that capture all the stakeholder relationships and activities; building a measurement system consistent with the organisational plans and goals; and, the provision of educated and reliable information to managers on how processes can be better improved or managed effectively (Bosilj-Vuksic and Popovic 2005). Unlike Business Process Reengineering, BPM does not aim at restructuring the existing business processes but is aimed at continuous evolution on the effectiveness and efficiency of a business process by providing the means to model, implement, monitor and manage the life-cycle of the business processes (Ko et al. 2009, Liu et al. 2008b). BPM allows organisation to have better understanding of customer satisfaction on the quality of product that is been delivered and has helped to improve the efficiency of business processes of organisations (Vera and Kuntz 2007, Kohlbacher 2009).

The main motivation of the research presented in this thesis is to provide a proof of concept implementation of an alternative e-learning architecture using the BPM conceptual framework to design an architecture framework. Part of the aims of the new architectural solution is to address the critical quantitative learning process information gaps that are typically found in many current VLE frameworks. The proposed architectural solution also aims to: provide course designers with the ability to model various online education pedagogies in the form of learning process workflows using a BPM type intuitive graphical flow diagram user-interface. Automated agents associated with BPM frameworks will be employed to capture the qualitative and quantitative process information of a modelled pedagogy. Consequently, course designers will be able to perfect their design and workflow through the ability to monitor, analyse and evaluate the effectiveness of their chosen pedagogy using live interactive learning process dashboards. As a consequence of this design, individual learners are also able to monitor and analyse their own learning performances in comparison to their peers in a real time or near-real-time anonymous manner through a personal analytics learning process dashboard.

1.2 Challenges

Higher Education (HE) pedagogies have evolved over time with sound educational value. However, e-learning pedagogies are focused on the method of delivery and pedagogy based on the process of learning has not gained traction (Esteves 2008). In an e-learning environment, for stakeholders such as the course designers, educational values are specific and focus on knowledge transfer. Course designers can measure the educational values against specified desired learning outcomes. For stakeholders such as the learners, educational values are determined based on knowledge gain in the form of interactive pedagogy usually in different interactive patterns such as learner-lecturer, learner-learner and learner-content (Moore 1989). Learners' knowledge gain can be demonstrated through mastery level or competency on assessments. In any case, whatever e-learning system is employed to drive education, it must prove its educational value through sound and flexible pedagogical frameworks that do not just focus on the delivery of content but also on the processes of teaching and learning (Dimitrova et al. 2004). One of the challenges that is often faced by course designers is to use the current e-learning systems in a pedagogically sound way that proves their educational worth (Vrasidas 2004). However, educational value can be difficult to prove as there are no methodical strategies for pedagogical development; and, no coherent framework within which to evaluate the effectiveness of their teaching approach (Britain and Liber

2004).

One of the key factors that could help influence a pedagogical reform is the results (learning outcomes) of a learning process that are based on either one or combination of the observable learners' behavioural, cognitive and constructive learning process. The development of an e-learning system that provides the mechanism to observe these learning processes can be difficult and challenging. There are many other challenges facing many e-learning systems today. The varying characteristics of all the e-learning participants (i.e., learners, tutors, lecturers etc.), technology and contextual (organisation, culture etc.) challenges can significantly affect teaching and learning within the online environment (Andersson and Grönlund 2009). Pedagogy and technology are vital to any successful e-learning system implementation. In other words, the technological platform behind any e-learning system will determine the extent to which such a system can enhance learning in higher education institutions through sound educational pedagogy. The challenge of using technology to radically change pedagogical practices in higher education has not yet materialised (Selwyn 2007). Despite the benefits of the current VLEs in providing course designers the means to manage course materials, current VLEs still lack an innovative technological approach to overcome many of the e-learning challenges today (Weller 2006). Within the VLEs, significant technological challenges still prevent or limit learning management related issues such as: adaptation/customisation of learning paths; enhancement of human interactive pedagogy; learning process management; pedagogical modelling; and, learning analytics (Chowdhury and Chowdhury 2008, Andersson and Grönlund 2009, Taylor et al. 2004, Weller 2006).

Designing and developing an e-learning system that will significantly address the issues of learning process management and pedagogical modelling is important. Where such system architecture would:

- Seamlessly integrate technology and multiple pedagogical approaches.

- Enable flexible learning process workflow to drive new learning management approaches.
- Enable learners learning pathway to be tailored to their profile and dynamically adapted to their run-time behaviour.
- Enable learning process analysis to be made possible for all of the e-learning stakeholders so that statistical analysis on learning progressions and performance can be captured and monitored.

Addressing these challenges is the basis of the research that is presented in this thesis. The aim is to formulate a new e-learning architectural framework that is based on the BPM conceptual framework. Therefore, this thesis presents state-of-the-art research and evidence-based results that support the proposed e-learning system architectural solution. Also, an implemented prototype (as a proof of concept) that demonstrates how these current VLEs limitations can be addressed is presented.

1.3 Research Questions

The main research question that this thesis aims to answer is:

> *Can Business Process Management concepts and technologies be used to model various pedagogies in order to utilise its quantitative process information capture framework in a way that allows course designers to develop and perfect their learning process workflow?*

The focus of the thesis is to outline an appropriate design model that could be used to implement and support learning process management by modelling various education pedagogies in the form of learning process workflow. Specifically, the captured quantitative learning process information will be analysed and the effectiveness of any adopted pedagogy will be evaluated with the potential to improve course design and positive learning outcomes. Also, other question that is addressed is:

> *How can customisation of learning paths; enhancement of human interactive pedagogy; and, learning analytics be modelled within a learning process workflow using a BPM framework?*

1.4 Contributions

This thesis makes a number of innovative contributions in the areas of learning process management and pedagogical modelling using the BPM conceptual framework. The major contributions of this thesis are:

- To prove that BPM technology can be used as a possible solution for a pedagogical-specific modelling tool that would allow a course designer to seamlessly model various education pedagogies.

- To prove that the utilisation of a BPM quantitative process information capture framework can provide course designers with an in-depth insight into the intricacies of the learners' learning processes. Consequently, course designer can be able to make an informed decision on the effectiveness of their chosen pedagogy based on the monitored learning process data; and, upon evaluation, pedagogy can be reformed with the potential to reduce future work load that will help to improve course design.

- To demonstrate the design and implementation of a BPM-based learning process management architecture known as Virtual Learning Process Environment as a prototype that can be used to prove the viability of a BPM approach to modelling education pedagogy and the management of learning processes.

Further minor contributions in this thesis are to show that: (a) Using the intelligent agents associated with BPM, learning analytics with statistical metrics can be enabled for all appropriate e-learning participants (learners, tutors and course designers in particular) with the aid of a learning process dashboard. (b) Customisation of learning paths for up to a very large cohort of learners can be facilitated seamlessly. (c) Human interactive pedagogy can be enhanced as human actors can be part of the learning process workflow elements. Human interactions within learning process workflow are crucial and the human roles are made explicit.

1.5 Structure

The thesis is composed of seven chapters, it documents the progress towards the stated research aims and objectives, as follows:

- Chapter 2 presents e-learning offerings within the Virtual Environment in greater details. The level of "real learning" in the current e-learning systems and the impact of pedagogy, blended learning and learning theory on the process of learning are discussed. E-Learning content standards, Learning Objects (LO) and Learning Object Metadata (LOM) are investigated with the view to identify their benefits and impact on learning process within the current e-learning systems. The potentials to enrich learning through the integration of LOM in learning materials and how they can be used to effect a better learning process is presented. Also, the advantages and limitations of the various categories of e-learning systems such as VLEs, Content Management Systems (CMSs) etc. are also discussed.

- Chapter 3 describes research-based evidence for the state-of-the-art requirements of an ideal virtual learning environment. The chapter also discusses the approach on how to address the issues surrounding an adaptive and flexible learning within the current e-learning solutions.

- Chapter 4 presents a new model of an e-learning architecture that is based on Business Process Management concepts. The BPM-based architectural concept and the technological frameworks that could facilitate its design and development are also presented. The rationales for the adoption of the BPM framework are outlined. The concepts of pedagogical modelling in the form of a learning process workflow; customised learning paths; enhanced interactive pedagogy; and, learning analytics are discussed as the main areas of focus.

- Chapter 5 presents a Virtual Learning Process Environment (VLPE) as a prototype implementation of the proposed architecture. The chapter presents a demonstration on how the BPM-based architecture can be used to facilitate learning process management through the possible modelling of educational pedagogies.

- Chapter 6 presents a further demonstration on the merit of the BPM-based architecture through learning analytics capability that is implemented as part of the VLPE solution.

- Chapter 7 summarises the work and concludes on the benefits and potential of the new architecture. This chapter also discusses the limitations of the conceptual frameworks employed within the proposed architecture. Finally, the chapter ends with proposals for future research work.

Chapter 2

E-Learning in Virtual Environments

2.1 Introduction to E-Learning

Over the last 5 decades, the impact of ICT in education has helped to achieve a significant milestone in the development and implementation of new educational strategies and goals (Cardinali 2003). Figure 2.1 shows how educational technologies have evolved as a platform for a higher level of interaction and collaboration; and, the enormous possibilities of its future application within the context of education.

One of the areas where education has tapped into the benefits of ICT is in the efforts to maximise knowledge sharing through an e-learning medium (Lin 2007, Hendriks 1999). With the aid of ICT, e-learning has gained traction and has helped to increase access to learning opportunities, consequently, enhancing the quality of learning. Today, there are no shortages of academic and non-academic bodies that offer fully accredited online educational programmes and courses all over the world (Mbatha and Naidoo 2010). Regardless of the geographical location or time variance, ICT allows online learning to take place with the use of different learning resources.

E-learning can be used in many learning situations and frequently interchanged with other

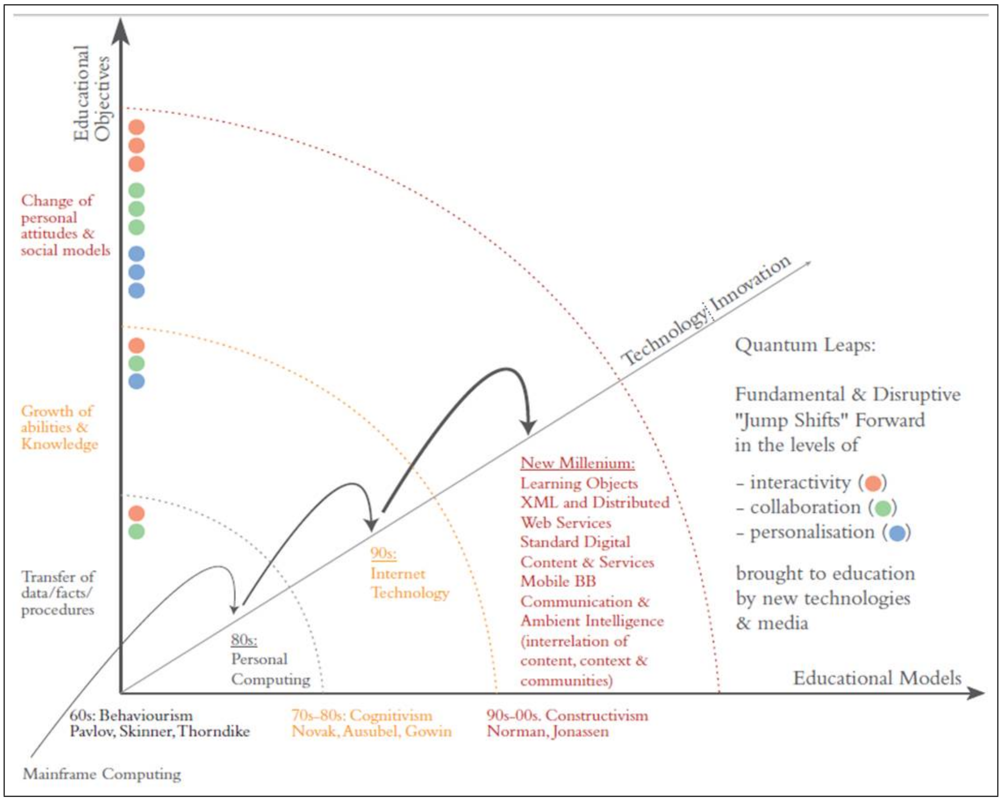


Figure 2.1: A quantum leap in educational technologies.
Source: (Cardinali 2003)

terms such as "online learning", "virtual classroom", "distance education", "online education", "technology-based learning", "web-based learning", "computer-based training" (i.e., learning from a CD-ROM), to name a few. Today, the trend is that many higher-level institutions are shifting away from a single traditional way of teaching - dominated by printing of course materials, writing on the blackboard etc. - to making use of ICT to advance flexibility in the ways teaching is performed (Nanayakkara and Whiddett 2005).

Within the literature, there are many different definitions of e-learning that reflect the different relationships that exist between education and technology. Some definitions recognise e-learning as the use of technology to conduct learning activities. The view of e-learning in such context would be descriptive. Some recognise e-learning as the use of technology to improve the quality of a learning process. Other definitions recognise e-learning as the use of technology to both conduct learning activities and improve the quality of learning process. In the report (E-Learning in Tertiary Education) published by the Organisation for Economic Co-operation and Development (OECD), e-learning was refereed to the use of technology to improve and/or support learning in Higher Education (Garrett 2005). While this reference is appropriate within the context of the report (tertiary education), a broader definition of e-learning regardless of the organisational or institutional context still varies. E-Learning according to Rosenberg (2002) is:

> *"the use of internet technologies to deliver a broad array of solutions that enhance knowledge and performance. It is networked, delivered to the end-user via a computer using standard internet technology and focuses on the broadest view of learning."*

Usluel and Mazman (2009) recognised e-learning both from the technical and educational side, with more emphasis on the educational value within the academic and non-academic domain. This recognition by Usluel and Mazman (2009) corroborates the view shared by Morrison and Khan (2003) and defined e-learning as:

> *"an innovative approach for delivering electronically mediated, well-designed, student-directed and interactive learning environments for everyone, regardless of time and place, using either the Internet or digital technologies in collaboration by the principles of instructional design."*

In spite of the numerous definitions of e-learning, these definitions, especially within the context of higher education, hardly make any reference to "pedagogy" even though the success of e-learning will ultimately hinge on how much educational pedagogy it can support (De Boer and Collis 2002). Perhaps this could be one of the geneses of many e-learning systems shortcomings. The general consensus here is that e-learning is: about learning and technology; and, knowledge acquisition through the use of ICT. Although, it is worth noting that e-learning and pedagogy are not the same. Nevertheless, an e-learning definition - from an academic point of view - that conveys the term "pedagogy" or its connotation could increase the significance of pedagogy itself in the minds of the e-learning vendors.

The context of e-learning research in this thesis is based on a novel architecture for an adaptive and flexible e-learning system within third level (tertiary) education using enterprise business technologies to enhance learning and the management of learning processes through various pedagogies. In this regard, the definition of e-learning by Morrison and Khan (2003), if juxtaposed with some sort of pedagogical connotation, would be appropriate in the context of the system architecture that is presented in this thesis. Hence, a definition is proposed:

> E-learning is a technology-enabled pedagogy that facilitates an interactive learning environment for all teaching and learning stakeholders (learners, tutor, course designer etc.) where a continuous means of knowledge improvements is possible.

Although, the educational value of any e-learning system is dependent of many factors, this definition is aimed to somewhat emphasise the importance of pedagogy and interaction within such a system. Therefore, within the proposed definition, the key components of e-learning entities such as technology, pedagogy, learning and teaching process (inherited from pedagogy definition), interactive (i.e., flexible and adaptive) environment, human actors, knowledge and learning management (i.e., possible improvement is a product of management) are captured.

In spite of the benefits and adoption of e-learning, especially within the formal educational institutions, e-learning has not proven to be the ultimate solutions for learning given the complex nature of what is being taught and learnt (Bunis 2003, Hedge and Hayward 2004, Tavangarian et al. 2003, Euler et al. 2001, Andersson and Grönlund 2009). As a result, many researchers have continue to advocate new ways in which technology can be used to improve learning within online environments (Hedge and Hayward 2004). For knowledge gain to be enhanced through the use of electronic media, "learning" must be the focal point of its strategies.

While there are significant differences between e-learning and traditional classroom setting from both the social and technical perspectives, this research has found no evidence to conclude that the traditional classroom setting is an ideal reference standard against which e-learning or all technology interventions must be judged (Ramage 2002, Neuhauser 2002, Lim 2002). Traditional classroom education is defined as:

> *"time and place bound, face-to-face instruction, typically conducted in an educational setting and consisting primarily of a lecture/note-taking model."* (Ramage 2002).

Tradition classroom environment is centralised and requires the physical presence of participants at a fixed time. In fact, one of the criticisms often levelled against the traditional classroom setting is that the pedagogical approach is often based on an instructor-led learning approach (behaviourist) where learners assume a passive role in the process of learning. Although, instructor-led learning could be reinforced within an online learning environment, advances in e-learning design and standards are increasingly making social learning a reality. With access to computing resources, e-learning can be accessed just about anywhere at anytime. Access to academic information and collaborations is possible at learners' conveniences. To achieve the best of both approaches (i.e., access to course content and collaborations), a blended learning concept was suggested (see section 2.1.2). It aims to bridge the discrepancies between e-learning and traditional learning methods. According to the European University Information Systems Organisation (EUNIS) survey in 2008, e-learning usage within the European higher educational institutions is predominantly based on a mixture of face-to-face and online approaches (i.e., blended learning) (Rothery et al. 2008).

2.1.1 Learning In E-learning Contexts

Traditionally, within an online educational system, knowledge is passed purely from lecturers to learners. This conventional approach has had a profound effect on the earlier design of e-learning systems and this approach has also influence the e-learning pedagogy in the same direction. One of the unintended consequences has left many scholars in the quest for the answer to the question, *"Where is the Learning in E-learning?"* (Woodill 2004).

Learning has been defined in numerous ways by many different researchers, theorists and educational practitioners. Learning according to Alonso et al. (2004):

> *"implies decision making on the basis of experience, which elevates "doing" as a basis for achieving an effective understanding of the knowledge."*

Watkins (2002) defines learning as:

> *"that reflective activity which enables the learner to draw upon previous experience to understand and evaluate the present, so as to shape future action and formulate new knowledge."*

Learning according to Kolb (1984) is a

> *"process whereby knowledge is created through transformation of experience."*

All of these definitions unequivocally emphasis on 'knowledge gain' and more importantly, it is gained through one form of a process or another. However, if learning as defined within the literature is to be taken into an educational context and teaching is seen as a means to facilitate learning, then, learning should result in knowledge gain regardless of the medium from which such learning is performed. Lecturers or tutors should engage with the learner through interaction on the grounds that a learning process involves the learner actively constructing knowledge. Furthermore, because learning is by no means static but a process that involves a bidirectional interactional process, the partnership of both the learner and lecturers/tutors should be one that fosters a good degree of collaborative interaction, thereby, resulting in a knowledge gain.

It is ironic that the concept that bears in its name 'learning' (E-learning) still leaves many to question the advancement of learning in e-learning itself. This is not to suggest that learning does not take place within e-learning. However, the quest for the evidence that learning is actually taking place during a learner's learning process (not during a summative process) can be a difficult challenge. It seems that the expectations are that it is necessary that e-learning systems provide learning analytical means to ascertain that learning and knowledge gain have occurred; and, the degree to which these are occurring right from the beginning until the end of a learning process cycle. These expectations may not be unconnected with the consistent claims of many e-learning providers that their e-learning services and products have the effectiveness, significant time and cost saving, and transformation of knowledge required in an individual and organisation. According to Woodill (2004), exaggerations by many e-learning providers are prevalent and a particular vendor was quoted to have used an expression such as "shock and awe!" to describe the expected results in the use of its e-learning system. In the Bunis (2003) summary, most of these e-learning providers' failure can be based on two issues. 1) The e-learning systems are either based on flawed educational principles. 2) Learners learning behaviours are not taken into account, therefore, real learning modelling is missing. In the survey conducted by Woodill (2004), several failures of e-learning providers in providing pedagogical-based learning environments for educational purposes were outlined. The survey result found that less than 1% (0.073%) of the 1004 e-learning providers said that pedagogy, instructional strategies, learning theory and instructional design were considered in their e-learning design strategies. However, all (100%) of these e-learning providers were emphatic about the innovative technological solutions and services for e-learning. This survey strengthens the argument to propose a new definition that includes pedagogy. Evidence of interest on the ethos of learning or teaching was found wanting (Woodill 2004). E-learning must involve learning through various stages of the process of learning itself if its role in education is to be sustained (Woodill 2004). The challenge for e-learning developers should extend beyond simple hyperlinks and chat-rooms to a more responsive, adaptive and truly interactive facility that accounts for learner's progression through each learning stage of the entire course material. A feedback loop that flags the action of one e-learning participant, when such participant is in danger of falling behind, should result in alerting the lecturer or at least the course tutor.

Learning is not an instant event, but a process that consists of some stages as every process does. It is safe to say that a single *"one-size-fit-all"* method or approach to learning will not suffice. There is the need for several e-learning technologies as well as traditional learning methods that best combine multiple approaches to teaching and learning - where new technologies encourage the value of face-to-face teaching. This face-to-face interaction between the lecturers and the learners can be embedded in an e-learning system in the form of a synchronous learning feature (i.e., virtual classroom); or, where possible, as an automated system that could initial a request for a face-to-face meeting between the lecturer and learner when the system detects the need for such in the case of asynchronous learning.

The emphasis of the research presented in this thesis is on learning and the process of learning in an e-learning system. This aims to demonstrate how learning and knowledge gain can be enhanced through: an effective method of managing the process of learning; the possible customisation of multiple learning paths; and, an enhanced human (learner, lecturer, etc.) interactive mechanism within a given learning material. Also, designing and developing instructional materials that suits learner's needs and learning goals in a way that caters for the institutional pedagogy is supported in the architectural model of the alternative e-learning concept that is presented in this thesis.

2.1.2 Blended Learning

The concrete ideal behind blended learning is to bridge the face-to-face gap that exists in a pure online learning through the use of various technologies and/or participation of all learning participants in a physical environment. Although the presence of the participants is registered in an e-learning system, technology can be used to create a virtual classroom that could bring them together as though they are in a physical classroom environment. There are many definitions of blended learning like many other learning terms. However, for the purpose of this research, the Clark (2003) definition fits into the objectives of this research thesis:

> *"Blended learning is the use of two or more distinct methods of training which may include combinations such as: blending classroom instruction with online instruction, blending online instruction with access to a coach or faculty member, blending simulations with structured courses, blending on-the-job training with brown bag informal sessions, blending managerial coaching with e-learning activities."*

The barometer of blended learning concepts and definitions point to a Hybrid method of learning that is typically characterised by the combination of different approaches of learning infrastructures (online classroom and tradition classroom, digital online and offline libraries etc) to achieve the aim of education - where learners are still expected to be able to successfully acquire the desired learning outcome of a particular module. It can be argued that the integration and adoption of blended learning within many higher institutions is another evidence of the limitations of a pure (i.e., non-blended) e-learning system vis-à-vis the educational technologies used for such system implementation. This argument is in no way aimed at undermining the significance of the traditional classroom and the non-blended e-learning system on an individual level. However, the challenge for any innovative technology that would dispense the value of education would be to mimic as closely as possible the strengths of the physical classroom environment. This is why blended learning thrives, even though it can be regarded as a coupling concept between virtual and non-virtual (face-to-face) education. Blended learning can be online (i.e., online collaborative learning) and offline (i.e., tutoring and mentoring) or both. It can be a powerful strategy, but can also be a recipe for disaster if not properly planned out or implemented. The degree of success of blended learning needs to be measured against learner's achievement and satisfaction, learning process and desired learning outcome. The evaluation process of the success of blended learning needs to account for the higher level of learning in a learning process (Garrison and Kanuka 2004).

What can not be measured can neither be improved, nor managed, nor monitored. Therefore, the conclusive remarks by Garrison and Kanuka (2004) provides a strong motivation and challenge for the basis of the research and novel e-learning architectural framework that is presented in this thesis. Monitoring learners' learning processes in a real time manner provides the measurability, manageability and improvability of learners' learning experiences through possible assessments of their learning performances. Based on the monitored data on learners' learning processes through course materials, timely supports from lecturers and/or tutors where and when necessary can be possible. The ability to monitor and intervene in various issues during learning processes will help lecturers to ensure that learners are on track in achieving the desired learning outcomes. This would also help the learners to gain knowledge in a more collaborative and interactive way. By explicitly defining the roles of the e-learning participants (course designers, lecturers, learners, tutors), the proposed architectural framework aims to strengthen the essence of blended learning through the possible orchestration of learning process that allows for the management of multiple e-learning participants and learning content/objects in a learning process workflow management system (see chapter 5). This framework would allow lecturers and/or tutors to be able to monitor, manage and help to improve learners' learning experiences in a learning process as learners learn through course materials.

2.1.3 Pedagogy

One of the areas of emphasis of e-learning is the justification for the use of innovative technology (Reichert and Hartmann 2004). This is crucial as the novelty of the research that is presented in this thesis is also based on the justification of an innovative technology that would help to address some of the major issues associated with the current e-learning systems. However, any technological solution for education without the desired pedagogical value would be detrimental to the core educational value it espoused; and, would simply involve a duplication of the current identified issues again and again without concrete or practical resolution to the pedagogical issues. Therefore, e-learning solutions should not be immune from pedagogical value as its importance can not be over emphasised. Again, a vivid understanding of what pedagogy means within an educational context would be of a benefit to it adoption within any e-learning implementation strategies. According to Tardif (2005),

> *"Pedagogy is the collection of means used by the teacher to attain his/her goals in the context of educational interaction with students."*

Bernstein (2000) went further and gave a specific definition of institutional pedagogy as:

> *"a sustained and formal process whereby somebody acquires new forms of conduct, knowledge etc from somebody or something deemed to be an appropriate provider and evaluator - appropriate from the point of view of the acquirer or by some other body or both, usually with accredited providers, and where acquirers are concentrated voluntarily or involuntarily as a group or social category."*

In a formal higher education setting for "traditional classroom" or "online" undergraduate studies (especially for distance learners), the desired learning outcomes are part of the broader context of pedagogical reform (Hubball and Burt 2007). Pedagogy, though a concept, is crucial to learning because it endows the relevance of the process through which knowledge-gain is achieved on lecturers' teaching methods and styles. The collective means involve: the content to be delivered through the rigorous analysis of the content; the learners' needs, through a proper analysis of the entire audience; and, the learning outcomes or objectives in the form of the goal analysis (Corcoran 2009).

Whatever means are used, the interactions between lecturers or tutors and learners is pivotal to the success or failure of any pedagogical approach (Tardif 2005). Esteves (2008) alluded to the complex and multidimensional aspect of higher education pedagogy and stated that lecturers from various institutions should engage in a pedagogical formulation; and that cross referencing of various institutional research projects may provide the stimuli for constructing sound pedagogy. While the assertions of Esteves (2008) may be correct, the future of learning, especial within the e-learning environment is such that learners can be part of the pedagogical formula. Learners can be permitted to: select course topics; formulate academic project or assignments; and, deduce course policies (i.e., attendance, learning schedule, classroom etiquette etc). The involvement of the learners would help them to be more responsible and help gives them a sense of ownership. Consequently, educational experience can be enhanced (Coombs and Rybacki 1999). Tardif's (2005) definition of pedagogy corroborates the idea that learners can be part of a pedagogical process as learners are part of the collective means.

To prevent the failures that were pointed out by Woodill (2004) in Section 2.1.1, and, to ensure that a new solution is compatible with many of the higher educational standards in terms of qualities as opposed to quantities; and, pedagogical norms, the new architectural framework in this thesis proposes that the concept of pedagogical modelling should be part of the curriculum or instructional design strategies. The sampled e-learning pedagogies that are modelled and presented in this thesis (see chapter 5) reflect just that - where learning objects/materials are wrapped around modelled pedagogies. The orchestration of pedagogy through a modelling approach would help lectures to be able to analyse the effectiveness of their pedagogy for possible reform (Dashwood et al. 2009). The technologies employed (see chapter 4) to drive this approach are not just to prove its technical merits, but more importantly, to augment the process of learning by allowing higher education pedagogies to flourish in such a process. The integration of program-level learning outcomes and institutional teaching methods form part of the learning process management strategies that are presented in this thesis. In any e-learning system for a higher education setting, pedagogy should always trump the choice of technology, even though technology would play a significant role in its implementation. The bottom line is that learners have to come out with more than being exposed to interesting e-learning applications, and they need to meet the sets of desired program-level learning outcomes and achieve real education (Redmond and Lock 2009).

2.1.4 Learning Theories

Learning theories can help to contribute to the understanding of the ways in which a learner exhibits the characteristics of learning. The most widely used models of learning theory are Behaviourism, Cognitivism, and Constructivism. Although, learning theories have been around long before technology began to influence learning (Siemens 2004), its concepts in understanding the complexity of a learning process are still relevant. To continue the quest for the answer to the question, *"Where is the Learning in E-learning?"*, it is vital to mention and understand the role that learning theories play in the process of learning. This section presents a brief discussion on learning theories and their potential impact on a learning process management within the architecture framework that is proposed in this thesis.

Behaviourism

A behaviourist learner can be considered as a learner that receives or gains knowledge passively. Behaviourists view of knowledge is such that knowledge does not depend upon examination of one's own mental and emotional state, and totally dismiss the argument about the internal mental states. Behaviourists assert that learners gain knowledge from outside resources. In an academic context, behaviourism has certain assumptions about the learners' behaviour and how learners learn. These assumptions are often reflected in the collective means that many lecturers use in teaching (lecturer-based pedagogy) - form a course note and give it to learner to learn. Verbal responses to questions are usually considered a measure or sign of success; and, good grades are assigned as a reward for such behavioural gesture (Amsel 1989). This would suggest that the role of a lecturer is to encourage the correct behaviour.

By integrating curriculum with topics, behaviourism is more in congruence with the traditional educational pedagogy, because traditional educational pedagogy provides so-called opportunities for lecturers to validate learners' perspective. Consequently, learners eventually assume the role of passive recipients in the process of learning. Subjective views on learning by the learners are lacking - learners cannot determine what to study or how to interpret and use information. This lack of a subjective element to learning is one of the contentious issue often labelled against behaviourist as lecturer-centred (usually frowned upon in e-learning environment, especially with the emergence of the Web 2.0 technology), and behaviourism is not considered to be learner-centred approach to learning. The nature of behaviourism tends to percolate through the traditional educational pedagogy.

Cognitivism

Cognitivism focuses on complex cognitive processes (mental process of the learner) such as problem solving skills, thinking, language, perception, knowledge representation and memory, concept formation and information processing (Shuell 1986). In cognitive theories, information is received through attention and integrated into memory. The information is transformed into knowledge and become part of the learner's cognitive structure for future usage. The stages of the cognitive process can be summarised as follows:

- receiving - information is received;
- storage - the received information is stored and integrated into memory;
- retrieval - information is remembered and retrieved.

The way learners assimilate, store, retrieve and reconstruct information is a key dimension that could influence the cognitive processes (Ertmer and Newby 1993). Instead of focusing strictly on behaviour, the emphasis is more on the mental processes. Cognitivism and behaviourism share similarities in that knowledge was still viewed as given and absolute; and, environmental conditions are influential in facilitating learning. Learners still respond to external stimuli (Shuell 1986).

Constructivism

Among the many types of constructivism, social, radical and critical are the most popular ones. However, all types of constructivism share the same belief (Boghossian and Peter 2006). In constructivism, personal subjective experience is just as valid as anyone else's and no single person has the ultimate opinion on what constitutes knowledge. What is considered knowledge to one person may not be knowledge to another person, because the frame of reason and logic of every person is different (Boghossian and Peter 2006). Depending on each learner's experience, there is a unique meaning of what is experienced or perceived, even without the lecturer's necessary view. These experiences and perceptions form the educational value for the learner. Evidence in the literature has shown that constructivism learning theory is compatible with the e-learning didactic ethics because it ensures learning among learners in a more critical and engaging manner that could only spur motivation (Koohang and Harman 2005, Harman and Koohang 2005, Hung and Nichani 2001, Hung 2001).

2.1.5 Summary

Constructivism, behaviourism and cognitivism are learning theories, not pedagogies. Behaviourists consider knowledge to be nothing more than passive, and cognitivists consider knowledge as abstract representations. Behaviourism tends to focus on the "learning outcome", while the focus of constructivism is on the "learning process". While the learning process (the focus of this research) is of great importance, the value of what is being learnt is also important if educational standards are to be maintained. Conversely, the values of what is being learnt are being ignored by these theories (Siemens 2004). Theorists have the tendency to revise and evolve theories perpetually to fit the changing condition. However, the revision and evolution of these theories do not keep pace with significant changes in educational technologies (Siemens 2004). This natural tendency reveals the incongruence between learning theory and technology.

One significant theory that has emerged from constructivism is constructionism - the idea that "learning-by-making" is an essential component for constructing knowledge for deep learning (Papert and Harel 1991). This concept was introduced by Seymour Papert from Massachusetts Institute of Technology in the 1980s. Papert and Harel (1991) argues the importance of the use of tools or artifacts for personal knowledge construction. He emphasised that by experimenting or interacting with tools or artifacts, learner's understanding can be enriched, particularly, when such interactions socially encourage public participation and construction of a "public entity" (Hamat and Embi 2010). Papert and Harel (1991) explained that:

> *" Constructionism - the N word as opposed to the V word - shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe."*

Social constructivism is a problem-based learning approach that fosters collaborative work through the use of tools like online whiteboards, charts, email, audio/video conferencing, forum, etc. (Hamat and Embi 2010). On the other hand, Papert and Harel's (1991) constructionism is considered a more pragmatic approach than constructivism. Therefore, it's oriented towards project-based learning. An online learning environment can be equipped to facilitate constructionism through the use of hands-on tools such as oline/virtual laboratories to perform experiments, computer language to develop programme and presentation tools (e.g., powerpoint) to share results. Constructionists believe that knowledge construction is developed by solving real-world problems that are meaningful to them. Within the proposed BPM-based architecture, the integration of learning tools that support constructive learning is possible and supported. However, the architecture is not oriented towards an online lab or project-based learning model.

The combination of technology and connectivity to generate learning activity can bring learning theories into the digital age (Siemens 2004). Since knowledge is either acquired through personal or other people's experience, such experience is related to the level of exposure and connectivity with others. Within the proposed e-learning system architectural framework that is presented in this thesis, the concept of modelling an online pedagogy is aimed at encouraging a closer connectivity with more experienced e-learning participants (i.e., tutor or lecturer). Also, creating and granting access to an interactive learning process dashboard for all participating learners could help to strengthen self-efficacy and provide motivation for an individual learner; especially when such learner can compare his/her learning process progression and performance anonymously against his/her peers in a non-intrusive way. This is known as a behavioural learning process. While learning theories may be hard to model, a connectivity technique within a virtual learning environment can inherently provide elements of learning theories where the learner is: encouraged to be critical in response to what is being learnt (constructivism); expected to provide acceptable answers to questions and subsequently rewarded to progress through the learning process ladder (behaviourism); expected to learn, understand, remember and reproduce information (cognitivism). The system provides a middle ground between the three learning theories based on the principle of connectivity between all of the e-learning participants (learners, lecturers, tutors, etc.). This is one of the core strengths of the conceptual framework that is adopted for the proposed BPM architecture for the management of learning processes. For the purpose of reuse of a pedagogical model - which is one of the significant benefits of the BPM model, the BPM nodes (regardless of how they are constructed to form multiple pathways) can provide an insight into the nature of any adopted pedagogy. It is important to note that multiple pathways are not the same thing as pedagogy. While multiple pathways are shaped by the use of connectors to link various activities, pedagogy, on the other hand, is shaped or driven by the types of learning activities (nodes). Therefore, the types of BPM nodes (i.e., learning activities/tasks, assessment activities/tasks, learning collaboration activities/tasks, etc.) can provide a good indication of the nature of an adopted pedagogy.

The philosophical objective is to develop a flexible and adaptive e-learning system that aims to foster 'learning' in a learning process through course materials. Hence, the concepts of flexible pedagogy; blended learning; learning theory are reflected in the didactic modelling and implementation of a learning process which, where applicable, are designed as an adaptive personalised and interactive e-learning application.

2.2 E-Learning Content Standards

Today, one of the areas in which e-learning has been particularly successful is in the abundance of learning content. Current e-learning standards are content-centric and shortage of e-learning content is not an issue for e-learning environments in today's e-learning world. Traditionally, e-learning content is distributed on the Web where HTML tags and hyperlinks are the predominant mechanisms in the way that e-learning content are constructed. Although the availability of this content on the Web has meant that access is possible just about anywhere, in reality, it is often difficult to search and find the desired content because of the limitations of haphazard link pages or keyword-oriented search engines. The pedagogical facet of the e-learning content also becomes a failure in the absence of a well defined annotation or metadata. Consequently, learning process management, especially through a customised or personalised learning approach, is harder to organise (Jekjantuk and Hasan 2007). Despite the potential to use and re-use content in a collaborative and interactive way, most e-learning in reality is only focused on the authoring and delivery of content.

The efforts to standardise e-learning content have recently received recognition and attention internationally from various specialist organisations. The emergence of Semantic Web technologies has made the annotation of content possible (even with pedagogical attributes) using explicit metadata. With the possible annotation of content, it is possible to use authoring tools and standards metadata to generate richer-in-metadata-content that can be integrated as a package within many e-learning systems (Jekjantuk and Hasan 2007). Metadata is a data about a data or as expressed by the LTSC (2002):

"Metadata is information about an object, be it physical or digital. As the number

of objects grows exponentially and our needs for learning expand equally dramatically, the lack of information or metadata about objects places a critical and fundamental constraint on the ability to discover, manage, and use objects".

If e-learning content are properly annotated and organised in the specific domain ontology, it would effectively facilitate authoring, publication, discovery, and reuse of content in an intelligent way. It would also be possible for artificial agents to discover and organise the annotated content from variegated sources, and combine them into a personalised course material that satisfies learners' needs. Crucially, e-learning content exist as learning objects (LOs) and are described by metadata as learning object metadata (LOM). LOs and their associated metadata are usually stored in learning object repositories (LORs).

This section discusses the roles that LOs play in learning process management, especially through possible customisation and enhanced interactive learning process. The major organisations (The IEEE Learning Technology Standards Committee - LTSC, IMS Global Learning Consortium and Sharable Content Object Reference Model SCORM) that are actively involved in formalising the e-learning LOs specifications and standards are also discussed. The impacts of standard specifications on e-learning content are briefly discussed. Finally, the potentials of learning objects based on DOCBook are explored.

2.2.1 Learning Objects

Learning Objects are fundamental to the formation of e-learning content and the technological standards that support their formation began in the early 2000s (Lee 2011). LOs can be regarded as any learnable digital object that helps to increase knowledge and awareness with the aide of the computer/Internet. In practice, the dynamic nature of the virtual grid environment (i.e., the Internet and the Web) is increasingly becoming more intelligent in the way that these digital contents are sourced, used and re-used. In some cases, systems (i.e., e-learning systems) that reside in the virtual environment are able to re-structure or re-formalise a new structured content from aggregated sources. Therefore, what is been presented as a learning object (LO) could in fact be a combination or aggregation of many modular objects. The ability to model, create and distribute e-learning content in a modular or aggregated fashion is fundamental to the intelligent and adaptive ways of formalising new e-learning content. LOs are the essential units and building blocks of a learning material in an e-learning system. Figure 2.2 shows the relationships between these standardisation bodies that are responsible for various e-learning LOs specifications and standards. Although,

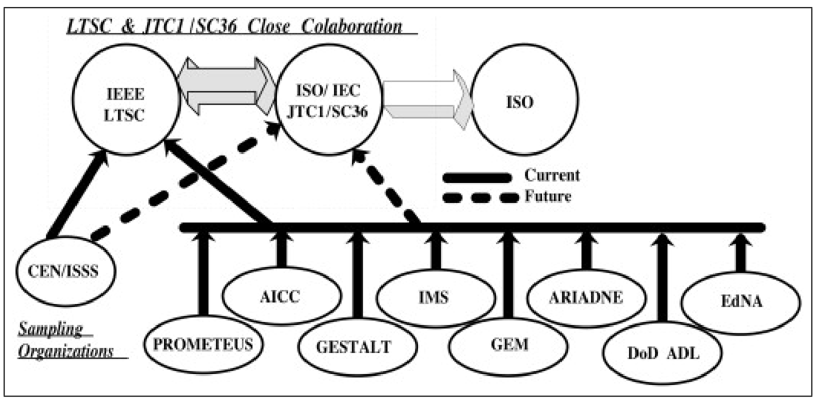


Figure 2.2: Relations among LOs standardisation bodies.
Source: (Anido et al. 2002)

there have been considerable efforts by various standard bodies (e.g., IEEE-LTSC, IMS) to bring about the standardisation of LO metadata so as to facilitate a common approach to identify, search and retrieve LOs. These efforts have yet to result in a common conceptual definition of Learning Objects (Polsani 2003). A list of several definitions of LO given by different researchers and the standard organisations are explored as follows:

> *"Any reproducible and addressable digital or non-digital resource used to perform learning activities or support activities".* (IMS 2003).

> *"A relatively small, reusable resource, through which a coherent, identifiable piece of learning can be achieved."* (Banks 2001)

> *"Learning Objects are defined here as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning".* (LTSC 2002)

Sosteric and Hesemeier's (2002) definition, however, deflates that of the LTSC (2002) because all digital and non-digital materials cannot be a category of learning object. Including everything in a definition can hardly be a definition at all. Sosteric and Hesemeier (2002) defined a LO as:

> *"A digital file (image, movie, etc.) intended to be used for pedagogical purposes, which includes, either internally or via association, suggestions on the appropriate context within which to utilise the object."*

A "Sport magazine" could not be used for learning, therefore, could not simply be considered as a LO. Nevertheless, the definition is interesting - a LO must be linked to "pedagogical purposes". Sosteric and Hesemeier (2002) definition gives a clear distinction between data, an information object and a learning object. The LOs defined by Sosteric and Hesemeier (2002), is adopted for the purpose of the proposed e-learning system architecture that is presented in this thesis, because part of the aims and objectives is to use LOs to promote learning through a flexible pedagogical model. LOs can be in granular forms and interoperate at different levels. The granularity forms of LOs as shown in Figure 2.3 is a hierarchical structure of LOs that can be used to build and fit together a Course - Module - Lesson - Topic, through the combinations of well structured and annotated LOs. Examples of LOs include a Web page, a book chapter, an electronic text, map, a graphic image, an interactive application, a Java applet, a multimedia resource, a QuickTime movie, a wiring diagram, a simulation, or any other digital resource that can be used in learning. The concept of Learning Objects is founded on that principle of the object-oriented programming where the creation of instructional components can be reused numerous times in different learning contexts.

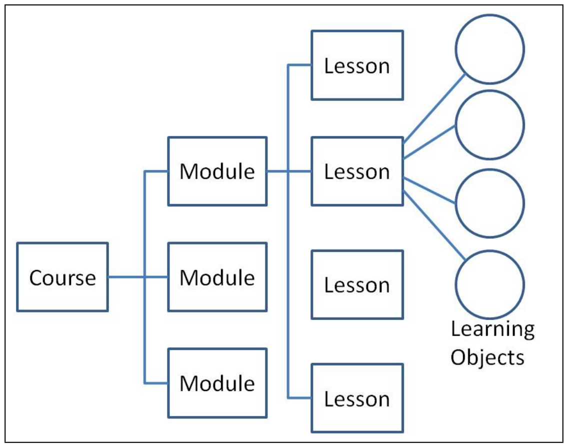


Figure 2.3: Learning Object Hierarchy

There are many functional requirements or attributes of LOs. Some of these attributes are:

- **Accessibility**: allow LOs to be accessed from one remote or heterogeneous location and delivered to many locations. Exploring this attribute will enable any e-learning system to be rich in learning resources (LOs) by accessing external LOs either supplementary to the existing course material or as an aggregation of LOs into a new lesson.

- **Interoperability**: with the aide of appropriate metadata, LOs that are developed with one set of tools or platforms in one location can be transferred and guaranteed to integrate well in a different set of tools or platforms in another location.

- **Adaptability**: allow LOs to be tailored to the needs of individual and situation.

- **Reusability**: LOs can be sourced internally or externally and integrated into multiple existing applications.

- **Discoverability**: by simple searching of metadata terms, LOs can be easily discovered;

- **Retrieveability**: extract LOs when and where it is needed.

2.2.2 Learning Object Metadata

One significant benefit of tagging LOs with metadata is the possibility of using such LOs in designing personalised course materials that could be used to target a particular audience. The first task before using LOs is to find them. Finding anything in a distributed environment like the Internet/Web can be challenging, especially in the face of an increasing use of digital LOs such as images, slides, exercises etc on all educational levels (Edvardsen and Sølvberg 2007). Learning Object Metadata (LOM) is

> *"a data model, usually encoded in XML, used to describe a learning object and similar digital resources used to support learning. The purpose of learning object metadata is to support the reusability of learning objects, to aid discoverability, and to facilitate their interoperability, usually in the context of online LMS"* (Barker 2005).

Some of the challenges facing the current e-learning systems is the inadequate or non existence of metadata that described the LOs that have been presented (Edvardsen and Sølvberg 2007). Consequently, discoverability, accessibility, adaptability, reusability and retrieveability are hindered. Storing LOs and the metadata that describes them in a Learning Object Repository (LOR) would be an ideal solution where keywords can be used by search engine to query LOs in the LORs. Many LO specifications exist but the internationally recognised open standards such as the Institute of Electrical and Electronics Engineers Learning Object Metadata (IEEE LOM), Instructional Management System (IMS) specification and Advanced Distributed Learning (ADL) for Shareable Content Object Reference Model (SCORM) are the most popularly accepted LO specifications (Brooks and McCalla 2006).

The term "LOM" can be used to refer to both the IEEE standard and the IMS Learning Resource Meta-data (LRM) specification. Figure 2.4 shows a graphical representation of the IEEE LOM elements and structure in the data hierarchy. The hierarchical structure of the LOM elements in Figure 2.4 are divided into nine levels of categories: 1. General, 2. Life Cycle, 3. Meta-Metadata, 4. Technical, 5. Educational, 6. Rights, 7. Relation, 8. Annotation, and 9. Classification (LTSC 2008). Each of these categories represents a branch that also consists of several elements which can also have its own branches and these branches can be divided into other branches and leaves. The connections between branches and leaves are shown in Figure 2.5. Each element has a specific definition, value space,

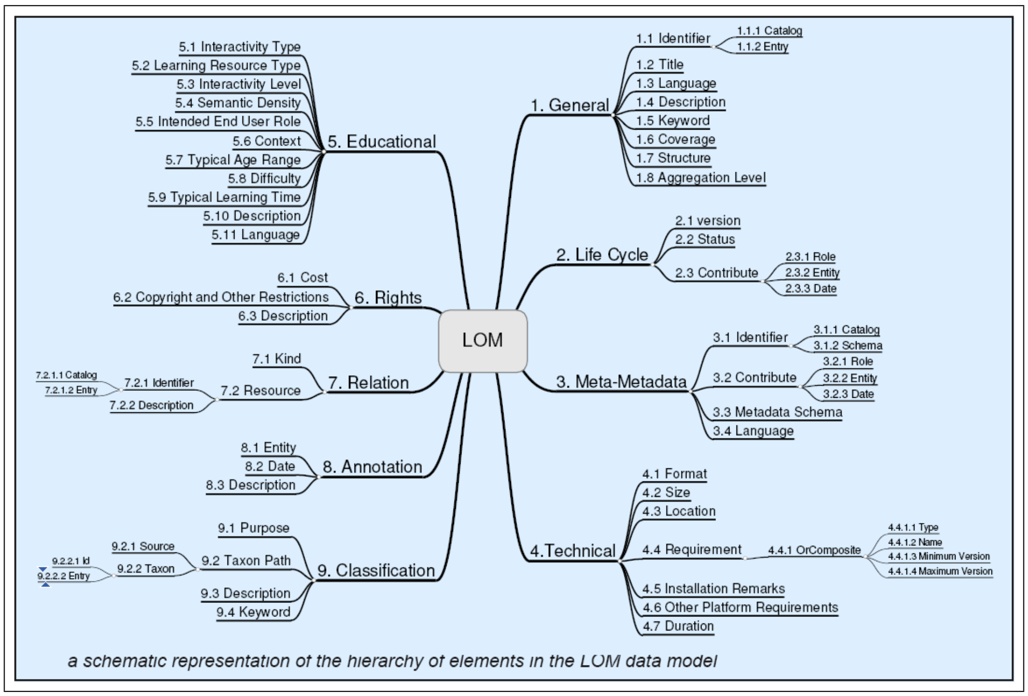


Figure 2.4: The hierarchy of the IEEE LOM Meta-data elements and structure.
Source: (Barker 2005).

and data type (IMS 2006). Figure 2.6 depicts an example of how a learning object can be constructed together with its associated metadata.

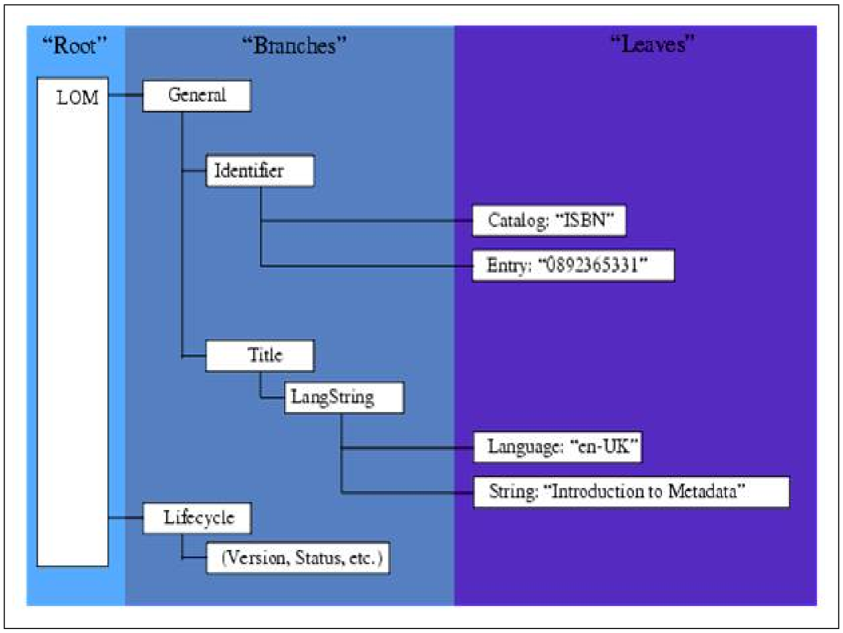


Figure 2.5: Root to leaf "tree view" of meta-data.
Source: (IMS 2006).

```
<?xml version="1.0" encoding="UTF-8"?>
<lom xmlns="http://ltsc.ieee.org/xsd/LOM" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://ltsc.ieee.org/xsd/LOM http://ltsc.ieee.org/xsd/lomv1.0/lom.xsd">
  <general>
    <title>
      <string language="en">Ship</string>
      <string language="nl">Boot</string>
    </title>
    <language>en</language>
  </general>
  <technical>
    <location>http://en.wikipedia.org/wiki/Image:Bateaugoelette.jpg </location>
  </technical>
  <classification>
    <keyword>
      <string language="en">schooner</string>
    </keyword>
  </classification>
</lom>
```

Figure 2.6: An example of a Learning Object and its associated LOM metadata.
Source: (Ternier et al. 2008).

2.2.3 Institute of Electrical and Electronics Engineers Learning Technology Standards Committee (IEEE LTSC)

Since 1997, IEEE LTSC has been providing the specification that governs the development of the LOM (LTSC 2008). It is one the most accredited standard bodies for learning objects standard specifications with over 20 different groups (including SCORM and IMS) creating e-learning content standards using the IEEE LTSC specifications. IEEE LTSC provides specifications relating to almost all aspects of digital-based educational content. The IEEE LTSC groups are actively working with similar groups from other organisations with the aim of developing standards in many areas - Content, Vocabulary, Identifiers, Architectural Models, and other topics - of e-learning content. The main objective of the IEEE LTSC working groups is to develop and promote technical standards. They recommend best practices and guidelines for software tools, components, design and technological methods that help to facilitate the development, implementation and interoperability of e-learning systems and its content (Anido et al. 2002). In all of its work, e-learning content innovation is the one with the most significant impact on educational systems.

2.2.4 Instructional Management System Global Learning Consortium (IMS GLC)

Instructional Management System Global Learning Consortium (IMS GLC or IMS) is one of the non-profit consortiums that develops content specifications and provides developer support through workshops and seminars. Its contributing members collaborate with other organisations such as the IEEE LTSC. In 1998, it delivered specifications to the IEEE LTSC from which the IEEE LTSC Learning Object Metadata standard was built (IMS 2006). This specification was also adopted by Advanced Distributed Learning (ADL) as part of the SCORM specifications. The IMS LOM specification provides a set of elements that are fundamental for describing e-learning content resources. Figure 2.7 shows some of the significant IMS specifications that are currently very active within the e-learning content standardisations.

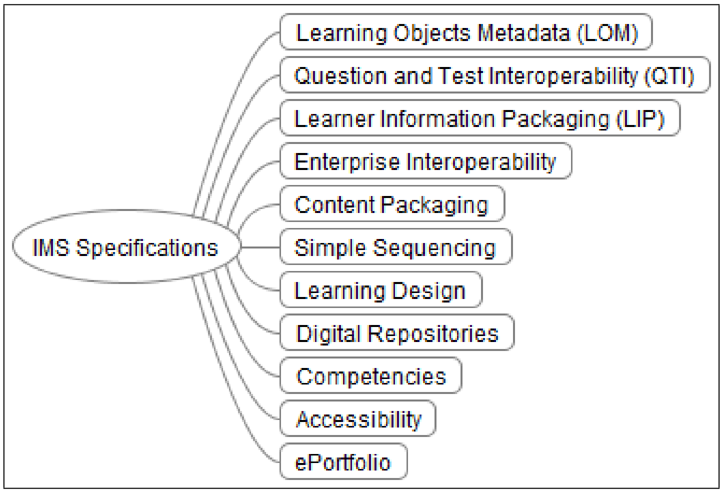


Figure 2.7: IMS specifications

2.2.5 Advanced Distributed Learning (ADL)

Advanced Distributed Learning (ADL) is the initiative of the United State Department of Defense and White House Office of Science and Technology Policy. The most significant specification contributed by ADL organisation is the Shareable Content Object Reference Model (SCORM). The aim of SCORM specifications is to provide metadata that allows e-learning content to be packaged in a manner that permits this content to be shared and interoperable. If multiple e-learning projects comply with the SCORM specifications, then, from content integration perspective, these projects are guaranteed to inter-operate together. SCORM specifications are made up of other specifications that are developed by many other international standards organisations (i.e., the IEEE LTSC and IMS), thereby, providing recommendations for consistent e-learning content implementations. SCORM provides a means to embed metadata in every learning object and content package. SCORM also separates learning object architecture from system architecture and divides the system functions into various functional components. The main functional components are: virtual learning or management system, and, Shareable Content Objects (SCOs). Figure 2.8 shows the relationship between SCOs, virtual learning or management system and the end user.

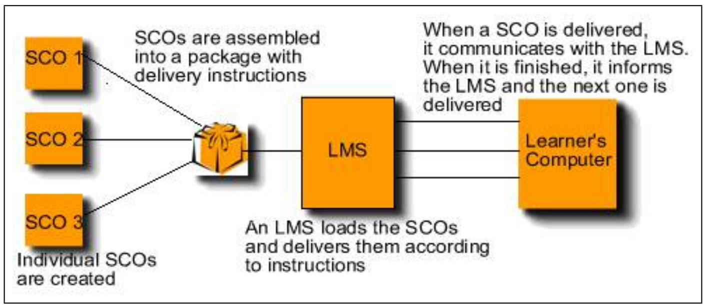


Figure 2.8: SCORM model.
Source: (Eduworks 2009).

SCOs are standardised form of reusable learning object (i.e., LOs plus the SCORM metadata = SCOs). For the purposes of SCORM, a virtual learning or management system that is SCORM compliant is any learning system that can keep user information, able to launch SCOs when requested, and, allow cross-communication between SCOs, so as to tell it which SCO comes next (Eduworks 2009).

Although complexity surrounding SCORM implementation is causing many less experience content authors to consider it as a last resort; it is still however a popular specification for implementing e-learning content by the vendor community. According to Friesen (2003), the SCORM documentation resembles a military approach to standards and is very engineering like and hard to relate to educational training. This rigid approach to what standard to apply to LOs can be a stumbling block in an initial implementation of standardised LOs, even though it is arguable that such SCORM-based LOs are rich in metadata. Furthermore, the SCORM specification does not fully support deployment in enterprise architectures.

2.2.6 Issues with the metadata standards

Clearly, LOM standards should not define how teaching should or should not be carried out. It is however expected to provide the metadata on how pedagogical dimension of LOs can be specified (Allert et al. 2002). Current metadata standards are not without their downside when trying to create an adaptive online learning environment with LOM, particularly, when software agents are employed to carry out the task of adaptation or decision making process. The real time adaptivity is often compromised as a result of over reliance on human users to create and utilise the metadata for the content of the learning object itself (Brooks and McCalla 2006). The task of filling metadata attributes and fields in a learning object repository can involve a great deal of effort. This has contributed to the slow rate of adoption of LOM, considering the high level of interest surrounding the field in the past few years (Neven et al. 2003). According to Wiley (2002), many authors lack a specific set of information about LOM. Consequently, the ability to reuse learning objects is often inhibited. This, in a way, undermines the essence of the LOM standard that aims to expedite the means of finding and reusing learning objects within e-learning systems.

Standard overload was another mitigating factor. Many authors admit that developing learning objects that require the support of over 80 metadata attributes and elements was too much of a task. Many authors are not willing or prepared to follow all of these attributes, especially, during the initial period of implementation (Brooks and McCalla 2006). Brooks and McCalla (2006) and Agostinho et al. (2004) went further to advocate for the use of sufficient ontologies suitable for a specific need instead of a compelled and overbearing taxonomy of LOM. This does not mean a complete disregard for the LOM standards but a different approach to using a different set metadata that is simpler and yet able to reflect the valued that constitute educational rational would be appropriate. Depending on the scale of an e-learning system, the adoption of a simpler metadata (i.e., DocBook) or ontological structure based on LOs relationships would be plausible.

The issues with the metadata standard have lead to the quest for a different solution that is different from the ones specified by the renowned standard bodies that are discussed in above sections. For this reason, a simple, flexible but powerful learning object metadata that is based on DocBook is investigated. The aim is to explore the possibility of learning objects content authoring within the proposed architectural framework. Even so, the possible use of the IEEE LOM standards that could facilitate learning process management is still an ongoing investigation for future LO implementation and design within the proposed e-learning system framework.

2.2.7 DOCBOOK

DocBook is an Extensible Markup Language (XML) or schema language defined in: Document Type Definition (DTD); REgular LAnguage for XML Next Generation (RELAX NG); W3C XML Schema; and, Standard Generalised Markup Language (SGML). Currently, it is maintained by the Technical Committee of Organisation for the Advancement of Structured Information Standards (OASIS[1]). DTD defines the valid framework blocks for an XML document. DocBook DTD specifies a lexicon that is particularly suitable for writing technical books and papers initially within the computer and software domain. However, its usage is widespread within academic environments for learning object content creation (Walsh and Muellner 1999). Though DocBook is popularly used to create "technical document", Martínez-Ortiz et al. (2006) however pointed out that authors are compelled to consider using DocBook for instructional material used for teaching a particular course. Packaging and publishing of DocBook content in a virtual learning environment is made possible using an automated mechanism in conjunction with the DocBook XSL stylesheets. The DocBook XSL stylesheets are part of the existing DocBook Projects that aims to support the develop-

[1]https://www.oasis-open.org/

ment and implementation of a range of open-source DocBook resources. This allows content reuse and adaptation by separating presentation from content as depicted in Figure 2.9. DocBook is highly modular and extensible. The simple and well structured markup of Doc-

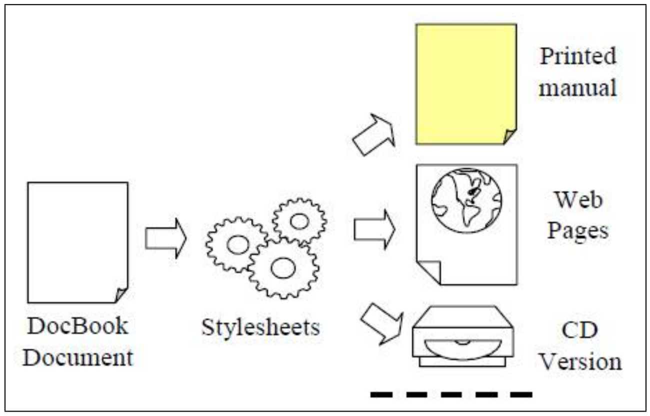


Figure 2.9: DocBook promotes a single sourcing model of content management. Source: (Martínez-Ortiz et al. 2006)

book constructs simplify interoperability with other XML compliant languages, particularly those related to e-learning (Téllez 2010). This according to Téllez (2010) gives Docbook advantage over the use of other content authoring tools or standards such as the SCORM, IMS CP and IMS QTI, as these standards still (ironically) do not easily generate the interoperable needed in the e-learning systems. Furthermore, a rich set of DocBook XML constructs can be mastered by advanced and proficient DocBook XML users, but ordinary users can easily produce increasingly sophisticated documents by slowly learning only a few tags. The adoption of DocBook amongst many renowned organisation such as Hewlett Packard, Sun, Microsoft, Red Hat and the Linux Documentation Project is prominent, well tested and given weight to its merits as a learning object content authoring tool (Martínez-Ortiz et al. 2006). The benefit of adopting DocBook within the proposed BPM-based architectural framework is purely to simplify e-learning content authoring through the use of its simple metadata. However, DocBook metadata are not designed for the management of a learning process itself. Unlike some of the standard e-learning content specifications such as the IMS LD, DocBook has no specific technical support for pedagogical strategy.

2.2.8 Summary

E-learning content can be created in the form of learning objects. Any e-learning content that serves to fulfil a learning objective can be referred to as learning objects. Learning objects use specification standards to address the issues of reusability, technology standards, metadata description, granularity, LO's structure and packaging. Learning objects usually exist in smaller units of learning. They can be aggregated to form a chunk of e-learning content.

Learning Objects potentially have a critical role in learning management by the possible creation of a personalised learning programme that can easily be updated and adapted. While DocBook Metadata does not fall into the categories of the most popularly known international standard (i.e., IEEE LOM), it is very popular amongst lecturers for e-learning content authoring. Without standards the value of LOs is substantially reduced. These standards are suggested because they facilitate uniformity in the creation of quality instructional materials (LOs) with the potential for understandable pedagogical strategies. LOs stand to benefit from the established standards that are describe in the above sections. However, LO authoring and delivery are not enough to manage the process and intricacies of learning in such a way that could account for the learning behaviours and styles of the learners. Within the proposed e-learning system architecture, LOs based on DocBook metadata are considered purely on LOs design, use and reuse purposes. With DocBook as an authoring choice for LO, maintenance and distribution of learning materials can be facilitated seamlessly. The adoption of DocBook with the architecture is not to facilitate pedagogical modelling through a learning process workflow. However, it is considered for creating LOs.

Furthermore, upon completion of the investigation into the exploration of the IEEE LOM and IMS LOM standards, the extensions of these standards could be adopted and integrated within the proposed system architecture in order to enhance pedagogical modelling and customisation of individual learning processes. The IEEE LOM and IMS LOM standards that would be further investigated, include: assessment standards like IMS QTI (Question & Test Interoperability); IEEE PAPI (Public and Private Information) - to define a 'portable' learner; IMS LIP (Learner Information Profile) - in part, been derived from the PAPI; IMS LD (learning design) - for content design and IMS CP (content packaging) - used to export, import, aggregate and disaggregate content packages between multiple systems.

2.3 Current E-Learning Systems

Following the emergence of the Internet, there has been a commensurate support for learning and teaching activity using software-aided tools through the Internet (O'Leary 2002). An important aspect of any e-learning project is the E-learning system. Once a learning material is designed and produced, it requires a platform through which it becomes available to the learner. E-learning uses web-based technology to create valuable learning environments in education. This can potentially provide flexibility, interactivity and a continuous exposure to a better learning experience. Within many E-learning systems, it is now possible to integrate learning enhancement features such as e-mails, instructional materials, quizzes, online live chat sessions, assignments, online discussions and forums (Yi-Cheng et al. 2007). There are different types of e-learning systems. There are subtle, yet significant differences between them; and, many of the current e-learning solutions fit into one or more categories of the existing systems. This section sets out to: explore and analyse the solutions offered by some of the most widely used e-learning systems; analyse the impact of their limitations on learning management; and, ascertain, if possible, the category that would be most appropriate for the implementation of a learning process management architecture that is proposed in this thesis.

2.3.1 Content Management Systems (CMSs)

Content management systems (CMSs) deal with the process of designing, storing, modifying, retrieving and displaying content. They are also used to facilitate content creation and organisation through the used of a managed workflow. CMSs separate the content from the web interface design. Examples of CMSs include Joomla[2], Dotclear[3], WordPress[4], Moodle[5] etc.

CMSs provide features such as data management; web life cycle management; content personalisation; syndication; versioning and workflow that allow management of content to be possible in a robust way (Browing and Lowndes 2001). They focus on information resources and learning content, therefore, it is a unit or part of the global concept of e-learning strategy. CMSs allow institutions to focus on creating courses and populating them with learning objects. For learning to be part of such system it need to greatly focus on the acquisition of knowledge and learning related communication strategies amongst all e-learning participants.

2.3.2 Learning Management Systems (LMSs)

While CMSs focus on the courses delivery, a Learning Management Systems (LMSs) focus on tracking individual learning needs and learning outcome achieved by such individual learner (Roqueta 2008). LMSs are more comprehensive, have more features. According to Carliner (2005) A LMS is software system that mainly act as an electronic medium that performs various tasks related to the administration of registration; enrolment; track participation (signing on and signing off of online courses); track completions (online ratings, scores, or grades); summation of reports, e.g., the number of registered learners for particular courses;

[2]www.joomla.org
[3]www.dotclear.org
[4]www.wordpress.org
[5]moodle.org

and, course records. LMSs allow the delivery and management of training to be possible on learners' learning activities. They can use software agents that automatically send an email to learner before or after an activity is complete (e.g., submit assignment). Examples of LMSs include Moodle, ANGEL Learning[6], Dokeos[8], Learning Activity Management System (LAMS)[9], etc.

2.3.3 Learning Content Management Systems (LCMSs)

The concept of Learning Content Management System (LCMS) is that it is a combination of related technology that focuses on the management of learning environment by facilitating developers' ability to manage, create, use, reuse, discover and deliver learning object content from a single or multiple LORs (JURUBESCU 2008). At the same time, LCMSs have the characteristics of LMSs (administrative and management) and CMSs (content creation and personalised assembly). In effect LCMSs = LMSs + CMSs. The obvious differences between LMSs and LCMSs with respect to course management are show in Figure 2.10 and Figure 2.11. Figure 2.10 depicts a simple way by which LMSs manage courses without any particular granular details of the course object content. Figure 2.11 on the other hand depicts a more complex way of managing a course through its LOs that can be used to personalised learning.

The administrative and management aspect of a typical CMS to create content and the content personalisation aspect of a traditional LMS are blended together by LCMS to provide the management of e-learning content in a complex but desirable manner. Course management systems are aimed primarily at formal education, particularly at postsecondary level (JURUBESCU 2008). While LCMSs functions are more similar to the LMSs in

[6] www.blackboard.com/ANGEL (Acquired by Blackboard[7] in 2009)
[7] www.blackboard.com
[8] www.dokeos.com
[9] www.lamsfoundation.org

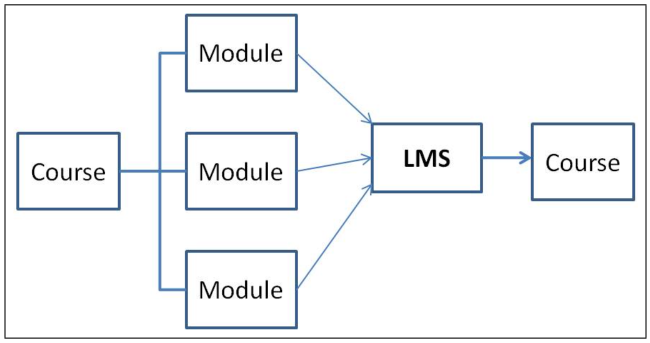


Figure 2.10: LMS model of course management.

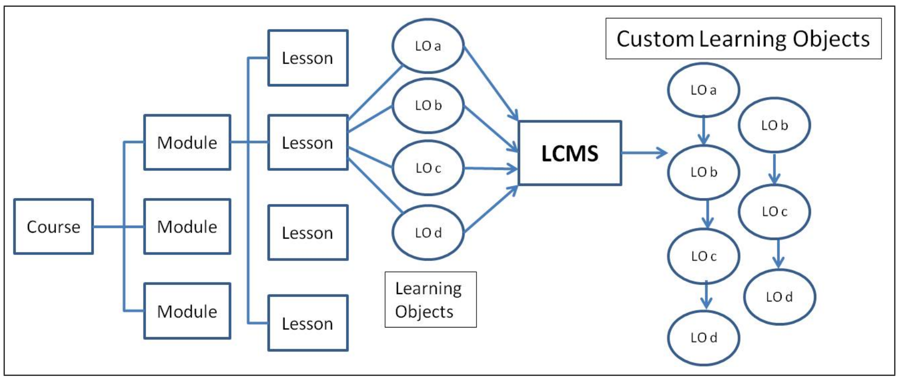


Figure 2.11: LCMS model of course management.

terms of providing content creation for personalisation, LCMSs are appropriate when institutions have a large amount of learning content and wish to separate learning content silo from learning process management. Learning object is the heart of the LCMSs to creating personalised learning for learners. Examples of LCMSs include Claroline[10], e-doceo solutions[11], Ganesha[12], Openelms[13], ATutor[14] etc. Other benefits offered by LCMS are: Powerful Collaboration Tools; Rapid Content Creation; Open Authoring; Assessment and Survey Capabilities; Multi-lingual Support; and, SCORM Capabilities etc.

[10] www.claroline.net
[11] www.e-doceo solutions
[12] www.ganesha.fr
[13] www.openelms.org
[14] www.atutor.ca

2.3.4 Virtual Learning Environments (VLEs)

A Virtual Learning Environment (VLE) is a software system that aims to help lecturers in the administration and management of instructional materials such as providing course notes, multiple choice quizzes and on-line communication (mailing lists, message boards and chat). Similar to the LMS, it is a set of teaching and learning tools designed to enhance learners' learning experiences through the use of computer resources and the Internet within the learning process. VLEs were originally designed for distant participants (learners and lecturers) but they are not restricted to distance education (Dillenbourg 2000). The essential features of a VLE package are made up of: electronic communication; online support for learners and lecturers; curriculum mapping; internet links to external curriculum resources; and, learner tracking (Weller 2007).

The adoption of VLEs are widespread, for example, a report in 2003 shows that 86% of the institutions surveyed in the United Kingdom revealed that VLEs are currently been used in their institution (Weller 2007). The most popular VLEs currently available are Blackboard/WebCT, Moodle, LAMS and SAKAI[15]. Blackboard/WebCT is one of the leading commercial systems that are used worldwide. Moodle is an open source VLE that is increasingly popular (Weller 2006) and SAKAI is a community source VLE. The term VLE is often used interchangeably with many e-learning systems such as those discuss in previous sections (LMS, LCMS and CMS) or Learning Support System (LSS) or Managed Learning Environment (MLE) or Learning Platform (LP) - all of which provide the means to conduct education through computer-mediated communication (CMC) (Denev 2007). Denev (2007) pointed out that the use of a particular term to describe an e-learning system largely depends on regional location. For example, in the United States, LMS is the commonly used term while the United Kingdom and many European countries favoured the use of the terms VLE

[15] www.sakaiproject.org

to describe e-learning systems. One difference between VLEs and LMSs is that LMSs are traditionally developed to handle complex organisational training programmes and are more expensive to implement (Bach et al. 2006, Pinner 2010). Also, the pedagogical practices within the VLEs tend to concentrate more on constructivism while pedagogical practices within the LMSs tend to involve a multifaceted pedagogical approach and provide more complex interactive control to enhance participants' learning experiences (Bach et al. 2006, Pinner 2010).

2.3.5 Current E-Learning System Limitations

Current E-Learning Systems have in no doubt helped to advance learning experience through a relatively flexible online learning environment that fosters collaboration, communication and assessment (Dong and Li 2005). In essence, current e-learning systems do offer a solution to learning management through content authoring, delivery and course tracking. Course materials can be uploaded and be permitted for download by learners. Therefore, it can be argued that whatever way an e-learning system is used by the lecturers to dispense their course materials to learners, it is by itself a pedagogy. Just because a pedagogical position is not explicit or obvious, it does not mean that it does not exist. The issues though are that there are no methodical strategies for pedagogy to be modelled in a manner that reflects the complexity of their teaching, similar to the traditional classroom environments. There is no adequate framework that could support course designers to re-evaluate and reflect on the effectiveness of their chosen pedagogy. Also, the argument by most e-learning system vendors that e-learning systems should be pedagogically neutral is at best naive and at worst a failure to understand the unintended consequences on the principle of their neutrality stance on pedagogy (Friesen 2004). The lack of pedagogical strategies to the lack of managing learning through its processes lessens the significance of teaching and learning management itself.

The extent of flexibility to accommodate or provide customised learning paths in a learning process is still difficult to achieve, as customised learning paths are not ingrained or modelled into an instance of a learning process in the current e-learning systems. Many educational technologists and researchers treat current e-learning systems with contempt due to the lack of innovation (Weller 2006). Weller (2006), Davis and White (2011) went further to express a number of shortfalls that are often levelled at the more popular e-learning systems:

- Content focused - The administration and management of content is often the target of improvement.
- Lack strong pedagogy - Sound educational value is founded on sound pedagogical strategy, policy and principles. There is also the need to enhance the current means of interactive pedagogy.
- Based around a lecturer-classroom model - This is fundamentally about what lecturers want to do and the role of learners in how learning activity should be conducted are grossly under represented.
- Combination of many web tools that often fall short of adequately addressing educational needs.
- They operate on a lowest common denominator approach.
- Diversity on the range of subject areas to accommodate the needs of individual learners is deficient.
- Interoperability is still a challenging area where the exchange of content between various systems for the purpose of creating a new learning subject is still not an easy task.

According to Davis and White (2011), discussion boards, chat rooms, and email can all form part of the electronic communication features of many e-learning systems (especially the VLEs, LMSs or LCMSs). Discussion boards are useful in addressing frequently asked questions; chat rooms are used by learners to collaborate with each other virtually and tutors can add input and advice when required. Communication by email has been the most popular means to contact lecturers but it is still very under-utilised by learners as they still prefer face-to-face discussion (Perrie 2003). The extent to which these communication features impact on the learning process is still difficult to measure. An automated communication mechanism that informs the right people at the right time when intervention is required in the middle of a learning process is not a feature that is inherent in the current systems.

The pedagogy commitments of learning system environments or technologies are not inherently explicit. Nevertheless, the relationships and interactions between pedagogical commitments and particular learning environments are largely expressed by the ways in which learning activities are designed and used to engage learners in a learning process. Apart from the CMSs that mainly cater for content creation, which ultimately leads to a transmission model of pedagogy where content is distributed to learners and learners are passive recipients of knowledge, it is possible to use VLEs, LMSs or LCMSs for several pedagogical purposes such as behaviourism, cognitivism and constructivism. Generally, the pedagogic model within these systems is such that content is still being pushed to the learners (Davis 2010). There is, however, a tacit commitment by these learning system environments to support a pedagogical theory that is based on social constructivism. VLEs and LMSs, in particular, strive in this regard. In a sense, one issue with these systems with respect to their pedagogical commitments is the lack of adequate frameworks that could help to evaluate the effectiveness of their pedagogical commitments (Britain and Liber 2004).

Many of the e-learning systems developed today capture the process and management of teaching and delivery of courses, with the advantages of eliminating time and location barriers. Their values towards the integration of better learning outcomes are still focus areas of research, with some researchers recognising the issues and providing innovative solutions to solve related problems (Au et al. 2009).

In an effort to address some of these issues, extensional packages (e.g., LAMS, e-Portfolio) where developed to fit or integrate into some of the categories of e-learning systems that are discussed above. The potentials and shortfalls of some of these extensional packages to provide learner-centric features through Learning Process Management are discussed briefly.

Learning Activity Management System (LAMS)

Learning Activity Management System (LAMS) is an integrated software system based on Learning Design (LD). It is a tool for designing, authoring, managing, running and delivering online collaborative learning activity (Dalziel 2006). According to Dalziel (2006), LAMS is a tool for creating *"sequences of learning activities which involve groups of learners interacting within a structured set of collaborative environments"*. It is developed using Java, Flash, XML and HTML technologies. As a Learning Design tool, it can be integrated within some of the existing e-learning systems (i.e., VLEs and LMSs). In February 2003, a group meeting held in Valkenburg noted a number of challenges arising from LAMS development for Instructional Management Systems Learning Design (IMS LD). Some of these challenges, according to Dalziel (2006) were:

- Representation of multi-learner activities in simple sequential steps. Learning activities are more complex than what could be represented in a sequential form.

- The need for the development of an effective monitoring capability of a complex, multi-task activity whereby lecturers can approve actions in a real time manner based on monitored data.

LAMS is inspired by, and heavily based on IMS LD (Dalziel 2006). However, it is faced with the challenge of a sequential learning path that provides only a one-way (forward) learning path as shown in Figure 2.12.

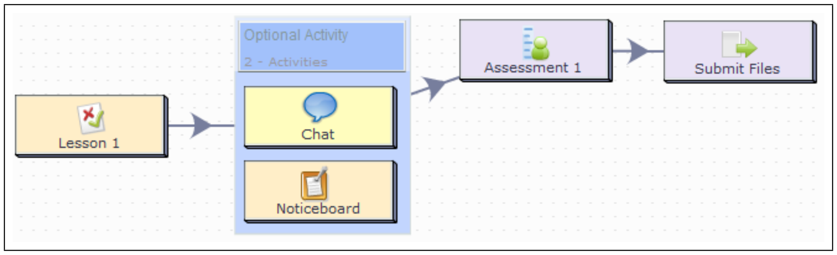


Figure 2.12: One-way (forward) learning path in LAMS.

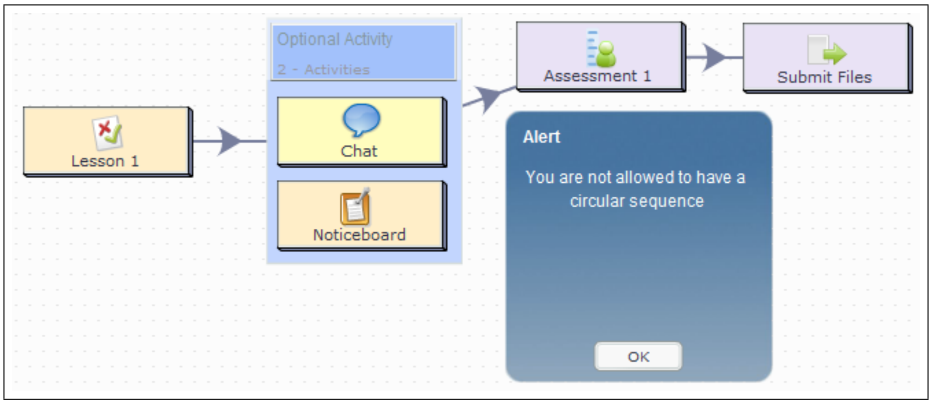


Figure 2.13: An alert message when attempting to connect a link from "assessment 1" back to "lesson 1" in LAMS.

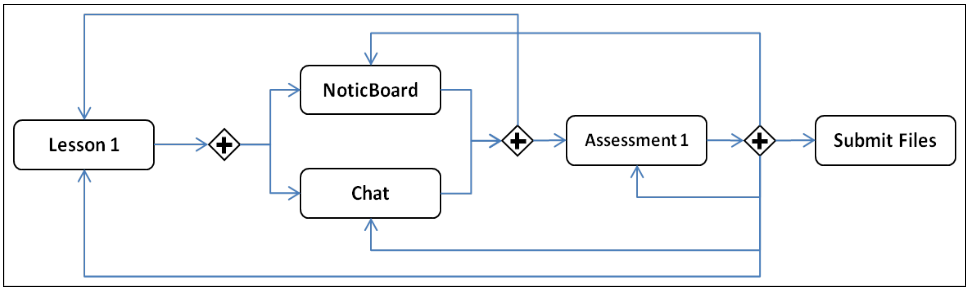


Figure 2.14: An example of an ideal possible back and forth flexible learning path.

In addition to the challenges expressed by Dalziel (2006), it is currently not possible, as shown in Figure 2.13, to model pedagogy or organise learning activities around structured course material in such a way that could allow learner-controlled back and forth navigation among previously completed learning content if and when needed. Consequently, learners are unable to perform cyclic navigation. Learner-controlled back and forth navigation through learning materials is consistent with the nature of the heterogeneous interactions that constitute learning in the real world. For example, using the modelled pedagogical scenario shown in Figure 2.12, a learner might either want to navigate back to "lesson 1" after collaborating with his/her peers using the chat tool or navigate back to "lesson 1" after realising that "assessment 1" was more difficult than anticipated. An example of how this flexible pedagogical scenario can be improved using the proposed BPM conceptual framework is shown in Figure 2.14. Additional limitations of LAMS include: the lack of automated agents to perform learning data mining and aggregation that could facilitate a more in-depth diagnostic analysis of the effectiveness of a modelled pedagogy; and, the lack of the use of a learning rules engine to cater for complex learning needs.

HTML tags and hyperlinks are the predominant mechanisms in which learning pathways are constructed within the conventional VLEs. These, of course, impose little control on learner pathways, so learners are completely free to engage in arbitrary pathways ("back and forth" - or even jumping forward - as they wish). However, the use of a graphical modelling mechanism (a key concept of the proposed BPM-based architecture) to construct learning process workflow with flexible multiple learning pathways is inadequate. LAMS provides one solution to this regard. However, the rigid one-way (forward) learning path solution provided by LAMS negates the concept of "Think globally, act locally". Thinking globally is to define and expect the same learning outcomes through well designed course materials; however, acting locally is to expect that each learner is different and consequently requires a mechanism for which each learner can uniquely navigate or browse through course materials to achieve the same learning outcomes. Within LAMS, learners cannot navigate to a different part of the course content if they need to. Once a learning task is complete, it cannot be revisited, hence, this describes a one way sequential learning path which is not a flexible pedagogy. This is tantamount to "Think globally, act globally" where every learner acts in a one-dimensional way (i.e., learning process only through forward navigation) to achieve the same thing. This replicates the same issues of *"one-size-fit-all"* approach. Since the learning path in LAMS is sequentially predetermined, what is left to monitor is the learning process through a sequence of learning activities. The desired "learning outcomes", without a flexible learner-controlled back and forth navigational option, is reduced to the "outcomes". Although, LAMS has the potential to provide specialised high level tools for learning design that could address specific pedagogical strategy or approach; LAMS, however, does not adequately address flexible pedagogic structures. Rather, it caters for solutions that meet the needs of practitioners (Griffiths and Blat 2005).

ePortfolio

> *"An ePortfolio is a highly personalised, customisable, web-based information management system, which allows students to demonstrate individual and collaborative growth, achievement and learning over time".* (LDP 2004)

It is a selective and purposeful collection of learners' task and work made available on the Web in the form of a digital filing cabinet that allows storage of information and digital content over time. It provides the ability to track goals and experiences, where users can maintain a plan of study. Apart from goals and plans of study, ePortfolios allow information about: jobs, degrees and awards, internships and co-ops, and unofficial transcript information to be kept and managed. Any type of digital file (photographs, Flash movies, videos, audio files, résumé images, documents etc.) can be uploaded into an individual's file. These digital files can be used to build a personal portfolio that could demonstrate what a user has learnt; what they do best; what a user likes to do; what a user knows how to do; and, the profile of such user. ePortfolios also allow for links to a personal repository containing items of work, tutor/employer comments, feedback and reflections. It has a similar look-and-feel to a personal website, except the learner is able to create front-end displays that are tailored to the task requirements (Tosh and Werdmuller 2004). A learner can showcase a selected portfolio and invite faculty, guests, friends, employers and others to view and comment on the portfolio view. The benefits of ePortfolios are apparent through its strong use of Web 2.0 principles and technologies, where the user can co-contribute/interact with the content/information being consumed and it can be integrated into a VLE/LMS. However, ePortfolios do not manage the human workflow process or learning workflow process, where the task of learning a specific content object is orchestrated in a computer language that can automatically adapt to learner learning profile. There is no auto-route mechanism between learners and other e-learning participants for real time feedback on a learner's learning process. Learner's competency on each topic is not certified by either the system or a human actor (e.g., a lecturer) before progression to the next topic is permitted. As such, learning process management is not a feature of an ePortfolio system.

2.4 Summary

E-learning systems should not be pedagogically neutral. Optimally, e-learning systems should support: frameworks for pedagogical strategies and planning; learning process management through a sound pedagogical approach; standards (e.g., SCORM) and portability of learning object content; content personalisation through course materials; and, strong interactions amongst all of the e-learning participants. The proposed architectural framework that is presented in this thesis aims to support these processes. By using the BPM conceptual framework (see Chapter 4) to address the issue of pedagogical neutrality, flexible and adaptive learning process through an enhanced human interactive pedagogy and a customised learning path are also addressed. E-learning content design, integration and delivery using the conceptual framework can be orchestrated in a manner that fully embed/integrate learning objects and e-learning actors (lecturer, tutor, learner, etc.) within an instance of learning process workflow.

Chapter 3

State-Of-The-Art Requirements of an Ideal Virtual Learning Environment

3.1 Introduction

Current e-learning systems have provided significant benefits to the ways in which online teaching and learning are conducted; and, many of the e-learning providers do recognise the significance of adaptive and flexible learning within an e-learning system. However, issues still remain and some of these issues are discussed in Chapter 2. In addition to the issues discussed in Chapter 2, current e-learning systems have not yet adequately addressed many other issues that are related to the complex process of teaching and learning within an online environment. In order to achieve an ideal system that adequately supports the teaching and learning process, significant improvements would need to be made to the current e-learning systems. In particular, current e-learning systems need to be improved through:

- Learning process management through adaptive and flexible learning process - The management of learning through its process can just be as important as learning itself. Therefore, there is the need to advance learning management beyond the current level of content authoring, delivery and course tracking to a more process-oriented learning management.

- Personalisation through possible automation of multiple learning pathways - While multiple learning pathways can be achieved with the current e-learning systems through the use of HTML tags and hyperlinks, the automation of learning pathways would provide a significant benefit. One of the benefits is that an automated process can determine a learner's learning pathway based on his/her runtime learning behaviour. A possible solution to this can be achieved through the orchestration of learning process workflows that can be executed within a workflow engine.

- Enhancement of human interactive pedagogy - Current e-learning systems provide several interactive tools (i.e., e-mails, chat-room etc.) that allow learners, tutors and lecturers to interact. The management of the interactions between the e-learning participants and the learning activities/objects can be part of a learning process workflow in a way that could enhance collaborations and ultimately learning experience. This way, each learner's participation in a learning process will not be in isolation but in a larger context that includes other participants.

- A visual (graphical) modelling of an online educational pedagogy in a way that would allow course designers to adequately plan and design their teaching methods can improve online pedagogical practices significantly. Graphical modelling of online pedagogy can also be beneficial to the concept of pedagogic reuse (i.e., reuse of course materials and tools).

- Learning analytics that could allow for the monitoring of the cohort's learning processes in a real time manner and for the evaluation of the effectiveness of any adopted pedagogy.

This chapter sets out to present research-based evidence for the state-of-the-art requirements of an ideal virtual learning environment. This research-based evidence also provides the basis of the proposed new architecture for learning process management. This chapter also discusses in details the approach on how to address the issues surrounding an adaptive and flexible e-learning solution.

3.2 Adaptive and Flexible E-Learning

The basic axiom to improving learning outcomes and experiences in an online environment is the adaptivity and flexibility of an e-learning system (Beldagli and Adiguzel 2010, Tsolis et al. 2010, Surjono 2009). The very complex nature of our environment (real or virtual) and the uniqueness of every individual (physically and mentally) have made adaptation and flexibility even more compelling (Beldagli and Adiguzel 2010, Nguyen and Do 2008), especially when such environment is meant to facilitate learning.

Flexibility is an important benefit of e-learning systems (Childs et al. 2005). A flexible e-learning system that supports flexible learning processes for learners and flexible pedagogical model for the course designers is desired. Flexibility learning according to Dimitrova et al. (2003) implies:

> *"different modes of interaction between the lecturer and the student choice of traversal paths through electronic learning materials, choice of medium in which the materials are represented (both part of the method of the learning process) as well as choice in place and time of learning."*

Flexibility, to a larger extent, has been encouraged within the current e-learning systems - 24/7 access to learning materials and interaction with the materials by the learners is possible; and, communication between lecturers and learners are possible usually via emailing. Flexible learning fosters the transition from the traditional classroom teaching didactic to an individual or group collaborative and interactive ways of learning where lecturers can provide structured materials, group work or projects that spur motivations for learning.

Adaptive learning is another important part of e-learning. The concept of adaptive learning emerged as an alternative approach to solving the traditional *one-size-fit-all* approach to learning (Brusilovsky and Nijhavan 2002, Beldagli and Adiguzel 2010, Mulwa et al. 2010). There are numerous definitions of adaptive e-learning system, for the purpose of the proposed e-learning system architecture that is presented in this thesis, the definition provided by Stoyanov and Kirchner (2004) will suffice, as it captures learners, content and pedagogical model as part the of adaptation process:

> *"... is an interactive system that personalises and adapts e-learning content, pedagogical models, and interactions between participants in the environment to meet the individual needs and preferences of users if and when they arise."*

The grand ideal behind this concept is to allow learning content and pages that are presented to learners be dynamically changed based on their learning needs and profiles, and to be changed appropriately at the right time (Verpoorten et al. 2009, Shute and Towle 2003). Consequently, a special type of adaptive system called Adaptive Hypermedia System (AHS) was introduced in the early 90s as a solution to the traditional standard hypertext systems that are often characterised by static hyperlinks and often limit the capacity to enhance personalisation (Brusilovsky 2003, Graham et al. 2005, Mayfield 1997). The overwhelming benefits of an AHS in education is its strategy for the personalisation of learning materials in a manner that caters for the need of the individual learners with the potential to enhance learning outcomes (Colace and Santo 2007, Mulwa et al. 2010). Brusilovsky (1996) defined AHS as:

> *"... all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the*

system to the user."

Thus, there are different models such as the user model, observation model, knowledge space and adaption model that exist within the AHS. These models provide information about the user and this information can be used by lecturers to better analyse and adapt the user needs (Singhal 2011). In all of the AHS models, the two most essential models are: the user model - the hypermedia performs data collection on the user and the collected data can be used to adapt content based on the specific user model (Tsolis et al. 2010); and, the adaptive model - generates the adaption of both the page content and the behaviour of hyperlinks (adaptive navigation) (Beldagli and Adiguzel 2010). With the vast amount of information available to learners, the AHS can assist in the discovery of the only necessary information and can also help to solve the issue of information overload (Tsandilas 2003).

In spite of the significant benefits of the AHS, there is still a significant issue in realising an adaptive learning process within an online learning environment. The issue does not lie with how well the current systems perform but their underlying architectures that have often made adaption impossible (Tsolis et al. 2010, Meccawy et al. 2008). According to Tsolis et al. (2010), many of the current e-learning systems now rely on an extensional framework in order to support adaptive learning. In this context, e-learning developers are charged with the responsibilities of developing systems capable of flexible features that adapt learning paths and foster pedagogical modelling (Ardimento et al. 2011). Such a design should be effectively planned in such a way that provides a dynamic and evolving teaching and learning environment, where learning materials can be formed and changed during the delivery state (Tsolis et al. 2010, Redmond and Lock 2009). Verpoorten et al. (2009) went on to relate a good pedagogical model to that which inherently allows adaptive learning through personalisation. This strengthens the argument to develop a pedagogical modelling strategy that will help to formulate many aspects of learning process management, of which personalisation of learning is one. The BPM-based architecture that is presented in this thesis enables personalisation on two fronts: modelling of multiple customised learning pathways (i.e., navigation adaptation) using BPM intuitive graphical flow diagrams; and, an inference mechanism to detect the need for supplementary learning materials which may be tailored to the specific needs of an individual.

3.3 Customisation of Learning pathways

Within the literature, it is widely recognised that an important component of success in distance education is related to the ability to customise the learning process for the specific needs of a given learner (Colace et al. 2005); whereby learners' runtime behaviour in a learning process should determine the path to progression through course materials. An e-learning content should not be rigidly designed without the ability to adapt to learner needs during course progression (Graf and List 2005). The delivery of content to all learners should be tailored to each individual need based on learning characteristics. This would increase the relevance of the learning material during course progression (Takhirov and Sølvberg 2009). However, such an implementation is still far from realisation. There is much interest in investigating a new formative process and tools to moulding a new approach to teaching, learning and assessment that would provide the necessary structure and platform for effective teaching and learning. This new approach should be based on sound pedagogical principles that address the specific needs of individual learners (Colace et al. 2005, Rate 2008). In the general context, a personalised approach to meet potential future demand for education can provide new options for promoting learning competence between individual learners (Bentley and Miller 2004). Heller et al. (2006) gave a definition that:

> *"personalised or customised learning is tailoring the teaching to individual need, interest and aptitude so as to ensure that every learner achieves and reaches the highest standards possible."*

According to Jarvela (2006) personalisation of learning has become imperative, where personalisation of learning does not mean an approach towards a singular isolated mode of learning, but as a way in policy and practice, whereby all learners count - giving equal opportunities for learning in terms of learning skills and motivation. Jarvela (2006) further investigated the capabilities of personalised learning systems along seven critical directions:

- The development of key competencies that are often targeted at specific areas.
- Levelling the competitive environment through education and guidance to improve learners' learning ability and motivation (i.e., encouraging learners to engage in analytical, creative and practical thinking can improve learners' learning ability and motivation).
- Promoting learning through a motivational scheme.
- Collaboration through the construction of knowledge.
- The development of a new evaluation model.
- Use technology as a means of personal and social cognition.
- New role of teachers in a learning environment.

It can be said that the cognitive abilities of learners and their academic performances may be the determining factors for success rates, especially after an examination process. The quest to reduce the level of knowledge deficit amongst learners should also focus on the content structuring, re-structuring and delivery. The decision to find alternative paths for learners raises a fundamental question as to whether the same expected learning outcomes can be achieved by learners through: customised learning pathways; learning materials supplemented with contingent teaching - where lecturers do not have a fixed and inflexible "script" but a diagnostic branch of tree where learner's answers to previous questions determine what is delivered next (Draper 2004). An e-learning environment is considered adaptive if it is used for: keeping track of user activities; interpreting the specific domain model based on the tracked activities; infer the learner's needs and preferences based on the interpreted activities; and, ultimately, providing information and content for learners in a manner that can act to promote an active learning process (Paramythis and Loidl-Reisinger 2004).

A learning process workflow model is part of the new architectural model for personalisation through customisation of learning pathways. The implementation of learning process workflows is based on the assumption that some learners have a broader requirement of needs and/or supports than others. The approach links learning objects (LOs) and competency on each topic as the basis for adaptability of the assessment of skills and individual learning path. The learning state and learner's current competent state (mastery level) are used to create a personalised learning path - the system, learner and lecturer/tutor can be part of the decisional maker on which path to take after completing a specific learning task. Profiling a learner's knowledge through competence-based assessment can give practical indications of achievement and learning level, thereby making it possible to support the learning process. Wolf (1995) also advocated for this approach and gave a clear definition of Competence-based assessment as:

> *"A form of assessment that is derived from a specification of a set of outcomes; that so clearly states both the outcomes - general and specific - that assessors, students and interested third parties can all make reasonably objective judgements with respect to student achievement or non-achievement of these outcomes; and that certifies student progress on the basis of demonstrated achievement of these outcomes."*

This definition encapsulates the important components of competence-based assessment:

- The significance of learning outcomes, especially, multiple outcomes, and assessment of each individual's performance is separately assessed.

- Outcomes can and should determine the point at which competence is clearly and transparently gauged. Assessor, assessees, and other third parties should understand what is being considered, and what should be achieved.

To create individual learning paths and efficiently discover the competence level of a learner, a prerequisite for assessing the learner's skills are useful (Steiner and Albert 2007). A prerequisite for such structural adaptation can be used to support Web-based learning navigation (Brusilovsky 2004), i.e., by connecting to a hidden or annotated learning content, in line with existing knowledge and skills of learners. Educational systems that meet individual needs, through the establishment of individual learning paths, have the potential to provide learners with the means to achieve excellence in their personal learning experience (Heller et al. 2005). Heller et al. (2005) further stated that among the various benefits of a personal learning environment is that less time is spent on learning, and learning retention of learners improves. The collective impact and relationship between LOs, assessment problems and skills assessment (competencies) allows for the creation of personalisation and efficient adaptation of assessment of knowledge and skills acquisition (competent-level). Figure 3.1 illustrates an overview of a learning path through course material within a VLE, where competence-based assessment is incorporated. The learning path shown in Figure

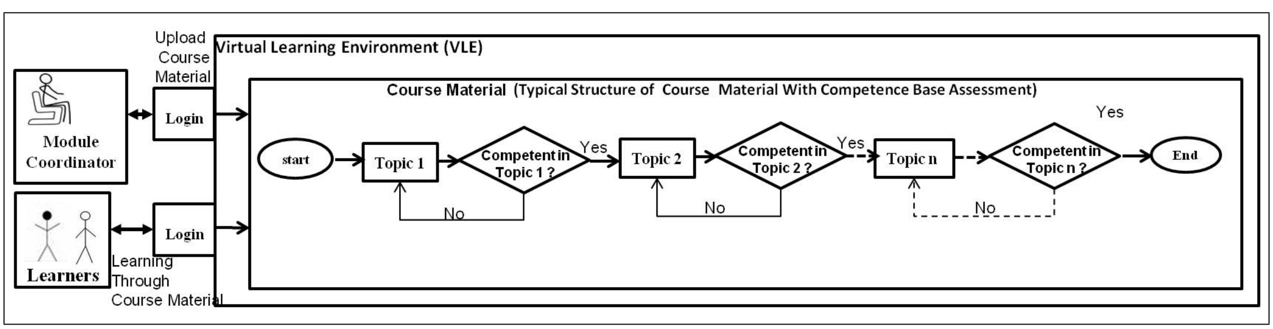


Figure 3.1: High-level learning path diagram through course material of a typical VLE

3.1 is linear and not customised. The linearity engages learners in the path categorised by Chuang and Shen (2008) as follows: (1) Sequential: Learners continue to learn in a monotonous manner. Sometimes they navigate away from this approach, but soon returned to them; (2) Challenging: Learners browse the summary page and attempt the test in the first unit. When they failed the test, return to teaching materials, find detailed and repeat tests iteratively until they passed; (3) Free: Learners flip freely without any specific rules or sequences, often because of their interest in other course subjects different from those presented; and, (4) Iterative: More hybrid learning paths like the combination of those discuss above. Often learners browse continuously at any webpage that they considered engaging and interesting.

Figure 3.2 illustrates an architectural overview of the customisation technique within the proposed BPM-based architecture, which allows for monitoring of an adaptive learning process. It depicts how customised learning paths can be created, depending on a learner's unique needs. In Figure 3.2, a learner logs into the BPM-based solution to view course

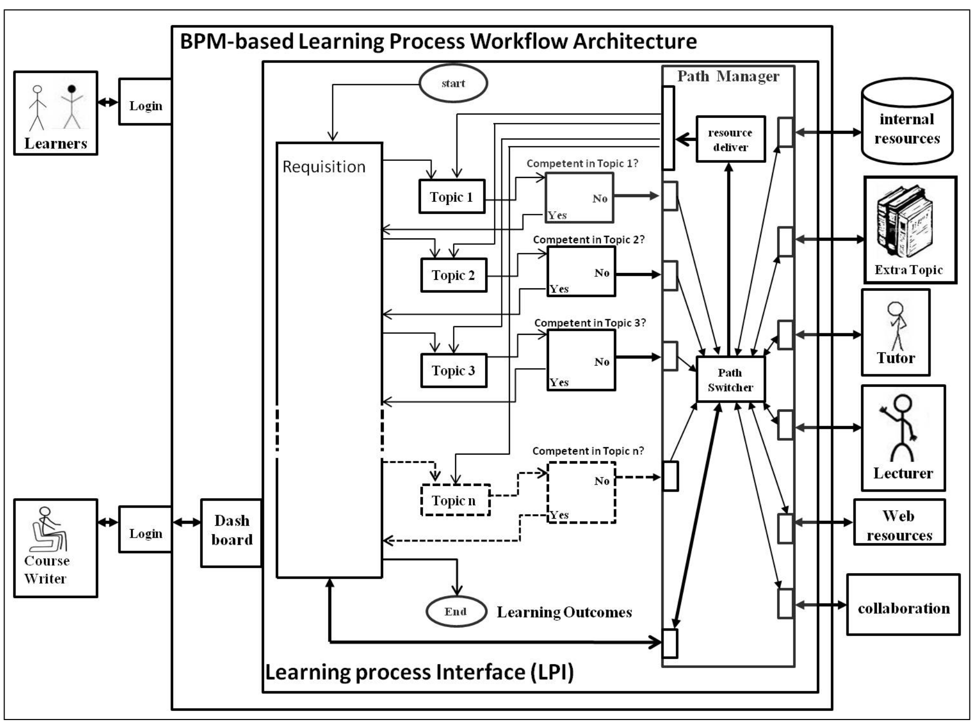


Figure 3.2: High-level customised learning path diagram of the various pathways through course material in the proposed BPM-based architecture

materials. The requisition component checks for outstanding pre-requisite or special needs that might impede on the learner's ability to progress through a learning process before any topic is displayed. Competence (mastery level) in each topic is examined, and if each topic is not passed the learner is auto-routed through the learning path manager. This is where multiple learning pathways (e.g., additional external resources, tutor and/or lecturer support, collaboration etc.) are possible. The path manager affords learners the ability to gain additional knowledge through relevant resources. The course designer can login to the same system to view progressions through a learning process dashboard. This provides the visualisation and monitoring of individual or aggregate learners' progressions through the course materials. This is to allow course designers to access learning process information during learners' learning sessions, which can result in the provision of a personalised learning materials based on the monitored data.

The significant difference between Figure 3.1 and Figure 3.2 is that, in Figure 3.2, learning pathways are controlled by an adaptive mechanism known as "path manager". The "path manager" component itself is controlled by an automated agent known as "path switcher". The "path switcher" validates a learner's current learning status based on a series of learning rules and directs or proposes a learning path for the next learning task. This can be particularly useful in a case where different groups of learners from different study backgrounds are expected to undertake a similar course. Before beginning the course, the "path manager" can identify the pre-requisite for the new course (i.e., background agent performing data profiling on the user). If a group of learners has not met the necessary pre-requisite, they can be automatically directed to a new course that will prepare them for the main course. While this scenario can be replicated within current e-learning systems using hard-coded low-level programming, the use of the automated tools available through BPM (e.g., JBoss, Drools) allows the learning pathways to be adaptive.

3.4 Enhanced Human Interactive Pedagogy

Interaction is considered to be an important component of pedagogy, in fact, quality learning can hardly take place without a concrete meaningful interactions between the lecturers and learners (Tardif 2005). Thus, for collaborative and quality education, interaction among learning participants has always been emphasised. Interactive environment for formal education is specifically designed to encourage learning amongst learners - learn from each other through a clearly defined learning objectives and/or outcomes. The interaction with lecturers is often an important part of a formal learning experience (Anderson 2003). Interactive pedagogy is core to the traditional classroom environment, where lecturer and learners are physically present in a classroom and face-to-face interaction for questions, discussions, quizzes, debates, etc. can take place. However, the level of interaction within the current VLEs solutions amongst e-learning participants is low, even as the adoption and usage of VLEs are increasingly been considered as a learning tool, either to complement the traditional classroom or to serve as the system through which distance education is conducted. The focus on strong interactive pedagogy through human interactions and/or intervention at a critical moment in a learning process is inadequate in the current VLEs (Kaur and Kaur 2005). Consequently, learners may not discover new material outside of what is suggested by the lecturer's course content and as Kirriemuir (2008) writes:

> *"Qualitative pedagogical techniques such as Action Research are valuable in the sense that in immersive learning environments we need to embed ourselves as teachers and get involved in the process of understanding. Traditional VLEs lack this engagement. We cannot just set up a learning environment and step back from it. That is why the role of teacher or lecturer is vital in this process."*

A qualitative pedagogical technique in a higher education includes some form of interactive pedagogy in an effort to foster an adaptive collaborative support. The purpose of enhancing interactive pedagogy is to capture support for the adaptive learning process; and, achieve the common objectives through a means of collaboration and communication between e-learning participants (and thus, social interaction) (Paramythis and Loidl-Reisinger 2004). One of the advantages of interactive pedagogy is that it creates an empathic approach to learning, whereby lecturers could take the perspective of the learners, providing real learning experience for lecturers to enable them to understand the perception of learners. This illuminating experience empowered the lecturers because they re-lived and re-experience learning (Mcgregor 2004). Mcgregor (2004) further stresses that interactional pedagogy applied to stimulate thinking in learning, including recognition of the impact of peers' ideas, observations and assessments of what is being learned. Learners can also gain more from the scientific knowledge and experience of their lecturers. Participation is an important aspect of this interaction. Lam (2004) stressed that although the online forum can be a great potential for mutual learning, one of the issues is that these online forums often lack learner participation. Moallem (2003) also expressed the view that if interaction is not strictly part of an online learning environment, the expected benefits of interactive pedagogy would not be achieved. Chong (1998) and Davies and Graff (2005) also raised the importance of strong online interaction. Roussou (2004) also pointed out that there is a general consensus amongst many educational technologists for the need of technologies in education that would help to enhance interactive learning.

If Web technology could evolve from web 1.0 (static content structure and delivery) to web 2.0 (dynamic content structure, delivery and interaction), then this same evolution should not elude the Virtual Learning Environments, where it is equally desirable. In other words, the VLEs need to evolve from a content-centric model of e-learning to one which focuses on dynamic delivery and personalisation (Davis and White 2011). When a lecturer spends time and energy in using a VLE to create, manage and deliver course materials, the manners in which learners chose to interact with or learn through the course materials are not transparent, and the learning footprints can be difficult to track by the lecturer. The progress of the learner in achieving the desired learning outcomes is usually not obvious to the lecturer except during the process of marking examination scripts or key assignments. Any attempt for intervention at that stage is usually "too little too late".

Within the literature review, various definitions of interaction exist, with particular attention to the content, participants and technology. On the participants, Moore (1989) explained three main interactions: learner-to-content, learner-to-lecturer, and learner-to-learner. Since learning is a dynamic process, when learners are learning through course materials within any VLE, strong interactive pedagogy should be maintained. This assertion is in line with the position articulated by Kirriemuir (2008), Mcgregor (2004), Paramythis and Loidl-Reisinger (2004) on the practicality of strong interactive pedagogy within the current e-learning systems. The nature of interactive pedagogy in the current VLEs with regard to learner-to-content and learner-to-lecturer is passive and does not provide continuous feedback to the lecturer on how progression from topic A to topic B, C and D are attained. This is due to the "linear and monotonous" interactive pattern of the current VLEs as shown in Figure 3.3 - lecturers can upload course materials and learners can login to download these materials. It is possible for a learner to contact a lecturer via e-mail. However, the learners (especially shy ones) are less likely to initiate contacts, even when they face difficulties. In addition to shyness, embarrassment and fear do not encourage interaction (Markett et al. 2006).

It seems, the best pedagogical approach is a participatory interactive education (i.e., peer discussion), and Contingent Teaching - no fixed script designed for all learning session, but to focus on the use of diagnostic questions to the point of identifying and addressing the most need of a particular audience (Draper 2004). This forms part of the motivations

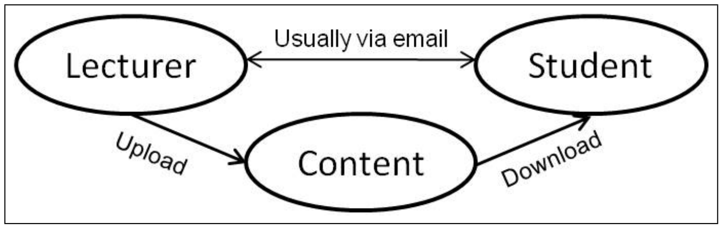


Figure 3.3: Mode of interaction in current VLEs

for the proposed BPM-based architecture. It proposes to allows human interactions (i.e., lecturer-learner) to be embedded as an integral part of a learning process workflow - where learning process workflow defines a common territory for various pedagogical scenarios and takes into account all of the e-learning participants as shown in Figure 3.4. An instance of the learning process workflow domain is a virtual territory where lecturers, learners, tutors and content share a common space in a virtual environment. The learners' learning activities are visible to lectures and tutors. In other words, within the BPM-based architecture, human interactive pedagogy can be enhanced by orchestrating the interactions between the learning services (learning objects and competence-based assessment) and human services (learners, tutors and lecturers) in an automated manner for every pedagogical scenario.

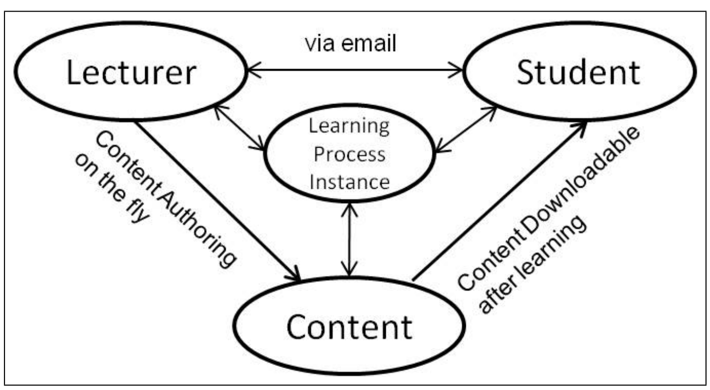


Figure 3.4: Mode of interaction in the proposed BPM-based architecture

The drawbacks of current VLE solutions that call for strong interactive pedagogy, when addressed with the conceptual framework that is presented in this thesis (see chapter 4) set a good foundation for the development of a future online learning environment.

3.5 Learning Process Management and Pedagogy

In many undergraduate education programs, much focus has been on the pedagogy of passing knowledge from lectures to learners. Focus on learners' learning process has received lesser recognition (Alonso et al. 2004) and the current VLEs are not exempted from this conventional pedagogical approach. The impact of this approach on learning is often measured against a set of learning outcomes and/or learners' overall performance during a summative process. However, the full appreciation of both the pedagogy and learners' knowledge level during learning sessions is hard to gauge within the VLEs.

Learning has been defined by numerous researchers, and from academic point of view, they unequivocally emphasised on "knowledge gain" as opposed to information regurgitation. More importantly, knowledge is gained through one form of a process or another. Therefore, an insight into the process of learning can advance the online management of learning by both the lecturers and the learners themselves. Learning theories can be useful and are applicable to the general understanding of the heterogeneous nature of learning processes (Kahiigi et al. 2008). Its relevance in the field of learning is linked with its widely used models of learning theory that are discussed in Chapter 2 Section 2.1.4: behaviourism, cognitivism, and constructivism - providing significant insight into the complex nature of learning. Evidence suggests that at least the constructivism is strongly linked with e-learning didactic (Koohang and Harman 2005, Harman and Koohang 2005, Hung and Nichani 2001, Hung 2001).

The research presented in this thesis argues that since learning is a process, a balanced account of learning theories (cognitive learning process, behavioural learning process and constructive learning process) within an online learning environment is desirable if learners' learning management is to be enhanced. A behavioural learning process involves, according to Awang-Shuib et al. (2011),

"... a retention or remembrance of observed behaviour, reproduction or acting,

> *as like the observed behaviour and motivational outcomes or a positive reason for adapted behaviour".*

The ability to observe learners' learning styles, pathways and choices can influence a change in pedagogical approach. The traditional classroom environments thrive in this process. Kesici et al. (2009) defined cognitive learning process as:

> *"a planning process used for administering cognitive sources, such as attention and long term memory, which help the learner reach his/her learning targets."*

Observation of cognitive learning strategies would be significant in learning process management. Bramming (2007) shared a view on constructive learning process and stated that:

> *"In the learning-based system, a constructive learning process is understood as the students being actively involved in transformative processes driven by problem solving".*

Records on the level of collaborations amongst the participant (learners, lecturers and tutors) during a constructive dialogue can also help in the management of learners' learning process.

Learning management can be referred to as the administration and management of: courses and learning objects; resources such as the chat room, e-mail; and, participants i.e., the learners. Current VLEs excel in learning management with lesser focus on the process of learning itself. However, since learning is a process, the management of this process would be an asset to further improve on learning management and enhance learning experiences. For the purpose of the research that is presented in this thesis, Learning Process Management is defined as:

> the collective means that enables e-learning participants (lecturer, tutors and learners in particular) to observe, monitor, track and analyse online learning progressions and performances continuously in a real time and/or asynchronous

manner with the possibility to improve knowledge gain and achieve the desired learning outcomes.

This can influence lectures' runtime pedagogical approach whereby contingent teaching can be supplemented with the existing learning objects. In other words, if lecturers are afforded the necessary learning process information then lecturers would not have a fixed linear "script" but rather a diagnostic branching route where learners' needs determine what is performed next (Draper 2004). Also, with learning process management, learners learning experiences can be positively impacted if they can perform self-analyses on their learning processes.

Beside the management of content or learning objects, another field of importance within the VLEs is the pedagogy that facilitates the learning process (Huang et al. 2006). Pedagogy is crucial to learning, learning management and learning objectives/outcomes (Corcoran 2009). However, the lack of strategic pedagogical planning and modelling within the current e-learning systems is still an issue as many of the e-learning systems providers continue to declare neutrality on the issue with pedagogy (Earle 2002).

Within the virtual environments, it is important to harness various educational or learning activities into an orchestrated learning process to form a pedagogical structure that is capable of being responsive to the heterogeneous nature and demands of learners. This would not only help the learners to engage in a flexible and adaptive learning environment but also help the lecturers to be able to assess and follow up on learners' learning processes and outcomes. As a result of such orchestration, the effectiveness of the orchestrated pedagogy can be evaluated for improvement with the potential to enhance positive learning outcomes.

Since the learning process involves a lot of interactions between learners and lecturers and/or tutor, managing the process without an insight into its complexity can reduce course designers' understanding on the level of knowledge gain, which is the goal of education.

Because learning is a complex process with complex activities, there are lots of unknown didactic variables; the ideal that all these didactic variables can however be controlled within a system is simply an illusion:

> *"education may not be best served by continuing to employ a solely cause - and - effect perspective. (...) In scientific enquiry, all factors are held as constant as is possible; in education, no factor remains stable when another is perturbed."* (Mason 1994).

Even then, modelling pedagogy with known didactic variables (i.e., the tasks proposed to learners, resources and tools at learners' disposal, relationships between the tasks and tools and resources, lecturers' role and the kind of intervention required, communication medium between lecturers and learners etc.) can go a long way to improving learners' learning experiences and outcomes. For an effective management of learning and the process of learning within any e-learning system, it is important that the adopted pedagogical model be flexible and seamlessly integrated with the learning processes in the form of an automated learning process workflow and other elements within the system (Huang et al. 2006). This is the focus of the BPM-based architecture that is presented in this thesis.

3.6 Learning Process Analytics

The use of monitoring or measuring tools to analyse many areas of our daily activities such as blood pressure, electricity consumption, heart rate and weather forecast have provided good knowledge on prediction, quality control practices and motivations for improvement on the areas of defects or performances. Within the academic environments, particularly the online environments, learning analytics has been inspired by these and many other fields of analytics, conceptually; and, has recently begun to receive attentions. Even then, current VLEs have yet to catch up with the conceptual reality and are lacking the adequate functionalities for learning analytics.

When course designers use VLEs to create, manage and deliver online course materials, learners can login and download the course materials. Although, there is no evidence that learners do not attend lectures if the course material is not available on the Internet, the provision of course material through VLEs is widely common in many educational institutions today. In some cases, course designers upload course materials periodically in an effort to prevent information overload that may de-motivate learners. In any case, whatever the pedagogical approach adopted within the VLEs, many questions still remain (Elias 2011): How effective is the online course materials? Do they sufficiently meet the learners' needs? How can the learners' needs be better supported? To what extent are the learners' interactions with the course materials, tutors, lecturers and their peers effective? How can the online course materials be improved? Answers to these questions would have a profound effective on teaching, learning and pedagogical reforms; and, would help to improve learning experiences and outcomes if there was a mechanism to analyse learners' learning processes (Vatrapu et al. 2011, Crawford et al. 2008). Also, there is evidence that learners' motivations, sense of self-efficacy, progressions and performances can be improved if they are provided the feedback and the means to gauge their learning performances (Stiggins 2001, Brookhart 2001). The research in this thesis presents learning analytics as part of the BPM-based architecture. This is another means by which learners can manage their learning processes.

There is a growing interest in how the data in an online learning environment can be used to enhance teaching and learning process (Davis 2010); hence, the emergence of a new field of learning analytics (Elias 2011). In fact, the 1st International Conference on Learning Analytics (LAK[1] '11) was organised and held in Alberta, Canada, in February/March 2011. The emergence of learning analytics to improve teaching and learning process is further

[1] https://tekri.athabascau.ca/analytics/

inspired by the advances of many existing analytic tools such as web analytics, Google analytics, business intelligence and business activity monitoring (BAM). These tools have advanced within the commercial sphere and the academic environments are beginning to catch up with analytical tools such as academic analytics, action analytics and educational data mining (Elias 2011). Nevertheless, Dawson (2010) observed that, though the growing need for educational data mining for intelligent reporting are beginning to gain traction, the access to this data still falls short of been used to address learning and teaching. Learning analytics is defined as:

> *"the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs".*(Elias 2011)

Since different learners browsing and studying the same online course materials will usually show different learning behaviours according to their personal characteristics (Chuang and Shen 2008), deeper analysis of their learning processes would required advanced techniques well beyond simple upload and download histories. Understanding the nature of learners' interactions with course materials can further enhance learning process analysis. How do learners meander through course materials? What areas of difficulties if any were encountered? What other learning resources do learners find most valuable? How are learners better supported? How are learners' satisfaction levels gauged? How often do learners seek supports on difficult topics? How often do they collaborate? How can the scenarios of their navigation, as categorised by Chuang and Shen (2008), help improve course design? Finding the answers to these questions can be difficult, especially within an online learning environment. It is difficult to perform learning analytics on learners' learning processes within the current VLEs as the data on the interactions with these learning materials is often no more than learners's login profile, quiz results, discussion boards, log files and downloads histories (Graf et al. 2011). There is not sufficient learning activity capture data for lecturers to adequately personalise learning needs for their learners (Zhang et al. 2007). Consequently, intelligent decisions on the effectiveness of the online course materials, pedagogical approach and learners' learning progressions and performances are difficult to make continuously during learning processes.

One of the challenging areas in learning analytics according to the report released by the Next Generation Learning Challenge (NGLC[2]) is:

> *"scaling the collection and real-time use of learner analytics by students, instructors, and advisors, in order to improve student success"*

This challenge is one of the motivations for this research and the new e-learning architecture that is presented in this thesis. It is a learning-process-focused and BPM-based e-learning system architecture. It provides a mechanism that allows for the analysis of up to a very large cohort of learners to be made possible within an online learning environment. Part of the design and implementation strategies of the BPM-based architecture is based on the use of BPM automated agents to aggregate the auto-generated learning data while learning processes are still under way; and, to enable learning analysis through a visual learning process dashboard. The learning process dashboard provides real time learning process performance details to all of the e-learning participants (course designers, learners and tutors) that are involved in the entire lifecycle of a learning process. The aims are to: prevent delay in early identification and provision of much needed support for the learners until the end of the semester or during a major summative process; capture feedback from the cohort satisfaction and competent level of achievements; adapt runtime pedagogy based on learning process performances; and, provide the means for learners to be able to observe and analyse their own learning progresses in comparison to their peers' performance anonymously.

[2] Next Generation Learning Challenges, "Wave 1: Building Blocks for College Completion," Retrieved December 5th, 2011 from http://nextgenlearning.org/sites/default/files/Final_RFP-1.1.pdf

3.7 Pedagogical Modelling

Within online learning environments, we are beginning to see the emergence of a new set of course designers who have never met all the learners, especially those in the distance, yet primarily decide on how learners are supposed to go about their learning goals or tasks. On what pedagogical or teaching principles, do these "virtual" course designers formulate the new virtual environment for learning? E-learning Pedagogy has always been seen as the key element by which e-learning educational values are predicated upon (Seale and Cooper 2010). Kelly et al. (2004) also shared the same view and stated that:

> *"At the heart of any e-learning experience is the pedagogy that drives it, the learning outcomes, the content, which illustrates those learning outcomes, the context in which the content is presented and the activities a student completes to aid his/her understanding of the learning outcomes. This can mean that a traditional course often has to be entirely re-engineered either for a wholly online experience or a hybrid approach of online and offline activities."*

Traditional higher-education classrooms allow lecturers to observe learners' behaviours and responses to a particular pedagogy during learning in a way that can influence changes to their pedagogical approaches. However, within the online learning environments, once an educational course material is made available, what learners do with the course material, when and how they learn the course material are difficult to observe in a real time manner. Spontaneous pedagogical decisions that are often possible in a classroom environment can be difficult to make in an online learning environment. Part of the reasons can be attributed to the lack of a real time learning process management around the content management capability of the existing e-learning systems. Moreover, modelling an online education pedagogical structure can be challenging because of the variety of choice or the lack of appropriate technologies.

Whatever the pedagogical stance of online course designers, the ability to quantify the effectiveness and impact of their chosen pedagogies will, in no doubt, help course designers to improve on their subsequent pedagogy formulations, if and when necessary. Subsequently, learners' learning experiences can be improved. How course designers quantify the effectiveness of their pedagogy within the current online learning environments is hard to measure. One of the e-learning standard specifications provided by the IMS Global Learning Consortium to address pedagogical issues is the IMS Learning Design[3] (IMS LD) standard specification. Released in 2003, IMS LD specification is used to describe various forms of pedagogical scenarios (Milligan et al. 2005).

> *"Pedagogical scenario is a sequence of phases within which students have tasks to do and specific roles to play."* (Schneider et al. 2003)

Since the release of the specification, many IMS LD tools such as LAMS, AUTC Learning Design[4], have been designed to assist course designers during their learning design planning. Course designers can formulate their pedagogies with IMS LD tools by the ordering of several sequences of collaborative learning activities (Seale and Cooper 2010). The contribution of the IMS LD specification with respect to pedagogy has been significant. However, IMS LD specification is not without its own challenges. It is a complex specification and course designers spend lots of time and effort just to be able to define a pedagogical scenario (Morales et al. 2008). The implementation of the specification within the current VLEs is riddled with so many complexities; and, the annotations of learning object, needed to obtain learners' prior knowledge, are often manually performed (Neven et al. 2003, Morales et al. 2008).

[3] http://imsglobal.org

[4] http://www.learningdesigns.uow.edu.au/index.html

This research argues that by taking the concept of IMS LD further, and juxtaposing such a concept with the concept of graphical pedagogical modelling using standardised modelling tools to orchestrate learning activities in an automated fashion, learning process management can be facilitated through a learning process workflow. In other words, while this research believes that IMS LD is a pedagogy of learning activities, this research further believes that learning process workflow orchestration would be a pedagogy of the process of learning based on the learning activities. Thus, in this thesis, pedagogy modelling is considered as a scaffold for learning process workflow within which various pedagogical scenarios can be orchestrated. Many researchers such as Schneider et al. (2003), Peter and Vantroys (2005), de Freitas et al. (2008) also shared the same view and have advocated for the need to support pedagogical strategy through pedagogical modelling practices.

With the right modelling tools that have intuitive graphical flow diagrams, graphical modelling of pedagogies can provide a platform for strategic pedagogical planning that describes the complexity of learning processes through structured course materials. Course designers can design pedagogical templates that can: be used and reused; be collaboratively developed for teaching and learning processes; and, capture various pedagogical scenarios (i.e., interactions with learning resources by learners) and the intricacies associated with learning activities. Equally, with the right execution language that can take the modelled graphical diagrams as an input, a modelled pedagogy can be deployed and executed by an e-learning participant (learner, tutor and course designer). For course designers, the most significant benefit of pedagogical modelling is the potential for capturing quantitative information on the process of learning that is needed to perform real time or reflective monitoring and statistical analysis of learners' learning process performances. For the learners, the consequence of this approach (pedagogical modelling) could facilitate an individual learner to monitor and analyse his/her own learning performance in comparison to his/her peers' in a real time anonymous manner.

Following this line of research (learning process management through pedagogical modelling), the major challenge is finding a system or platform that could actually interpret and run a graphical modelled pedagogy (Schneider et al. 2003). Focusing on this challenge, Schneider et al. (2003) went on to suggest that system based on the Web Services technology may help open up the future possibilities for the realisation of a pedagogically-driven system on which modelled pedagogy could be run. While this assertion may be true to an extent, thorough investigation and analysis on technologies, as discussed in Chapter 4, shows that Web Services architecture will not be sufficient. Any modelling architectural framework without a human-automation modelling capability will hardly serve the educational value it aims to espouse. This is because human interactive pedagogy, as discussed in Section 3.4, is key to any form of educational pedagogy. Therefore, this research proposes a BPM-based architecture as a conceptual architectural framework for which an online educational pedagogy could be graphically modelled, deployed and executed. BPM has grown rapidly in adoption within the commercial sphere and the reasons for the choice of BPM are in two folds: 1) It allows processes that include human interactions to be part of the modelling processes. This would be an important feature as it would enable course designers, lecturers and tutors to intervene in a learning process when or if needed. 2) It captures quantitative process information. This captured quantitative process information could be used by course designers, particularly, to monitor, analyse and re-evaluate in real time the effectiveness of their chosen pedagogy.

3.8 Summary

In this chapter, the arguments for what constitutes an ideal e-learning system functioning that is adaptive and flexible for learning management are presented. For such system, this thesis argues that an online learning should be managed through, not just the learning objects that are provided for learning, but equally importantly through the process of learning itself. This research believes that this approach can just be as important as learning for learners; and, course designer can improve their online pedagogical skills and practices. For example, if course designers are afforded significant opportunities to visualise and contextualise the immediate effect or impact of their chosen pedagogies on the learners then their runtime pedagogical adjustments can be facilitated within an online learning environment. It is believed that course designers/lecturers may choose to expand on a topic, change learning content, emphasis on a broader participation in class discussions or adopt a new formative approach based their pedagogical tendency. Consequently, learners' learning experience can be improved.

This chapter presents literature reviews and hypotheses on the subject of ideal features of an adaptive and flexible e-learning system solution. One of the hypotheses is that learning process management based on sound education pedagogy should be considered an essential part of any adaptive and flexible e-learning system. To facilitate such management, this chapter argues that such system should include the ability to:

- personalise learning through customisation of possible multiple learning paths and target tailored supplementary learning materials to the most needed learners;
- model an enhance human interactive pedagogy by defining explicitly the group of users (learners, tutors and lecturers) that are responsible to execute or collaborate on a particular learning task or activity;
- graphically model desired online education pedagogies; and,
- monitor and analyse learning process progressions and performances through learning process dashboard.

In this line of reasoning, this chapter also argues that course designers can, upon re-evaluation of their pedagogical approach, improve pedagogy design based on the monitored learning process information. Learners can also benefit from the concept of learning process management if allowed to monitor and analyse their own learning performance in comparison to their peers in an anonymous manner. The challenge for e-learning developers is to build a system that could translate these hypotheses into a viable e-learning environment that enables learning process management through the possible modelling of education pedagogies in a way that is fit for educational purpose. This thesis does not propose to present a grand or absolute solution to e-learning system but it outlined challenges that provide the motivation for the next chapter, where an innovative model of e-learning architecture (BPM-based) is presented. The BPM-based architectural concept and the technological frameworks that could support its design and development are also presented.

Chapter 4

The BPM-Based Architecture for Virtual Learning Environments

4.1 Introduction

With the different e-learning systems such as the LCMSs, CMSs, LMSs and VLEs that have been adopted and implemented by many higher education institutions (as discussed in Chapter 2, Section 2.3), the debates as to their substantive implications on teaching and learning continue. For example, current VLE shortfalls provoked an interesting debate in late 2009, in which the theme was dubbed "VLE is dead". It gave rise to a vigorous - though inconclusive - discussion on whether the VLE is dead and that a Personal Learning Environment is the solution for learning (Johnson et al. 2011). The research that is presented in this thesis does not find that the VLE is dead, the attempt to advocate its demise for the sake of its shortfalls would be tantamount to *"throwing the baby out with the bath water"*. As with many other e-learning technologies (LCMS, CMS etc.), the VLE still has a role in today's online education. However, there is no doubt about the fact that the future demand and sustainability of online education will be driven not just by the tools that bring about learning management through the management of course content alone but by continuous improvements to the existing methods, tools and technologies that would perpetually support and enhance educational value for all stakeholders - course designers and learners in particular. VLEs need to foster innovative and dynamic approaches to online educational methods - where lecturers and learners have to shift from the usual monolithic, repetitive and *"one-size-fits-all"* methods of teaching and learning to a more modular, personalised, adaptive and learning process-driven method that supports different learning models or pedagogical approaches, which can significantly enhance learning experience.

Many VLEs (Moodle in particular) flourish in course management and delivery through various learning activities. In fact *"the heart of Moodle is courses that contain activities and resources"* (Moodle.org 2011). Currently, it is estimated that there are about 13 different kinds of activities (Moodle features) available in the Moodle 2.0 release (Moodle.org 2011). These activities are assignments, chats, choices, records, feedback, forums, glossaries, lessons, SCORM, surveys, quizzes, wikis and workshops. These activities are significant to the ways in which online learning is managed and have contributed to learning within the VLE. However, it is currently not possible for course designers to orchestrate various educational pedagogies around these activities in an automated manner whereby course designers can gather statistical information on learning processes that could aid future pedagogical improvement. Furthermore, within the current VLEs, learning process management is inadequate. Therefore, this thesis proposes and presents a new e-learning system architecture - BPM-Based Architecture for Virtual Learning Environments - that aims to provide the functionality to do just that (i.e., the management of learning process through the effective modelling of education pedagogies in the form of learning process workflows using an intuitive graphical flow diagram user-interface). One of the challenges in the adoption of the BPM concept is that, while there are differences between a learning process and a business process, it is not clear whether the concept of process in BPM is compatible with or can be applied to the concept of process in a learning process. The aim is to investigate the relationships and, through implementation, to investigate if it is possible to apply BPM concepts to online learning process management through using a pedagogical modelling perspective. This chapter sets out to present an overview of the current VLEs architectural frameworks and technologies for the purpose of ascertaining whether the proposed BPM-based architecture can be integrated within the current VLEs. This chapter also presents the key concepts of the proposed BPM-based architecture in detail. The conceptual frameworks (SOA and BPM) that the proposed BPM-based architecture depends on are outlined and its underlying architectural framework is presented.

4.2 Current VLE Architectural Frameworks and Technological Solutions

There are different brands of VLE: in-house controlled software (such as the ones developed by the University), commercial systems (e.g., Blackboard/WebCT), and developed free software "open source" (e.g., Moodle). Depending on the VLE's implementation platform, various VLEs exist with various architectural structures. However, the most promising and popularly known VLEs are typically Sharable Content Object Reference Model (SCORM) compliant system models, dealing extensively with e-learning content management. A generic architectural model of such VLEs with SCORM compliant packages provided by the IMS Global Learning Consortium[1] is shown in Figure 4.1. There are three main elements provided by the SCORM run time environment (RTE):

- Launch - It provides a common structure for VLEs to start the learning resources.
- Application programmable interface (API) - It provides a communication gateway for

[1]IMS Abstract Framework: White Paper Version 1.0 http://www.imsglobal.org/af/afv1p0/imsafwhitepaperv1p0.html

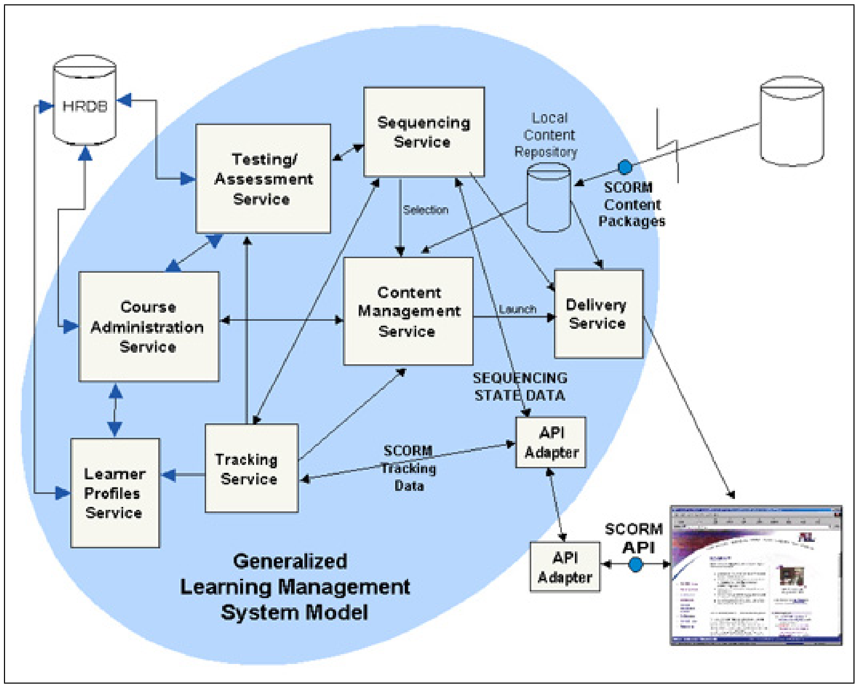


Figure 4.1: A generic VLEs architectural model with SCORM packages. Source: (Slosser 2002)

VLEs and manages the state of learning objects.

- Data model - It provides the standard used to define the communicated information between the VLEs and SCORM engine.

Figure 4.2 shows a low end technical overview of how the VLEs operate with these three main elements of SCORM RTE[2]. In conjunction with the SCORM framework, there are other technologies used for the front-end (client side) to provide the user interface. The user interface makes a request-response connection to the back-end (server side) usually through the Hypertext Transfer Protocol (HTTP) protocols - in some cases, dynamically with Asynchronous JavaScript and XML (AJAX) engine. The server side usually interacts with a data silo such as the relational database management system (RDBMS), Flat file and Lightweight Directory Access Protocol (LDAP) to store, organise and retrieve data easily.

[2]http://www.cen-ltso.net/main.aspx?put=242

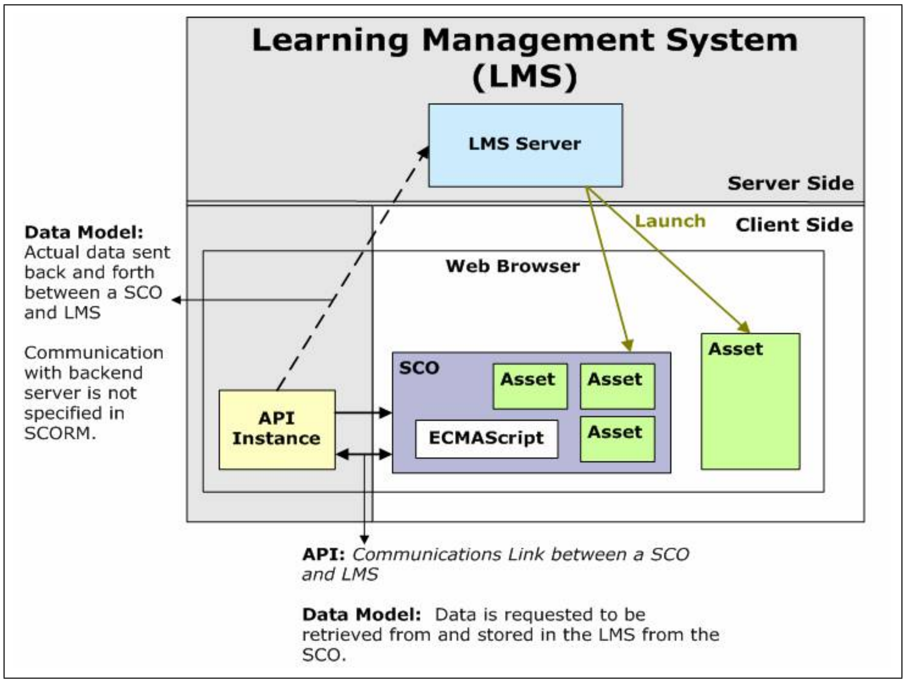


Figure 4.2: Low end technical overview of SCORM RTE interaction with VLE. Source: (Costagliola et al. 2006)

While the coverage of all the currently available e-learning systems and their packages, and the technological frameworks that underpin their existence are not within the scope of this research work, the most popularly known VLEs (Moodle and Sakai) technologies and the various learning activities that they support are briefly outlined as follows:

- **Moodle** (Moodle 2011)
  - **Technologies**
    - HTML and YUI JavaScript library for web client User Interface (UI) - application level.
    - Php - Scripting language that can be embedded in HTML, particularly suitable for Web development
    - Apache - Application server
    - Relational database - usually MYSQL

    - Others include Cascading Style Sheets (CSS), Extensible Stylesheet Language Transformations (XSLT) and XML

  - **Activities**
    - Assignment * Quiz
    - Chat * Lesson
    - Choice * Exercise
    - Forum * SCORM/AICC
    - Survey * Wiki
    - Workshop * Glossary

- **Sakai**
  - **Technologies**
    - Java technologies - Servlet, EJB, Hibernate etc.
    - JSP and AJAX framework for web client UI.
    - Relational database - MYSQL, Oracle or Postgres
    - CSS, JavaScripts, XML, XSLT
  - **Activities**
    - Consistent with Moodle

The use of these technologies and activities are well established and will continue to play a significant role in the development of the future VLEs. However, to address the requirements of an ideal VLE as discussed in Chapter 3 with respect to learning process management and pedagogical modelling in particular, a much more advanced technological framework would be required. One significant feature that is lacking in all of the existing systems is the ability to orchestrate a "Learning Process Workflow" in a way that is adaptive and dynamically responsive to learners' learning behaviour. The LAMS package offers a technique to organise learning activities sequentially and can be plugged into some of the existing VLEs. However, learning sequentially in a one-directional pathway (i.e., only a forward learning pathway) is not the same as a dynamic learning process, where multiple learning paths can be orchestrated and learners can meander back-and-forth through different paths in response to their runtime learning behaviours. The focus on learning and the ability to gauge learning progression is either indeterminate or virtually non-existence within the current virtual environments. Thus, the quest for real learning in the current systems continues (Woodill 2004). Tsolis et al. (2010), Meccawy et al. (2008) identified one of the issues facing the current VLEs for innovation as a poor and inflexible architectural structure. The linear, monotonous approach to learning (by virtue of the technological deficit) cannot be blamed on course designers - most of whom are equally unsatisfied with the incongruity between the educational pedagogy and the flexibility provided by the current system to facilitate such pedagogy. In addition, most existing systems technologies (e.g., Moodle) provide learners statistics related information and allows network access to social interaction, but, due to inadequate frameworks, do not provide tools to automatically perform analysis on these interactions (Nardini and Omicini 2008). In fact, even if the frameworks were customised to dynamically handle HTML on the client-side, the server-side will still require a significant architectural change to envisaged active services (such as agents), in the absence of which they may be unable to deal with automated learning activities (such as learning process workflow) for e-learning participants (Nardini and Omicini 2008). Consequently, the existing e-learning systems result in a *"one-size-fit-all"* approach to not just learning but also to teaching, as course designers are unable to analyse and evaluate the effectiveness of their chosen pedagogy. The challenge to address the issues of learning process management and pedagogical modelling lies on all e-learning stakeholders but more importantly on the educational technologists.

The drawbacks of current VLEs solutions, particularly on learning process management and pedagogical modelling (as described in Chapter 3), when addressed with the conceptual frameworks of certain open source technologies, set a good foundation for the architecture of the future e-learning system. This thesis presents a BPM-based learning process management architecture for Virtual Learning Environments. While BPM is the core backbone of the adopted architectural frameworks, a SOA framework that aims to facilitate learning services integration is also adopted within the BPM architectural solution. Therefore, the next section provides in detail the key concepts of the proposed BPM-based architectural solution.

4.3 The BPM-based Architecture

The proposed BPM-based architecture is an e-learning architectural solution that uses the BPM and SOA conceptual frameworks in a way that aims to facilitate learning process management through the possible modelling of educational pedagogies. Within the BPM-based architectural solution, course designers should be able to model desired education pedagogies in the form of learning process workflows using an intuitive graphical flow diagram user-interface. Automated agents associated with BPM frameworks could be employed to capture quantitative learning information from a learning process workflow. Consequently, course designers should be able to monitor, analyse and evaluate in real time the effectiveness of their chosen pedagogy using live interactive learning process dashboards. Once a course delivery is complete the collated quantitative information could also be used to make major revisions to pedagogy design for the next iteration of the course. The BPM-based architectural solution could potentially help to address the critical quantitative learning process information gaps associated with the conventional VLE frameworks. An additional potential solution to this new architecture is that it could enhance individual learners' motivations if they are allowed to monitor and analyse their own learning performances in comparison to their peers in a real time anonymous manner through a personal analytics learning process dashboard.

The architectural solution relies heavily on the use of frameworks and technologies that are associated with a BPM solution in a way that is relevant for educational purposes. The solution aims to enable educational pedagogies to be defined in a computer language, whereby learning process management can be facilitated through:

- An adaptive and flexible learning process workflow that is orchestrated to facilitate learning process in an automated fashion.
- The capturing and monitoring of the digital footprint of the cohort or an individual learner's learning processes in real time using the critical quantitative learning process information that is gathered from instantiated learning process workflows.
- Manual or dynamic adaptation (interactive pedagogy) of course materials to suit particular learners' needs (Contingent Teaching) based on the captured and monitored quantitative learning information from a learning process workflow.

The rationale behind the application of the BPM conceptual framework is to enable an online learning process management through the ability to model desired educational pedagogies in the form of a learning process workflow. Within the proposed innovative approach to an online teaching and learning management, the BPM-based architectural solution should allow:

- **A "full" learning process workflow to be made explicit within a BPM-based pedagogical modelling.**

  A full learning process includes all phases (preparation, presentation and assessment) of the learning cycle. Preparation should be aimed at establishing the learner's pre-knowledge, the need and introduction to the course material. At this stage the learner can be motivated and learn better if they are prepared for what is to come. Presentation of the information, concepts, rules, formulas and explanations of course material will be gradual, systematic and chronological - from lesson one to lesson two, from a simple to a more advanced lesson. Assessment covers all activities containing the practice of all kinds of information and knowledge by the learner after learning through the presented materials. Assessment techniques such as short question and answer tests, quizzes and multiple choice tests will be employed to determine the learners' competence level or how much knowledge is actually gained by the learner. These phases of the learning process will be orchestrated in a BPM solution as an instance of full learning process life cycle through course materials. The ability to model these learning phases would be significant for the course designers for future pedagogical improvement.

- **The creation of customised learning pathways through course materials.**

  As discussed in previous Chapter, it is widely recognised that an important component of success in e-learning education is related with the ability to personalise learning through a possible customisation of learning pathways for the specific needs of a given learner. The BPM-based architectural solution should provide the means that effectively allows course designers to be able use a BPM orchestration tool to draw out possible multiple pathways. The enablement of multiple learning pathways should not necessarily be construed as individual learning in isolation, but the need for social constructivism or peer collaborations. Learners should be able to: navigate their ways through online course materials in a way that accommodates their learning needs and styles; engage in a social constructivism through collaboration on learning tasks; and, achieve the desired learning outcomes as depicted in Figure 4.3. It aims to allow each learner to maintain his/her own

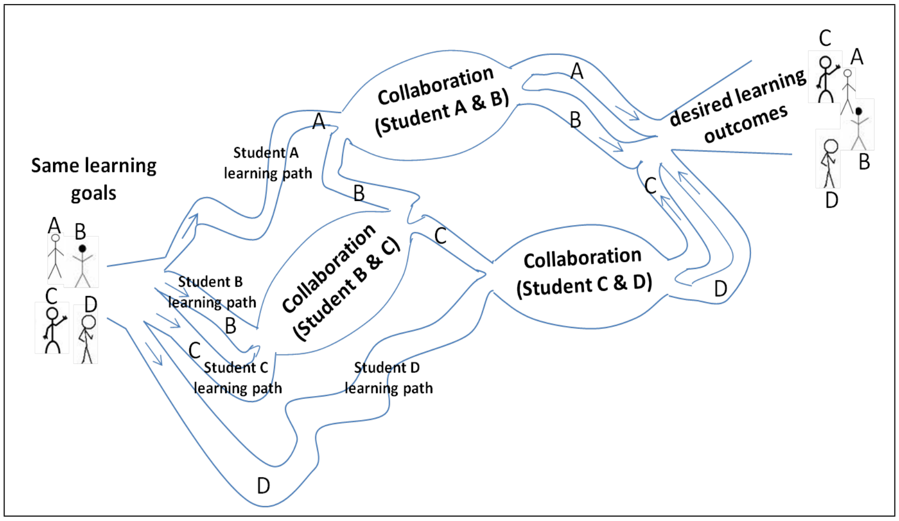


Figure 4.3: Same learning goals, different learning paths, peer collaborations and desired learning outcomes

learning workflow process that is adapted to his/her profile and dynamically adapted to his/her run-time behaviour. This would potentially allow the course content and learning activities proposed to student A to be different to those proposed to student B. The practical benefits of this customisation approach are: a course designer can draw and configure using a graphical interface the paths possible through course materials; a course designer (and learner) can see the progress of learners using this same graphical user interface; the course designer can see the statistical progress of an individual learner and the statistical progress of the entire cohort.

A similar concept of this approach is the knowledge map[3] created by the Khan Academy (a free online mathematics course) to check on student's progress as shown in Figure 4.4.

[3]Retrieved September 09, 2011 from http://www.khanacademy.org/exercisedashboard

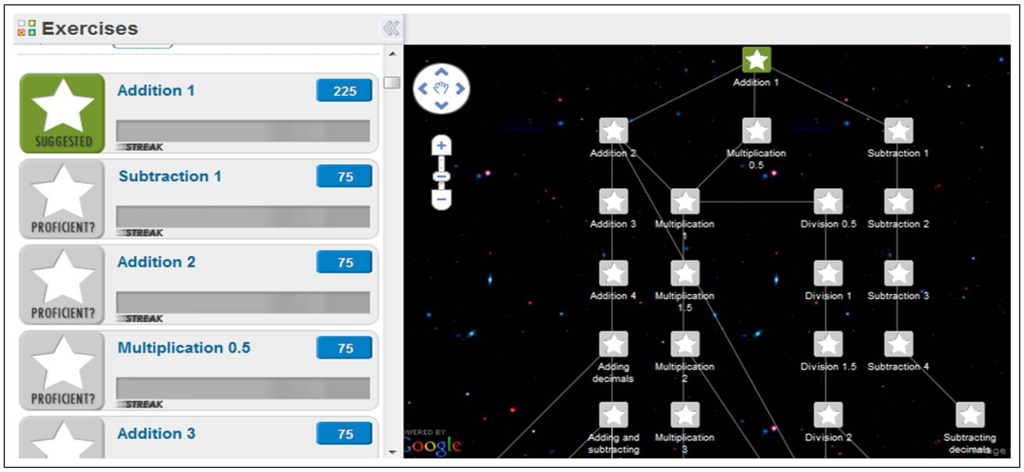


Figure 4.4: Khan Academy knowledge map

- **Human and system interactions to be integrated into a "full" learning process workflow - Enhancing the interactive pedagogy within the proposed BPM-based architectural solution.**

  Another key factor of success in e-learning education is the level of involvement and presence of the participants; and, the quality of technical support available to the learners. Enhancing the interactive pedagogy through human interaction and intervention is expected in the implementation of a "hands-on" adaptive learning process. Workflow traditionally has always been about software, computer or machine interactions, but a BPM based solution would helps the course designer to introduce human interaction into a workflow model. In fact, BPM technologies are the official standards for any workflow management system, particularly workflows that involve human inputs (Wang et al. 2006, Stohr and Zhao 2001). This is one of the greatest advantages of BPM. BPM technologies should be employed to integrate all possible authorised e-learning participants (course designers, lecturers, learners, tutors, etc.) into a full learning process workflow. This should be achieved by orchestrating interactions between learning services (learning objects, competence-based assessment, etc) and human-task services (learner, lecturer, etc). It aims to enhance the desired interaction amongst e-learning participants and to ensure that support is delivered when it is most needed.

- **The learning footprint of a learner's learning process to be captured, monitored in a learning process dashboard and an automatic/manual update can be performed in a real time or an asynchronous manner.**

  What can not be measured cannot be managed. Within the BPM-based architectural solution, the use of BPM technologies should provide analysis or a series of periodic and quantitative methods to measure, assess, control, or select a learner, process, event, together with procedures that helps to interpret the progression of a learning process in light of the previous assessment or comparison. The analysis should allow for the footprint of a learning process to be captured and monitored in a real time manner. These analytical concepts and values aim at: capturing the quantitative information on the process of learning that are vital for future analysis on the effectiveness of a chosen pedagogy; detecting and monitoring the progress and performance of a learner's learning process through course materials; lecturers should be able to view how and when a learner progresses from topic X to topic Y. This would give the lecturers the ability to manually adapt the learning path through course materials in response to the monitored data where a learner's progression is anaemic and unsatisfactory. Automatic adaption of a learning path should also be possible based on learning rules set by course designers (e.g., a learner could be allowed to attempt an assessment twice or supplementary materials could be made compulsory if prerequisites were inadequate).

- **Course materials (Learning Objects) in a standard format (DocBook/SCORM) to be integrated into a learning process workflow.**

  The quest to reduce the level of knowledge deficit amongst learners should also focus on dynamic content structuring, re-structuring and delivery taking into account the pedagogical values. To successfully customise and enhance course materials, LOs need to use appropriate metadata specifications such as those specified by standard bodies like the IEEE Learning Technology Standards Committee (IEEE-LTSC) or the instructional Management System Global Learning Consortium (IMS-GLC). Any e-learning system that is metadata standard compliant would effectively facilitate authoring, publication, discovery, and reuse of content in a more efficient and intelligent way. Integration of standard formatted LOs in DocBook or SCORM would be enabled within a learning process workflow. The content could be sourced internally within the BPM-based architecture using these standard formats. Where applicable, Service Oriented Service (SOA) technologies (i.e., web services) would be employed to source and present integrative content from heterogeneous system such as a CMS that is managed by third parties.

Following these lines of online learning management concepts, the proposed BPM-based architectural frameworks that could potentially support the concept of learning process management through the possible modelling of educational pedagogies are presented in the next section. Detailed analysis of these frameworks (SOA and BPM) is also presented.

4.4 BPM-based Architectural Frameworks and Technologies for VLEs

The research presented in this work claims that the choice of technological solutions for any e-learning system can potentially determine the extent to which such a system can ultimately serve to implement any educational pedagogy. The ethos of this research is based on the belief that any compromise on education pedagogical structure or strategy (due to technological deficit) would be detrimental to the expected learning outcomes; even though it is arguable that technology can influence the course or shape of such pedagogy. The roles of technology in education must be seen as a platform that helps to strengthen the pedagogical skills of the course designers/lecturers. Therefore, this section discusses the conceptual architectural framework of the proposed BPM-based architecture for learning environments; and, the underlying technological platform that underpins the architecture is also discussed.

4.4.1 Service Oriented Architecture Approach

Service-oriented architecture (SOA) is a conceptual architecture based on software agents linked loosely to software services in order to perform their assigned tasks. A software agent is referred to as:

> *"component of software and/or hardware which is capable of acting exactingly in order to accomplish tasks on behalf of its user."* (Nwana 1996)

Software agents can be autonomous from each other. This provides a major method of structure-oriented and development of distributed applications using commercial independent software services. As a concept of developing reusable software services, SOA provides strategies for the integration of large software services that could represent business functions.

Subsequently, SOA is increasingly been used as the prime design principle as opposed to the monolithic architecture for new business applications (Natis 2003). The strength of the technologies that are typically used in the context of SOAs lies in the support to collaboratively aggregate distant services (i.e., services from multiple platforms) (Schroth 2007). SOA is based on a more complex set of rules and standards (Hagel 2006). These rules and standards are governed by a set of SOA principles such as service abstraction; loose coupling; service reusability and interoperability. Although SOA principles have been around over the past decade, it is only in recent years that their level of awareness has started a major trend in enterprise software design (Hurle 2006). By implementing the software as a service (SaaS) concept, organisations can leverage existing business services by enabling them to dynamically discover and reuse existing services to building customised composite services. The concept of SOA is nothing new. In the past, Distributed Component Object Model (DCOM) - an extension of the Component Object Model (COM) and Object Request Broker (ORB) - a specification of CORBA - were the most popularly adopted implementation of many SOA models. However, Web Services have, in recent years, become the most popular connection technology for software services (O'Brien et al. 2007, Martin et al. 2007). One of the successful stories of SOA implementation using Web services is the open eBay[4] Web services API for online auctions.

Web Services

While SOA is a software architectural and design principle, Web Services on the other hand is about integration technology specifications. Web Services is the technology that allows connections to services regardless of the underlying platform and technology. In other words, it is a XML-based universal integration interface technology for both homogenous and heterogeneous software services. Web Service Descriptive Language (WSDL) and Simple

[4]https://www.x.com/developers/ebay/web-services-overview

Object Access Protocol (SOAP) based Web services are the most commonly distributed standards used to establish SOA connections to services. Web Services Protocol Stacks have four major parts as shown in Figure 4.5: Service Transport - based on Hypertext Transfer Protocol (HTTP), Simple Mail Transfer Protocol(SMTP), File Transfer Protocol (FTP) etc.; XML Messaging (XML, SOAP); Service Description (i.e., WSDL); and, Service Discovery - based on Universal Description Discovery and Integration (UDDI).

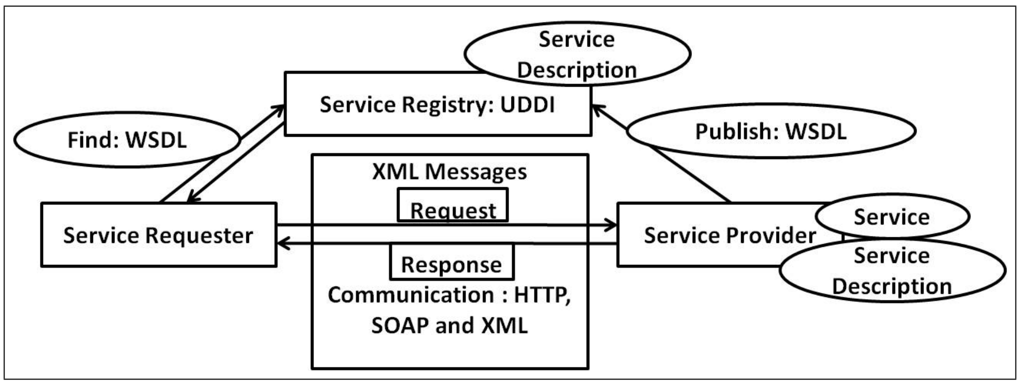


Figure 4.5: Web Services protocol Stack.

The availability of numerous open-source web services engines have contributed to the quick adoption and implementation of web services-based business applications by many organisations today. The viability of the open-source web services engines such as Axis1[5], Axis2[6], JBossWS[7], XFire[8] and Metro@Glassfish[9] were investigated for an implementation of the proposed BPM-based architectural solution for a VLE. The Axis2 web service stack is considered the preferential choice for services connections. This is in part due to the momentum generated from the Apache community but also the new architecture on which Axis2 is based on is more flexible, efficient and configurable by comparison to alternatives and it supports virtually all of the web services feature (WS-*).

[5]http://axis.apache.org/axis/
[6]http://axis.apache.org/axis2/java/core/
[7]http://www.jboss.org/jbossws
[8]www.xfire.com/
[9]http://metro.java.net/

The desire to reuse learning objects and activities or tools has been reflected in the development of e-learning content standards and specifications, for instance, the Tools Interoperability Specification by the IMS (see chapter 2, section 2.2) are aimed at addressing this issue. The initial focus was based on content reusability through the provisions of content metadata standards (McAndrew et al. 2006). However, due to the high cost development and maintenance associated with e-learning; and, with the potential offering of SOA, the focus has shifted from just reusable content to reusable e-learning software tools and learning activity structures within an e-learning system (Mircea 2012). This offering has equally help to strengthen the pedagogical position of the IMS LD specifications, where same learning designs or activity structures can be reused in various subject areas with a simple change to the underlying resources for different subject areas (McAndrew et al. 2006). Consequently, this pedagogic reuse can spur the motivation even more for both content and tool (lesson, email, chat, assessment etc.) reuse. The SOA approach to learning services and tools has a direct benefit to the learning design and both can be interlinked. E-learning environments that are configured as learning services would have the potential to provide learning designs with a specific instance of a service hosted by such e-learning environment (McAndrew et al. 2006).

In this regard, the SOA architectural approach applies to facilitate the development of reusable learning components such as referencing models for learning objects from external resources as services; and, exposing learning activities as services. This approach will have the potential to enrich the e-learning environments through an attractive combination of best of breed content that can plug together, instead of the simple integrated, monolithic systems approach (McAndrew et al. 2006). SOA principles would be a useful guide to creating, delivering and reusing learning objects and activities as a collection of services (independent of the underline platforms), where these services can interact/communicate to each other. Some of the popularly know open-source or community VLEs such as Moodle and SAKAI are also tapping into the SOA initiative. For example, Moodle provides a Web services API[10] that allows plugins' functions to be exposed to external systems using one of a number of protocols, like XML-RPC, REST or SOAP.

Within the proposed BPM-based architecture, the investigative focus for cross-platform implementation of learning activities, tools and resources will be to expose learning activities, tools and resources as learning services through the WSDL interface. This way, composite learning services through the aggregation of various learning services can be linked through their respective WSDL interface internally or externally to a VLEs that is based on the BPM-based architecture; and, communication through the SOAP protocol can occur. In fact, the orchestration of learning process workflow using the learning services that are exposed through the WSDL interface is possible using one of the BPM technologies (BPEL) that is discussed in the next section.

Even though SOA concepts within the e-learning context have gained considerable traction, especially in the areas of collaborative learning, learning objects and learning tools as services, the use of these learning services to model or orchestrate educational pedagogies is lacking. Perhaps one of the reasons for this is because SOA is not a concept for modelling software services (Mansukhani 2005). Nevertheless, modelling learning processes based on these learning services (lessons, assignments, choices, chats, forums, quizzes, glossaries, resources etc.) is a significant challenge within the current VLEs (Mircea 2012). Learning services that are exposed under the principle of SOA will still require a high degree of collaborative life cycle amongst the major e-learning stakeholders (course designers, lecturers, learners, tutors etc.) within a chain of service delivery to actually maximise and optimise the agility, adaptability and flexibility of a SOA. SOA specifications did not go far enough to providing a modelling language notation. This is not to say that the specifications are faulty, it is simply not a specification for modelling language. Therefore, this provides the

[10] http://docs.moodle.org/dev/Web_Services_API

motivation for the adoption of another conceptual framework (BPM) that can harness these learning services in a manner that allows them to be modelled/orchestrated in form of learning process workflows.

4.4.2 The Business Process Management Approach

BPM is a methodology by which the efficiency and effectiveness of business processes can be optimised through modelling, development, automation, deployment, management, monitoring and analysis of the operation of such processes in a way that involves humans, applications, organisations and other sources of information (Scott 2007, Korb and Strodl 2010, Mohamed and Noordin 2011). The possibility of creating business processes that coordinate between people, applications and services to solve business problems, ranging from embedded workflow to enterprise business process orchestration, is one of the key factors in its popularity and adoption. This is also one of the reasons for its adoption within the proposed BPM-based architecture. Business Process is:

> *"a set of interrelated tasks linked to an activity that spans functional boundaries"*(Unhelkar et al. 2010)

Learning process can also be referred to as set of interrelated tasks that are linked to the various learning activities mentioned in Section 4.2. Therefore, it would be plausible, to an extent, to attribute business process characteristics to that of a learning process. Even so, it is also worth noting that business processes have some characteristics that are fundamentally different from learning processes. For example, business processes aim to improve organisational performance while learning processes aim to improve individual performance. Within the commercial sphere, BPM has been adopted to meet and improve organisational performance needs. BPM can also be referred to the:

- mapping of processes with the strategic objectives of the organisational plans and goals;

- construction of process architectures that capture all the stakeholder relationships and activities;
- process of building a measurement system consistent with the organisational plans and goals;
- provision of educated and reliable information to managers on how processes can be better improved or managed effectively.

In other words, BPM allows the management of related activities undertaken by organisations, and, where necessary, provides the means to improve their business processes (Malkin 2009). BPM also provides a continuous monitoring mechanism of process performance in a real time manner and thereby improvement on processes and its components (organisational regulations, structure, business rules, policies, human resources and information and communication technology) can be harnessed in a more efficiency manner. The term is sometimes used to refer to different automation systems, such as workflow automation initiatives. BPM enables business processes automation by decoupling the process logic from the client applications that access them; managing relationships between members of the project; integrating resource processes internally and externally; and, monitoring performances.

BPM supports a number of phases throughout its life cycle. Figure 4.6 illustrates the typical life cycle - Process modelling, implementation, execution and analysis - of a BPM system around the operation of a business process concept.

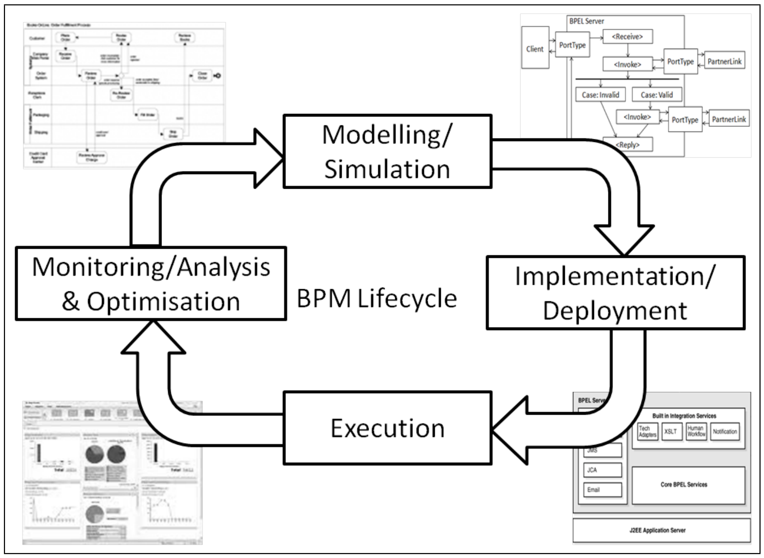


Figure 4.6: End-to-End life cycle of a typical BPM system.

- **Process Modelling**: This is the first phase of a BPM project life cycle. Using a modelling tool, a business analyst creates a blue print of a process model by defining the order of tasks that are linked to various activities within a business process. The BPM modelling tool is typically an intuitive graphical-based tool characterised by modelling notation. The widely used and adopted BPM modelling tool by most BPM analysts is the Business Process Modelling Notation (BPMN).

- **Process Implementation**: BPMN is not directly executable; therefore the next phase of the BPM life cycle is to transform a process model that is created in a BPMN tool into a machine readable and executable language. In the case where SOA services (exposed by the Web services) are part of the activities of a business process, then the standard executable language is the Business Process Execution Language (BPEL). Other execution languages such as the Java Process Execution Language (JPDL) exist to facilitate the execution of services that would not otherwise have been exposed as Web services. The executable model of the business process can be deployed into a process run time engine.

- **Process Execution**: The execution of business process instances occurs in the process run time engine and process instances are executed by navigating through the branches of a model process. The execution can be either invoked by machines (software agents), another process or an authorised user.

- **Process Analysis**: This phase of the BPM life cycle involves the monitoring of running process instances for efficiency and performance. Process monitoring provides information on the various stages of the running process instances in a dashboard, where an analyst can assess and analyse the performance of a process instance based on a set of key performance indicators. The outcome of the analysis at this stage can be feedback into the process modelling phase, again for process optimisation and improvement if necessary.

Currently, there are several standard BPM technologies and frameworks that have been initiated by various organisations as shown in Table 4.1. Each of these standards is intended for different BPM purposes. However, a typical BPM suite will contain at least a modelling tool and an execution language. The BPML was the initial business process execution language; however, since the introduction of the BPEL specification, the BPML has received less attention. BPEL is a specification for the execution of a business process model using the web services interface. The BPQL is an administrative management interface used to interrogate and monitor a BPM infrastructure. BPSM is a specification for a common metamodel that is used to describe all business process models. BPXL is an extensional specification that provides transactions, human workflow and business rule for the BPEL specification. UML Activity Diagrams are object-oriented-based specification that provides data flow and flow charts from one activity to another. XPDL is a specification that provides a standard format for business process definitions, thereby, allowing cross-platform sharing of a business process definition between different workflow environments. WAPI is a specification

Standard	**Organisation**	**Type**
Business Process Execution Language (BPEL)	OASIS	Execution Language
Business Process Modeling Notation (BPMN)	BPMI[a]	Notation language
Business Process Modeling Language (BPML)	BPMI	Execution language
Business Process Query Language (BPQL)	BPMI	Administration and monitoring interface
Business Process Semantic Model (BPSM)	BPMI	Process metamodel, in fashion of Object Management Group (OMG) Model-Driven Architecture (MDA)
Business Process Extension Layer (BPXL)	BPMI	BPEL extension for transactions, human workflow, business rules
UML Activity Diagrams	OMG[b]	Notation language
XML Process Definition Language (XPDL)	WfMC[c]	Execution language
Workflow API (WAPI)	WfMC	Administration and monitoring, human interaction, system interaction
Workflow XML (WfXML)	WfMC	Choreography (or similar to it)
Business Process Definition Metamodel (BPDM)	OMG	Execution language and/or notation language, as MDA metamodel
Business Process Runtime Interface (BPRI)	OMG	Administration and monitoring, human interaction, system interaction, as MDA metamodel
Java Process Execution Language (JPDL)	JBoss JBPM[d*]	Execution Language

[a] http://www.bpmi.org/

[b] http://www.omg.org/spec/UML/

[c] http://www.wfmc.org/wfmc-standards-framework.html/

[d*] A proprietary markup (XML) representation that does not follow any specific standards - http://www.jboss.org/jbpm/

Table 4.1: BPM technologies and standards

that provides access to WFM functions. WfXML is a specification that defines an asynchronous web service/XML-based protocol for interoperability of workflow engines. BPDM is a specification that provides XML-based semantic metamodels for a business process model that can be exchanged between modelling tools. BPRI is a specification for common interface for process execution engines. BPMN is a specification for modelling business process using graphical notations. JPDL is not a standard specification but a proprietary markup (XML) representation for business process execution language. For the purpose of the proposed BPM-based architectural solution for an online learning process management through pedagogical modelling that is presented in this thesis, two key BPM specifications - BPMN and BPEL; and, the JPDL are adopted and presented in detail.

4.5 BPMN + JPDL/BPEL as a Pedagogical Modelling Tool

4.5.1 BPMN As A Modelling Interface

The core driving force or promoter of BPM is the BPMN technology. It is based on standardised graphical notations for drawing/modelling business processes in a workflow management system. BPMN was developed by the Business Process Management Initiative (BPMI) to allow business users to understand graphical representation of the development of their business processes (Aldazabal et al. 2008). The BPMN standard specification was first introduced in May 2004 by the BPMI with the release of the BPMN 1.0 version. Following the adoption of the specification by the Object Management Group (OMG) in 2005, OMG has been responsible for the planning and development of the specification. In 2009, the latest standard specification (BPMN 2.0) was released by the OMG[11]. The BPMN 2.0

[11] http://www.omg.org/spec/BPMN/index.htm

specification defines not only the various type of the graphical notations that form the core set of the BPMN elements as shown in Figure 4.7, but also the metamodel - a non-graphical model that stores a BPMN diagram in an XML format.

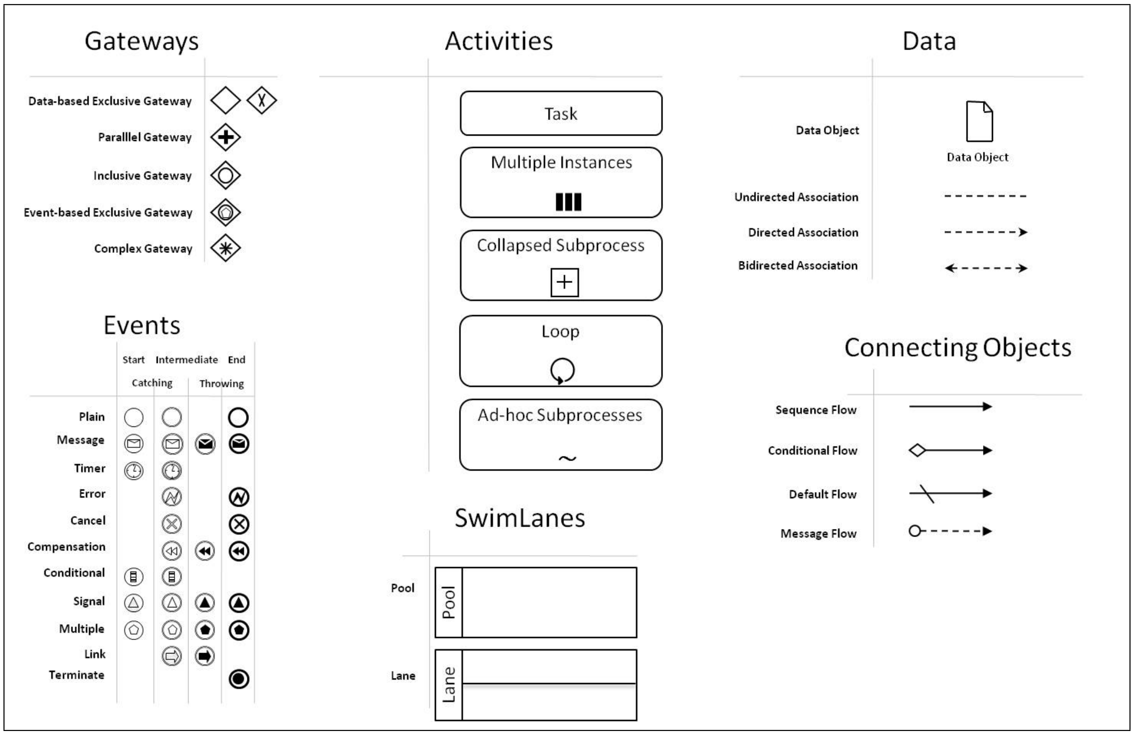


Figure 4.7: The graphical notations defined in BPMN 2.0 specification.

The Gateways modelling elements are the control logic that determines how sequence flows interact as process flows merge or diverge. The Events notations represent something that happens in the course of business process execution. These Events will usually cause a trigger and the result will have an effect on the flow of the process. Events can perform a "start", an "end" or "interrupt" function on a process. Activity represents the task needed to be performed by a human or "task handling" agent within a business process. Activity can be modelled as a task, sub-process, loop or multiple instances of a process. A Swimlane represents the user/group that can execute a certain task. A Swimlane can either be a pool or a lane. A pool container is used to encapsulate different sets of activities that are performed be a specific group and a pool can be partitioned to form lanes. Connecting objects are used to direct the order of sequence flow that activities will undergo in a process. Using these elements, Figure 4.8 shows a typical business process model diagram within a BPMN environment.

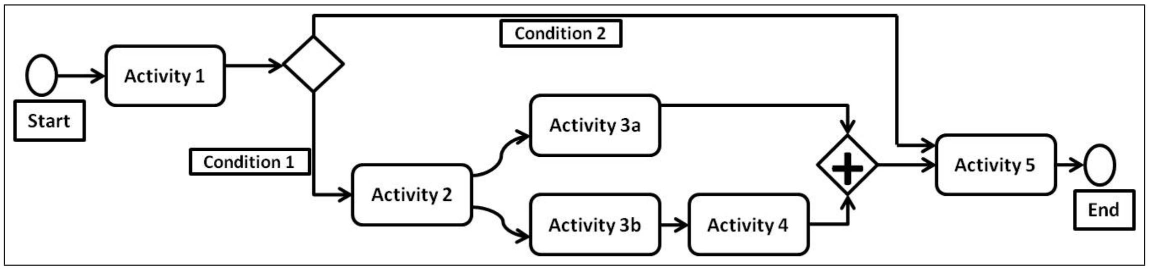
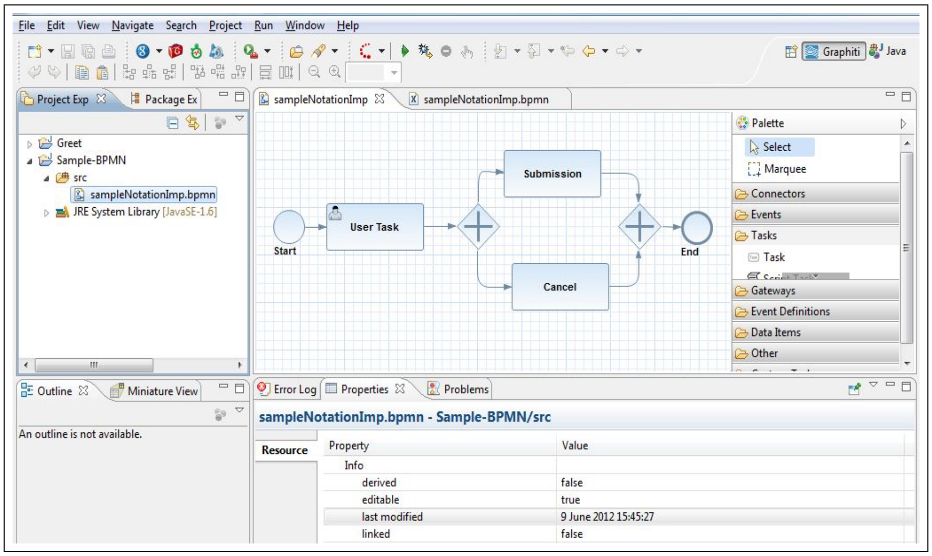


Figure 4.8: Typical business process model diagram in BPMN.

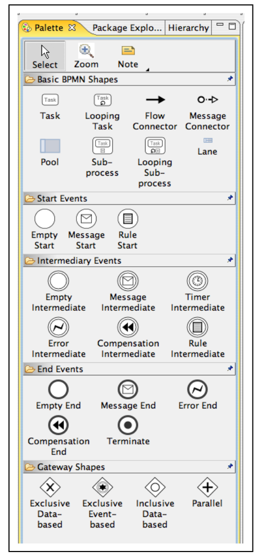
Sample Modelling Using Standard BPMN Elements

The use of standard BPMN graphical notations is currently available in many commercial (Activiti[12], Intalio[13] etc.) and open-source (JBoss JBPM, Spagic[14] etc.) BPM suites. Also, there are open-source BPMN frameworks (which this research relies upon) that can be plugged into many popular integrated development environments (IDEs) such as Netbeans[15], IntelliJ IDEA[16] and Eclipse[17]. For example, a learning process workflow can be modelled using the standard BPMN within an eclipse graphical editor (BPMN modeler) and a modelling sample is shown in Figure 4.9a; and, its correspondent metamodel (the XML version of the standard BPMN diagram) is shown in a snippet Listing 4.1.

[12] http://activiti.org/
[13] http://www.intalio.com/
[14] http://www.spagoworld.org/xwiki/bin/view/Spagic/
[15] netbeans.org
[16] http://www.jetbrains.com/idea/
[17] http://www.eclipse.org/



(a) A typical BPMN modelling perspective in eclipse.



(b) A BPMN palette in eclipse.

Figure 4.9: A BPMN modelling in eclipse IDE.

```
<?xml version="1.0" encoding="UTF-8"?>
<bpmn2:definitions xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:bpmn2="↩
    http://www.omg.org/spec/BPMN/20100524/MODEL">
    <bpmn2:userTask id="UserTask_1" name="User Task">
        </bpmn2:userTask>
    <bpmn2:startEvent id="StartEvent_2" name="Start">
        </bpmn2:startEvent>
    <bpmn2:endEvent id="EndEvent_1" name="End">
        </bpmn2:endEvent>
    <bpmn2:parallelGateway id="ParallelGateway_1">
        </bpmn2:parallelGateway>
    <bpmn2:parallelGateway id="ParallelGateway_2">
        </bpmn2:parallelGateway>
    <bpmn2:task id="Task_4" name="Submission">
        </bpmn2:task>
    <bpmn2:task id="Task_5" name="Cancel">
        </bpmn2:task>
  </bpmn2:process>
</bpmn2:definitions>
```

Listing 4.1: A snippet equivalent metamodel (XML) version of the BPMN modelling in eclipse.

Although the use of BPMN to perform business process modelling can be a complex task in general; and, the use of BPMN to model any process would required some kind of technical skill to an extent, for the purpose of the research presented in this thesis, there are two significant challenges in modelling within the IDEs. Firstly, it is a development environment (as the name suggests), therefore, it is often suitable for use by the software or IT engineers. It will be highly impractical for the regular course designer to start modelling an educational pedagogy within the IDE. Secondly, the names that are associated with the BPMN notations in the IDEs' palettes, as elaborated in Figure 4.9b, do not bear any relationship with the educational domain, which the course designers are interested in. In other words the BPMN names are too generic for educational or pedagogical purposes. This raises the fundamental research question about the relationship between BPM and online pedagogical modelling that is posed in this thesis:

> *Can Business Process Management concepts and technologies be used to model various pedagogies in order to utilise its quantitative process information capture framework in order to allow course designers to develop and perfect their learning process workflow?*

In spite of the challenges surrounding the use of BPMN in modelling learning process workflow based on educational pedagogy, the research presented in this thesis proposes that BPM has the potential to address the issues relating to the online learning management discussed in Chapter 3. Therefore, one solution to the challenges of using BPMN to model educational pedagogies is to engage course designers in an intense technological training in order to be able to use the IDEs to model educational pedagogy. This solution may be generally impractical, unwarranted and counter-productive to their philosophical and educational aims. Another solution will be to extend the challenge to the e-learning vendors to design and customise the BPMN specification in such a way that fits into the educational purposes - pedagogical modelling in particular. Within the research work that is presented in this thesis the latter approach is adopted and presented. The next chapter presents an implementation that is based on the proposed BPM-based architecture for course designers by implementing a customised BPMN modelling environment. Also, as the BPMN technological framework continues to improve overtime, a customised BPMN modelling environment for course designers should also significantly improve overtime.

4.5.2 BPEL As A Modelling Execution Language

The development of business services and exposing their functionalities through Web services are sometimes insufficient, especially when these services are to be aggregated to form a composite service. The need to create new business services from existing services is where BPEL comes into play. BPEL is an XML-based language used for specifying enterprise business processes within Web services. The specification of BPEL as a workflow language contains constructs such as Receive, Invoke, Assign, Reply, Wait, Flow, Switch etc. that are generally used to express abstract and executable business processes. BPEL allows a top-down process oriented approach to SOA through the composition and orchestration of Web services into a complex business process. The behaviour of the composite or orchestrated business processes between web services and as a web service is described by the BPEL language by using the web services stacks (WSDL, UDDI, SOAP WS-Addressing etc.) within its constructs. Many organisations such as Oracle[18], the Apache Software Foundation[19], JBoss[20], Active Endpoints[21] and Parasoft[22] have developed advance tools, some of which are available as open-sources.

BPMN is not executable and can not be deployed directly onto any BPM engine, hence, the need to convert BPMN to an executable computer language. Therefore, similar concepts of composing and executing new learning services from existing learning services that are exposed as Web services applies to the proposed BPM-based architectural solution for learning process management. By modelling learning process workflows using the BPMN framework, the BPEL framework can be used as an execution language for such workflows. The

[18] http://www.oracle.com/technetwork/middleware/bpel/overview/index.html
[19] http://ode.apache.org/ws-bpel-20.html
[20] http://www.jboss.org/riftsaw
[21] http://www.activevos.com/products/activevos/overview
[22] http://www.parasoft.com/jsp/products/bpel.jsp?itemId=114

translation of a modelled process within BPMN is made possible using the Eclipse SOA Tool Platform-Intermediate Model (STP-IM); the initial step involves exporting the BPMN to the IM (a "bridge" between STP editors). A BPEL process version is generated by the STP-IM tool and the BPEL is completed with all necessary data integration and artefacts syntaxes (e.g., deployment descriptor, the BPEL web services interface etc.) needed for deployment. Currently, BPEL has been developed with its own graphical user interface thereby making BPEL more user friendly as manual coding of BPEL is no longer necessary. Figure 4.10 shows an example of a learning process workflow that was initially modelled in a BPMN tool and subsequently translated into a BPEL.

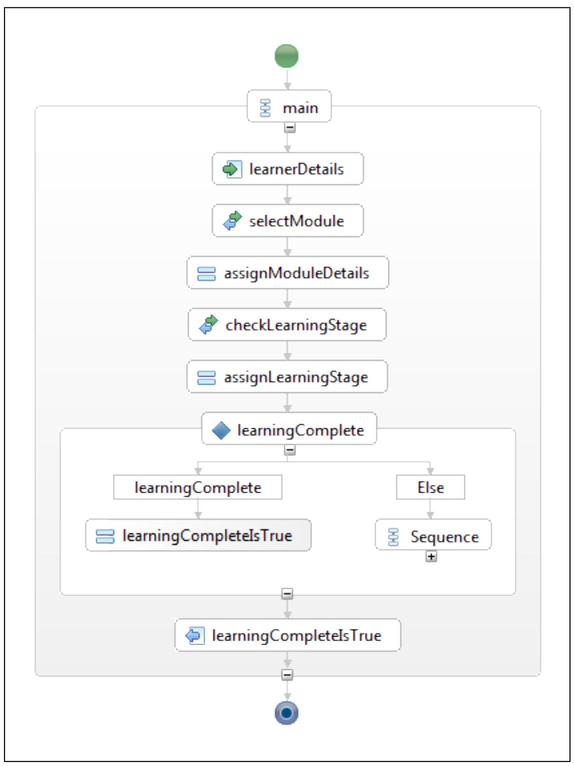


Figure 4.10: An example of a BPMN learning process workflow orchestration translated into BPEL.

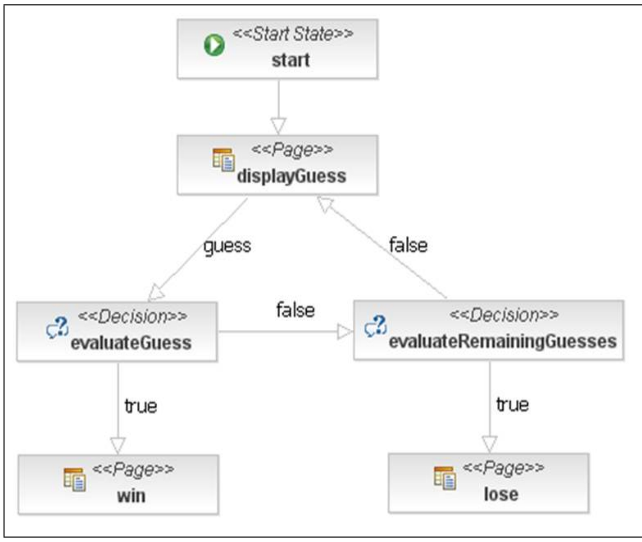
4.5.3 JPDL As A Modelling Execution Language

Since BPMN is not directly executable in any BPM engine, JBoss jBPM provides a framework to convert BPMN to its BPM execution language (JPDL) seamlessly with a click of a button. JPDL (executable computer language) is a Java programming environment for workflow management; and, it is a JBoss process orchestration language that is executable in a workflow engine (i.e., JBPM). It is an intuitive process execution language that depicts business processes both in graphical form as shown in Figure 4.11a and XML form as shown in Figure 4.11b (for the creation of activities such as tasks, timers, wait states for asynchronous communication and automated actions). To bind these activities together, jPDL has a mechanism for controlling the flow of processes (Chen et al. 2010). The dependencies of JPDL are fewer but are rich in Java libraries for business process modelling. JPDL can also be used in harsh environments where critical deployment via J2EE application server is clustered. JPDL can be configured to use any database and can be in any J2EE application server.

The introduction of software tools called BPM Systems has made the development of a BPM web-base application faster and cheaper. The release of open-source BPM frameworks such as JBoss jBPM and Apache Orchestration Director Engine (ODE[23]) has made traditionally expensive BPM tools available to the academic community. JBoss jBPM defines process definitions in two flavours: JBPM JPDL and BPEL that are described above. The Apache ODE on the other hand is a workflow management process engine based on XML language for Web services-Business Process Execution Language (WS-BPEL) or BPEL.

While BPEL is a potential execution language for a modelled learning process workflow, the implementation presented in this thesis uses the JPDL as an execution language. The main reason for adopting the JPDL is because the JBoss JBPM execution engine provides

[23] http://ode.apache.org/



(a) JPDL in graphical form.

```xml
<pageflow-definition name="numberGuess">

   <start-page name="displayGuess" view-id="/numberGuess.jsp">
      <redirect/>
      <transition name="guess" to="evaluateGuess">
        <action expression="#{numberGuess.guess}" />
      </transition>
   </start-page>

   <decision name="evaluateGuess" expression="#{numberGuess.correctGuess}">
      <transition name="true" to="win"/>
      <transition name="false" to="evaluateRemainingGuesses"/>
   </decision>

   <decision name="evaluateRemainingGuesses" expression="#{numberGuess.lastGuess}">
      <transition name="true" to="lose"/>
      <transition name="false" to="displayGuess"/>
   </decision>

   <page name="win" view-id="/win.jsp">
      <redirect/>
      <end-conversation />
   </page>

   <page name="lose" view-id="/lose.jsp">
      <redirect/>
      <end-conversation />
   </page>

</pageflow-definition>
```

(b) JPDL in XML form.

Figure 4.11: JPDL in graphical and XML forms.
Sourced: (Mison et al. 2010)

an advanced human interaction task flow within a modelled process workflow. BPEL on the other hand requires further extensional specifications such as a BPEL4People and/or WS-HumanTask to be able to handle human task flow. The open-source execution engines for these extensional specifications can be difficult to configure when compared with the JBoss JBPM execution engine for capturing human task flow.

This work postulates that there is the need for the orchestration of flexible and adaptive learning process workflow based on sound educational pedagogies; and, for the orchestration of such process, BPM technologies would be *sine qua non* to its implementation in the 21st century because BPM technologies are the official standards for any workflow management system (Brambilla et al. 2009). Therefore the next section presents a BPM-based conceptual architecture that aims to identify solution to the concept of learning process management through the modelling of educational pedagogies using the SOA and particularly BPM conceptual frameworks.

4.6 A BPM-based Conceptual Architecture

Architectural design reflects the components of computer system programs and the data structures needed. There are several types of architectural design, by and large, architectural design begins usually with design data and proceeds to the attribution of one or more components of the system architectural representations. Within the proposed e-learning architectural model, the key contribution of this thesis is the introduction of a BPM-based architecture that addresses the issues discussed in Chapter 3. The BPM-based conceptual architecture is a back-end (server-side) architectural framework that is based on an integrated solution of SOA and BPM frameworks in a way that serves to improve learning management through the management of learning processes based on modelling of educational pedagogies. In other words, BPM-based Architecture$^{\text{Back-end}}$ = SOA$^{\text{Web services}}$ + BPM$^{\text{BPMN/JPLD/BPEL}}$ as shown in Figure 4.12.

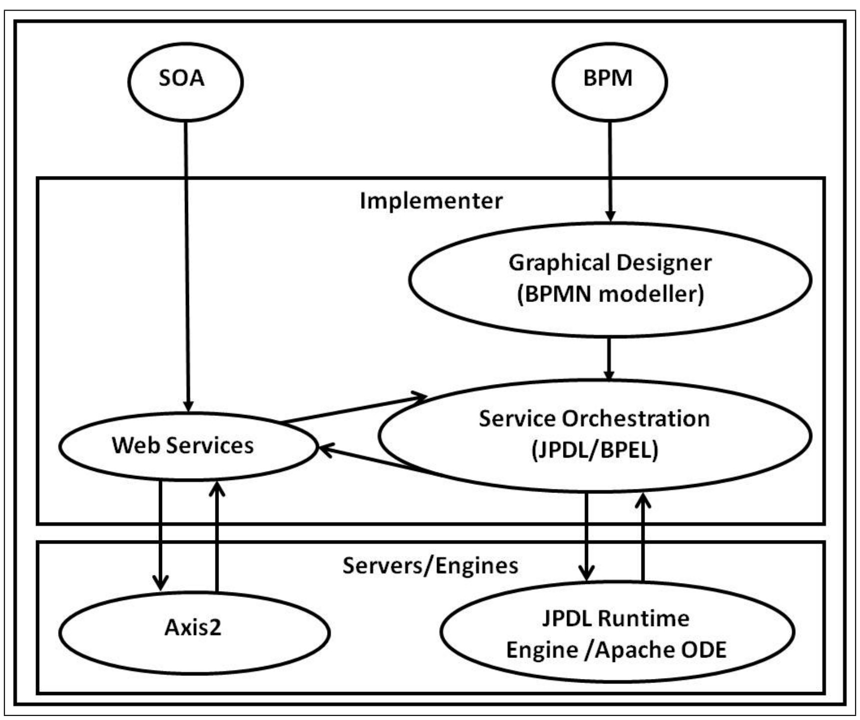


Figure 4.12: Integrated SOA and BPM solution layout.

For an implementation purpose, the general BPM-based architectural structure is designed as a client-server side architecture with five major layers shown in Figure 4.13. The user layer is a front-end layer that presents the user with an intuitive interactive graphical user interface such as the web page user interface. The "Learning Service Rendering" layer provides the front-end interface for rendering HTML and JavaScript that can interact with back-end learning services or learning process services. The "Learning logic" layer consists of the orchestrated learning process workflow services. The "Learning Service" layer consists of all learning activities and tools that are exposed as learning services using the Web services approach. The last layer is the "Learning Data" that represents the persistence layer for all learning data associated with learning process workflows. Figure 4.14 is an expansion on

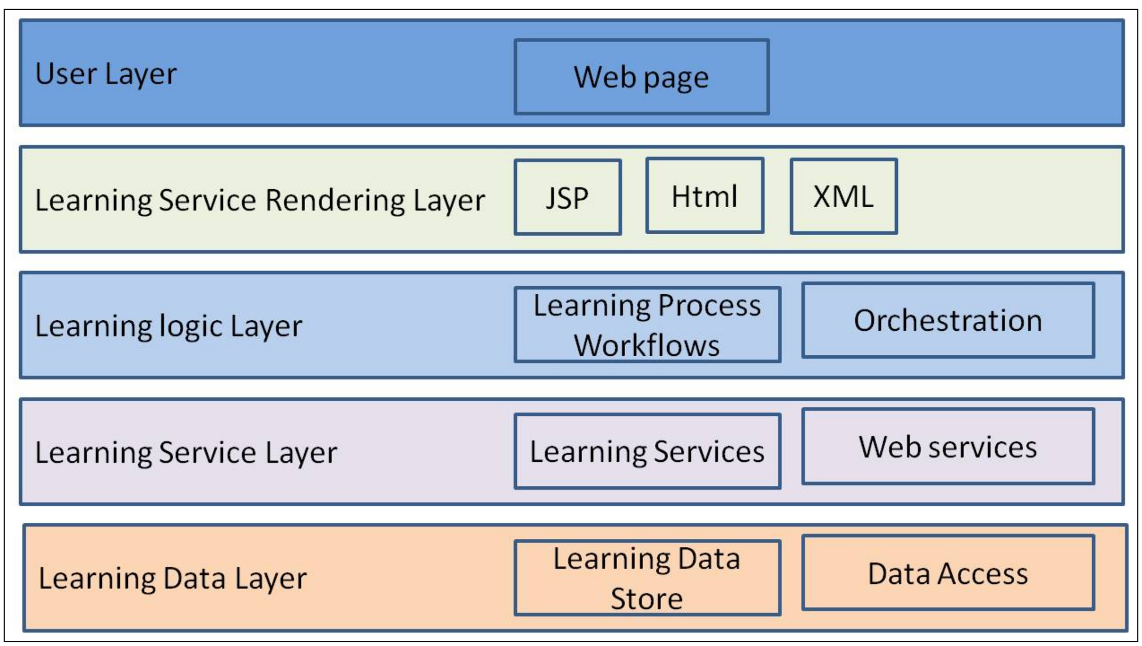


Figure 4.13: Five major layers of the proposed BPM-based architecture.

Figure 4.13 with little more details on the inter-connectivity with the various levels of the mentioned layers. Figure 4.14 shows an integrated solution that includes an AJAX engine (a Web 2.0 framework) as part of the presentation layer for the end users - course designers, learners etc. (i.e., BPM-based Architecture$^{\text{Back-end + Front-end}}$ = Web 2.0$^{\text{GWT + SmartGWT}}$ +

SOA$^{\text{Web services}}$ + BPM$^{\text{BPMN/JPLD/BPEL}}$). The reason for the adoption of Web 2.0 framework as discussed in Section 4.7 is simply to enhance front-end interactivity as research has shown that e-learning based on Web 2.0 helps to increase learners' participation and improve knowledge gain (Ivanova and Popova 2009). The BPM-based conceptual architecture shown in

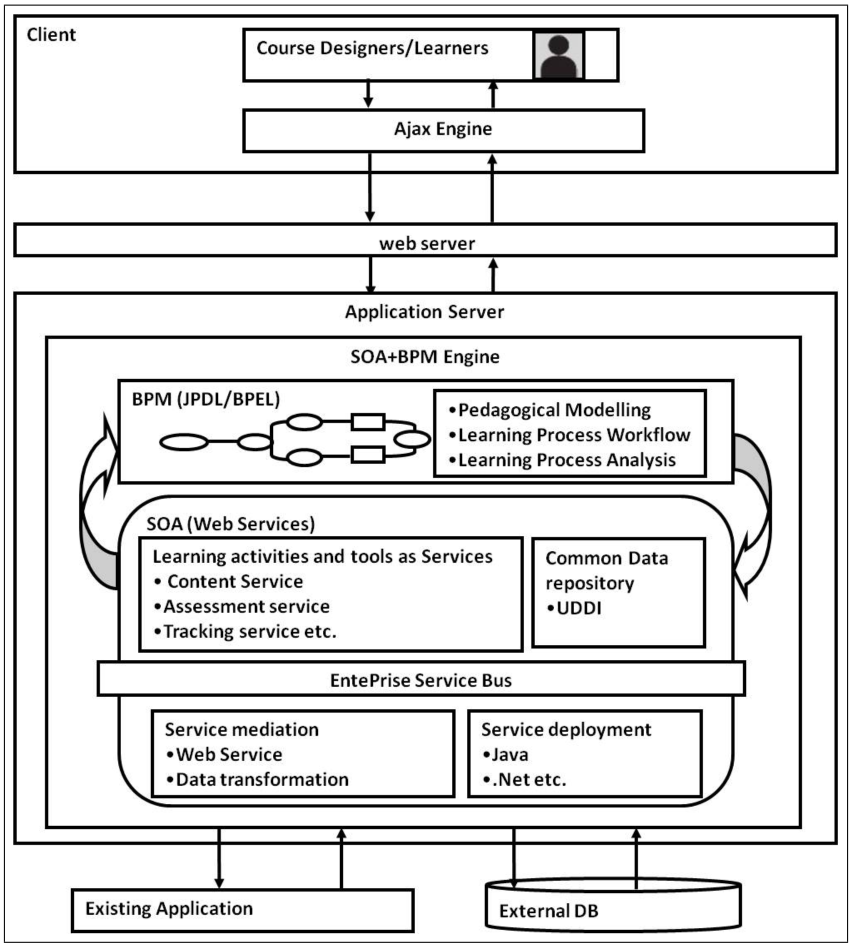


Figure 4.14: A higher-level conceptual architecture of the proposed BPM-based solution.

Figure 4.14 is made up of four layers:

- **Web client layer** - This is the web browser client layer that allows users to interact with the front-end BPM-based application and users can make HTTP requests to the web server. The BPM-based front-end architecture is designed to include an AJAX engine - a concept of Web 2.0 architecture. For implementation, GWT and SmartGWT

Web 2.0 frameworks were adopted and the reason is detailed in Section 4.7.

- **Web server layer** - This is a client-server model that receives HTTP requests from the web client layer. Since most of the requests are not based on a static web page that can be served by the web server itself, the requests can be sent to the application layer where a dynamic processing of the request takes place. Upon completion of the request by the application server, the web server receives a response and forwards it on to the client that made the initial request. For implementation purposes, the Jboss application server that is adopted is configured with an embedded web server inherited directly from Tomcat server. It is possible, however, to have a dedicated web server (e.g., Apache web server) if load balancing is of a major significance.

- **Application server layer** - This is a layer that facilitates the development and management of an enterprise application in a distributed environment. Essentially, it manages various complicated issues (concurrency, database connection pooling, load balancing etc.) that are often associated with the server side. This is the most focused area of the entire layers within the BPM-based conceptual architecture because all of the configurations for the adopted frameworks (SOA and BPM) occur within this layer. Therefore, the following layers are sub-layers of the application server layer:

  - **BPM engine layer** - This consists of the adopted BPM framework engines (i.e., BPEL engine and JPDL runtime engine). The engines provide runtime environments for modelled learning process workflows and control individual instance of the workflows.

  - **SOA engine layer** - This consists of the Web service engine (Axis2) layer. It provides the access control, rules and security to the learning activities and tools that exist as services.

  - **Enterprise Service Bus (ESB) layer** - This is a layer that provides the mechanisms for different software applications that are developed under different platforms (Java, .Net etc.) and protocols (HTTP, RMI, SOAP etc.) to communicate and interact. It is a message-oriented architecture that describes the general standards of communication and interaction between the loosely coupled services that are mostly heterogeneous. Since the learning services within the BPM-based architecture are homogeneous (i.e., services with the same system), ESB, though part of the BPM-based conceptual architecture, is not part of the BPM-based implemented solution. It is, however, worth considering in an environment where performance is of paramount. For example, if it is expected that over 100,000 message requests per day are expected and these services are on different environments, then ESB would be a major consideration.

- **Data layer** - This provides the mechanism to manage the persistence data. It simplified the retrieval and storage process of new and modified data in a database.

4.7 Web 2.0 Approach

The purpose of this section is to present the chosen frond-end framework that was used to designed a web-based user interface (UI) needed to interact with the back-end functionalities of the proposed BPM-based implementation that is presented in the next chapter. Following the emergence of the Web 2.0 trend, this section presents its concept and the technological framework that is adopted for the UI implementation of the BPM-based architecture.

Web 2.0 is a concept coined by Tim O'Reilly (founder of O'Reilly Media[24]) in 2004 to describe the new evolution of the Internet (Brown 2010, Ruskov 2009). Oreilly (2007) identified several principles and characteristics of Web 2.0 with three significant factors that

[24] www.oreilly.com

this research found to be of a particular relevance to the field of education: users (learners in particular) are co-generators of content; content generation is dynamic with a focus on learners' experience; and, connectivity and reusability are facilitated. The widespread use of Web 2.0 has had a major effect on the way learners search, find and collaboratively develop information and knowledge. Consequently, the Web 2.0 trend has had a significant impact on the culture of learning in the educational arena as e-learning environments are increasingly becoming a platform of knowledge Collaboration, Openness, Participation and Sharing (Sigala 2007). In fact, research in recent years has shown that e-learning systems based on Web 2.0 technologies are likely to: encourage the active participation of individuals and knowledge gain; support the activities of formal and informal learning; harness the "collective intelligence" to create a new learning experience; and, support a transparent learning process (Ivanova and Popova 2009). By introducing the concept of Web 2.0 into online education, learners are socially engaged, thereby improving their learning experiences.

The impact of Web 2.0 is also reflected in the term e-learning 2.0 that has emerged in the recent years, which is often synonymous with learning that is based on the used of Web 2.0 technologies. The advent of Web 2.0 has brought challenges to e-learning system developers, thereby strengthening the argument for a shift from the traditional VLEs to personalised learning environments with more personalised, learner-centred and collaborative features (Davis and White 2011, Brown 2010). As result of the potential benefits of the Web 2.0 application on e-learning, Web 2.0 concepts form part of the proposed BPM-based architectural solution. The aim is to utilise the technological benefits to: enhance learners' interactivities; integrate heterogeneous services (i.e., learning objects); and, enhance learners learning experiences. These are integral parts of the BPM-based architectural structure in creating a learning process management system framework. Therefore, certain open-source frameworks for Web 2.0 were investigated and are presented in the following Section.

Open Source Web 2.0 Framework

The prominent technologies that facilitated the growth of Web 2.0 are: The Representational State Transfer (REST) - It is an architectural style that allows interactive Web clients to communicate to any Web resources in a consistent manner, so that XML-based information can be exchanged. (Fielding 2000); An XML-based file format, the Really Simple Syndication (RSS) standard supports standard content from any source on the Internet; and, AJAX - key principle model of Web 2.0 applications (Oreilly 2007). The investigations and comparisons of some of the popular open source Web 2.0 framework findings are summarised as follows:

Google Web Toolkit[25](GWT)

- Develops AJAX applications with Java technology.
- Java to JavaScript compiler provided.
- Java classes are compiled to cross-browser compatible HTML and JavaScript.
- Dedicated Web browser debug GWT applications.
- Uses Java's graphical user interface (GUI).

Advantages

- It enables Java developers to use the Java language to develop AJAX applications.
- Knowledge of JavaScript language is not needed.
- A Google development (who are at the forefront in Web 2.0 promotion).

Disadvantages

- Session management is not easy.
- Significant effort required to manage browser history.

[25]Retrieved January 11, 2011 from Google code http://code.google.com/webtoolkit/overview.html

Dojo Toolkit[26]

- Open Source set of JavaScript libraries.
- Easy to add AJAX web pages.
- Support from key industries (Sun, IBM, AOL).
- Independent of Server side technology.

Advantages

  - Can be used with any server side technology.
  - Its Ajax libraries make request/response communications between the client and server side easier to implement.
  - Easy integration with other JavaScript frameworks.

Disadvantage

  - Developers still need to learn some JavaScript.

Qooxdoo Toolkit[27]

- Based on object-oriented model for JavaScript.
- knowledge of HTML, CSS or DOM is required.
- Includes AJAX enabled GUI toolkit.
- Independent of Server side technology.

Advantages

  - Can be used with any server side technology.
  - Integrate seamlessly with the Eclipse based Ajax project, making AJAX creation in Java relatively easy.

[26] Retrieved January 12, 2011 from http://dojotoolkit.org/
[27] Retrieved January 11, 2011 from http://qooxdoo.org/

Disadvantages

- There are approximately 350 classes offered in its library - a steep learning curve.
- It is based on UNIX, therefore, the Windows installation requirements are complex.

In this thesis, GWT and SmartGWT are the Web 2.0 conceptual frameworks adopted for the web client user interface (UI) implementation of the proposed BPM-based architecture. These frameworks provide robust and sophisticated Java APIs that allows Java programmers to design front-end solutions with rich widgets. The APIs also provide support for back-end connectivity seamlessly. The continuous support and stability of GWT are also significant factors that were considered.

4.8 Summary

Retrospectively, looking at the outcome of the research that is presented in this chapter, it is the case that there are clear similarities between a business process and a learning process when it comes to the aspect of managing both processes. Both processes are at their simplest sets of interrelated tasks that are linked to various activities needed to be performed by human user. Therefore, in this chapter, a new e-learning architecture that is based on the BPM concept is presented as the core contribution of this thesis. The BPM-based architecture is a process-oriented architectural model that facilitates a process-oriented pedagogy and pedagogic reuse. This is different from the commonly known e-learning platform such as the CMS, LMS, LCMS and VLE that are discussed in Chapter 2. The functional purpose of the BPM-based architecture is to provide a platform for implementing solutions to the issues that are presented in Chapter 3. Consequently, learning process management can be facilitated through graphical modelling of various pedagogies in the form of learning process workflows within a virtual environment. In this regard, a research and analysis is presented on the current VLE frameworks and the technological solutions they offer both course designers and learners. The analysis concludes that; while current VLE frameworks and technologies have had significant impact on learning within an e-learning environment, these frameworks and technologies do not go far enough to provide the means by which course designers can plan and model their chosen pedagogies in an automated way. Consequently, the effectiveness of their pedagogies are difficult evaluate; and, pedagogical reform and reuse is difficult. Furthermore, current VLE frameworks do not allow for the management of learning easily through the process of learning itself but through a monolithic approach where the same course materials are deemed sufficient for all learners.

Shifting from the current status quo, this chapter also presents the adoption of conceptual frameworks that are based on SOA and BPM concepts, principles and technologies as a model for the BPM-based architecture that is presented. The technologies that facilitate both concepts - Web services, BPMN, BPEL and JPDL - are analysed for their benefits. With SOA as a concept to expose learning activities and tools as services, BPM is introduced as an orchestration concept to automate learning process workflows using various learning services provided by the SOA. The ability to orchestrate learning process workflows by course designers aims to provide the platform to model their chosen pedagogies in a way that is compatible with their online didactic goals. Lastly, this chapter also presents the BPM-based conceptual architecture that underpins the overall approach to learning process management architecture. It describes the higher level interactions of various software components and building blocks from which an implementation solution can be developed. In the next chapter, an early prototype solution is built to prove that it is possible to realise the architecture that forms the core contribution of this work.

Chapter 5

Virtual Learning Process Environment: A Prototype Implementation

5.1 Introduction

In Chapter 4, the conceptual architectural frameworks and technologies (BPM, SOA and GWT) that could potentially provide an implementable solution for learning process management through pedagogical modelling within the proposed BPM-based architecture are established and presented. This chapter presents a prototype design and implementation of the proposed BPM-based conceptual architecture termed Virtual Learning Process Environment (VLPE). As a proof-of-concept, the prototype solution aims to provide a demonstration of one possible implementation of an e-learning solution that facilitates learning process management through pedagogical modelling based on the proposed BPM-based architecture. The VLPE prototype implementation is made up of two parts: a custom BPM standalone application as a pedagogical modelling tool; and, a BPM web-based application that is capable of running and processing the modelled pedagogies as a learning process management application. Both applications are based on the following core technological frameworks:

- Hibernate - An Object Role Modelling (ORM) framework designed and used to query databases at the conceptual level. The framework is easily understood by non-database technical users to describe the database entity. This represents the Data Access Object (DAO) level.

- JBoss jBPM - Flexible Java based workflow engine. It provides the necessary Application Programming Interface (API) and libraries to program and manage workflow that consists of process logics. This API is particularly important for the development of the VLPE (BPM web-based) application. Therefore, this represents the logic level of the application.

- EJB3 stateless session beans - A process workflow that includes human input can, in theory, run indefinitely. Therefore, a human-based process workflow would need to exist in a stateless context. Hence, EJB3 stateless session beans are used for remote access and transaction demarcation of services. This represents the service/delegate level.

- Java programming language, JSP 2.0 and Servlet 2.3 - For server side logic or service controller

- GWT - Web client User Interface (UI).

5.2 An Implementation of a Custom BPMN Standalone Application as a Pedagogical Modelling Tool

In Chapter 4, a general-purpose BPMN-based framework for modelling business processes is presented. However, the relevance or direct correlation of the general BPMN notations to modelling educational pedagogies can be difficult to establish or conceptualise, especially by the course designers who have no background on the technical lexicons used by business analysts to model business processes. The purpose of this section is to present a Custom Lightweight Pedagogical Modelling Application (CLPMA) as part of the VLPE prototype for pedagogical modelling.

The recent release of the JBoss JBPM framework (version 5) includes the implementation of the standard BPMN 2.0 specifications. What this means is that BPMN is now part of the JBoss JBPM offerings; albeit, its underlying execution structure and language (BPEL and JPDL) still remains large the same. While the implementation of the BPMN specifications may help to reduce some of the technical integration and configuration of the IDEs (i.e., Eclipse), it still has not solve the initial identified issue - what is the correlation between the BPMN elements and learning process elements that could aid pedagogical modelling. Since it is not practical (at least within the scope of this work) to begin the re-implementation of the BPMN specifications all over again, the plausible option for the purpose of this work is to significantly overhaul the modelling framework (JBoss JBPM) through refactoring of the source code, thereby making it an ideal platform for pedagogical modelling. The refactoring process requires significant efforts as there are quite a significant number of components to work with. Adding and/or subtraction any segment of code in one component or a completed elimination of a component within the entire JBoss JBPM framework can significantly impact on the functioning of the framework and the outcome of the CLPMA itself. Figure 5.1 shows an overview of some of the components of the framework for the CLPMA application.

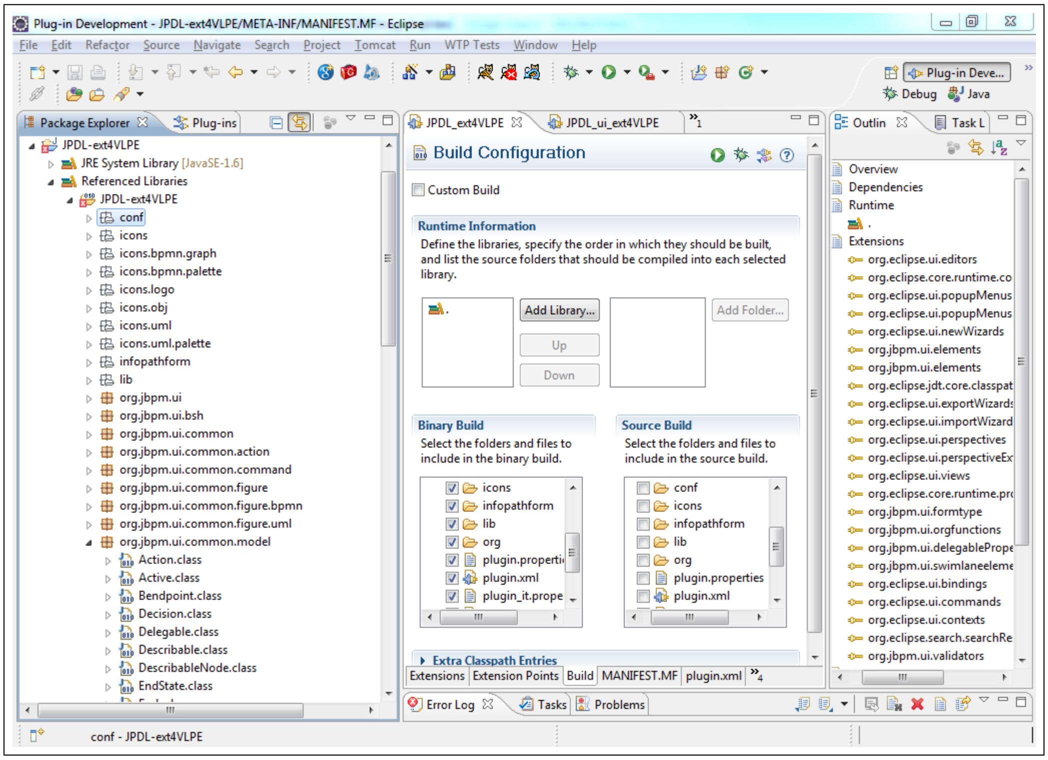


Figure 5.1: CLPMA development through refactoring of the JBoss JBPM and Eclipse RCP interface development.

The refactoring process is targeted at building a pedagogical modelling tool around the basic BPMN elements shown in Figure 5.2. This process involves custom re-annotations and re-structuring of the basic BPMN elements and development of a new simpler but yet fit for pedagogical modelling user interface that is based on the Eclipse RCP (Rich Client Platform) as shown in Figure 5.3.

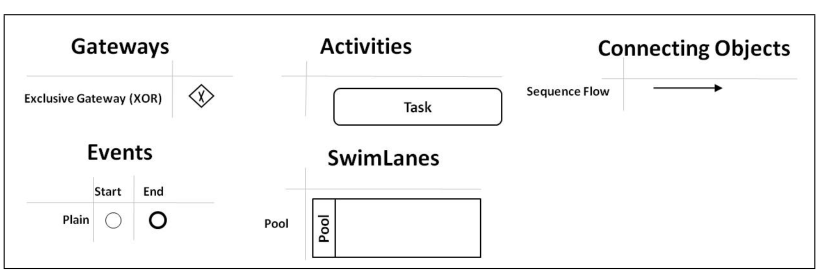


Figure 5.2: Core set of BPMN elements.

The basic BPMN elements that are implemented with meaningful annotations can be associated with learning process modelling; as a result, they can be intuitively used by the course designers for pedagogical modelling purposes. Although, the CLPMA is a prototype implementation of the proposed BPM-based architectural concept for pedagogical modelling as discussed in Chapter 4, the use of the CLPMA would still require some level of technical skills, as modelling in any BPMN tool is generally a complex endeavour. However, by providing a simpler modelling environment, the learning curve to being able to model an online educational pedagogy can be reduced significantly. With a technical skill similar to using Microsoft Visio[1], it is possible to start drawing a BPMN diagram. In fact, Microsoft Visio has a template for drawing BPMN diagrams. In any case, as open-source frameworks and technologies (adopted in this research work) improve with time, it is believed that continuous improvement will be made to enhance and simplify a modelling environment by using the standard BPMN elements for pedagogical modelling purposes.

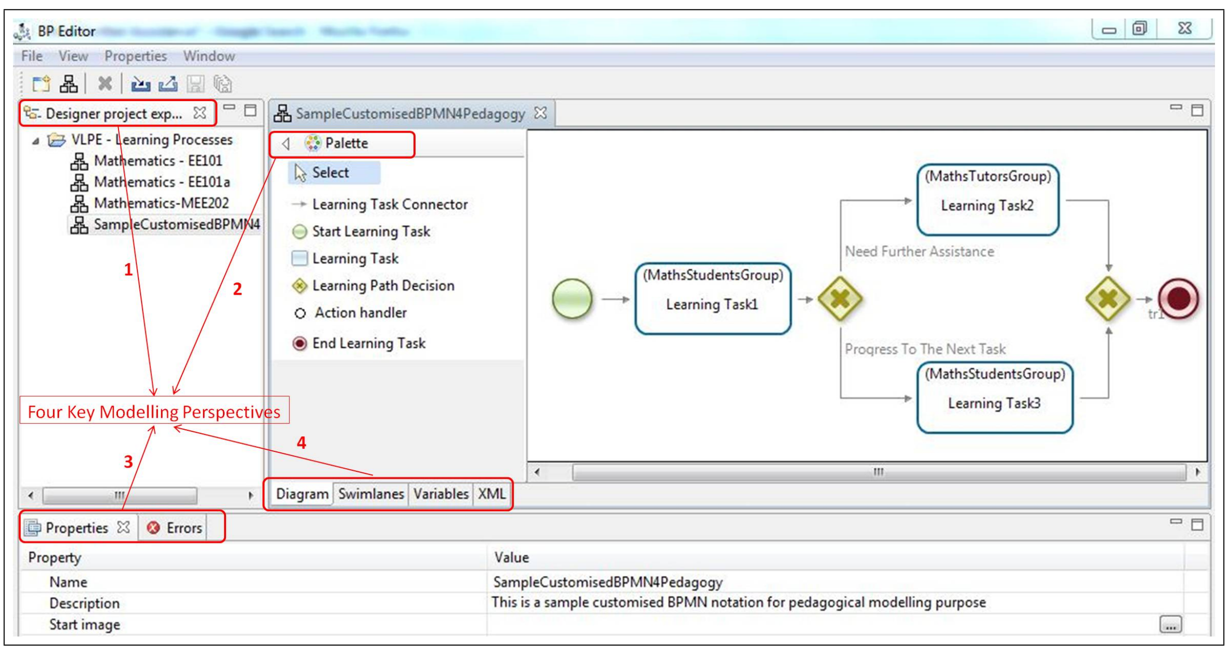


Figure 5.3: Prototype implementation of a custom lightweight pedagogical modelling tool.

[1]http://visio.microsoft.com/en-us/FeaturesAndCapabilities/DoMore/Business_Process/Pages/BPMN-Diagramming-Basics.aspx

Within the CLPMA shown in Figure 5.3, there are four modelling perspectives that can be used to model educational pedagogies for online structured courses. These perspectives are:

1. **Design Project Explorer** - This contains and displays the existing pedagogical modelling projects; and, all the learning process workflows that are orchestrated under each project are displayed under the associated project folder.

2. **Palette** - This consists of the basic implemented BPMN elements - details implementation of these custom elements are shown in Figure 5.4.

3. **Property and Error View** - This displays the information about a project and a description attribute of a project can be set within the property view. The error view displays any invalid connection or configuration of a modelled learning process workflow. Before a modelled learning process workflow can be exported for deployment it must be error free.

4. **Editor Tab** - This contains three panes: The Diagram pane - graphical modelling editor where the BPMN graphical notations can be assembled; The Swimlanes pane - this is where the groups responsible for task execution are created; and, The Variables pane - this is where internal variable (e.g., counters) are declared. XML pane - this is the container for the XML version of the created process.

In the palette perspective of the CLPMA, the five key BPMN elements that were adopted as shown in Figure 5.4 are: Events (i.e., start and end events); Activity (i.e., task); Gateway (i.e., a diamond shape for decision making); Connection object (i.e., a directional arrow); and, Swimlane. The selective use of these five elements from the numerous elements provided by the OMG in the BPMN 2.0 specification is based on the need to simplify the prototype implementation that will serve the purpose of the research work that is presented in this

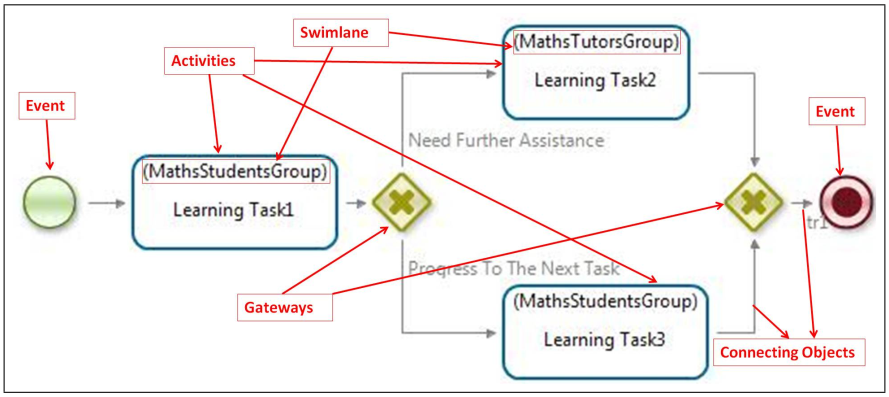


Figure 5.4: The five key BPMN elements.

thesis; and, therefore not as to undermine the significance of the other BPMN elements in the effort of pedagogical modelling. Other BPMN elements can be built as added functionality where necessary. The five chosen BPMN elements that were implemented with meaningful annotations and their functions are:

- **Start Learning Task** - This is a BPMN "start event" element. This is implemented as a trigger to start a learning process instance. It is the first action that will need to be performed usually by the human when a learning process is to be invoked by any of the e-learning participants (i.e., it is an entry to the learning process workflow).

- **Learning Task Connector** - This is a BPMN "sequence flow" of the connecting object element. This is implemented to direct the order in which the learning activities are to be performed. It transits the flow of a learning path and/or task from point A to B. The learning task connector connects all other BPMN elements that are used within a modelled learning process workflow.

- **Learning Task** - This is a BPMN "task activity" element. This is implemented to represent the single unit of a learning task that will usually be performed a user. It encapsulates the learning objects or forms that are usually served as a task list to the user.

- **Learning Path Decision** - This is a BPMN "exclusive (XOR) gateway" element. It is implemented as a decisional rule for learning outcomes on each learning task. It is usually invoked by the process engine based on learning rules (e.g., repeat chapter if assessment is failed or progress if assessment is passed). The learning path decision can also be of a significant benefit in the creation of customised multiple learning paths. In fact, the use of the exclusive gateway with a learning task connector is inherently a path-oriented approach to the modelling of a learning process workflow. By providing multiple learning task connectors to a learning path decision element that is invoked in an automated manner by the process engine, the *"one-size-fit-all"* approach to learning process can be avoided.

- **End Learning Task** - This is a BPMN "end event" element. This is implemented as an end to the learning process workflow. Once the learning task connector transits to the end learning task element, the life cycle of a learning process instance is concluded.

- **Learning Task Action Handler** - This is also a BPMN "activity task" element. It is implemented as a task that is executed by the software agents (e.g., an auto-mailing agent could send email across to learners, reminding them of an assignment due date or an update agent could update learners' record from time to time).

- **Swimlane** - This is a BPMN "pool swimlane" element. It is implemented as the group that is responsible to perform a learning task. Once a learning task element is created, a group can be assigned to the task element by tagging it with the group name. Swimlane is implemented as variable (group name) that can defined within the editor tab as shown in Figure 5.5.

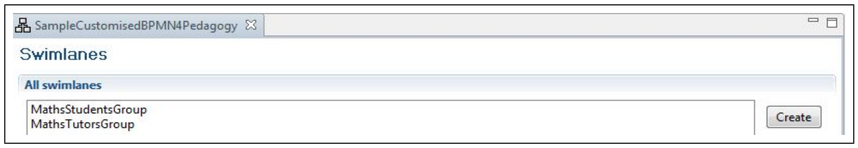


Figure 5.5: Sample swimlane variables.

5.3 Graphical Modelling a Pedagogy in the form of a Learning Process Workflow within the CLPMA

Graphical modelling of Pedagogies is one of the significant benefits of the proposed BPM-based architecture presented in Chapter 4. As a proof of concept, this section aims to demonstrate how course designers can use the intuitive graphical flow diagrams of the CLPMA to model a chosen pedagogy in the form of a learning process workflow. To model a pedagogy, a course designer will usually begin with a pedagogical plan. A pedagogical plan is a simple hierarchical domain of tasks that is separated from a specific model. Pedagogical plan and model are similar in terms of providing a strategic framework for effective learning processes. There is, however, a subtle difference between them. While pedagogical plan (often embodies the concept of learning design) is descriptive and abstract at a higher lever, a pedagogical model is directly linked with a practical implementation of learning theories and pedagogical scenarios. The scope of a pedagogical plan can be broadened so as to account for not only the immediate pedagogical needs but also the various aspects of the learning situations during a learning process. This can be achieved through the design of pedagogical scenarios around the learning activities that are specified in a pedagogical plan. Designing pedagogical scenarios is done by specifying the roles, resources, tools, services with the implementation of the activities that are described in a pedagogical plan to create an integrated learning process workflow. This is where the CLPMA comes to play - a lightweight tool for pedagogical modelling. It is worth mentioning also that the CLPMA is just one example of a prototype implementation intended to serve as a proof of concept and not as the ultimate solution.

There are different pedagogical scenarios that can be aimed at different learning goals. This section does not aim to define the procedures for designing pedagogical scenarios but aims to provide the course designers with the means to model their adopted pedagogical scenarios using a graphical modelling tool that can be implemented in a web-based learning environment. Therefore, for the purpose of the research work that is presented in this thesis, a simple example of a pedagogical plan for an online course with five chapters is described in Figure 5.6.

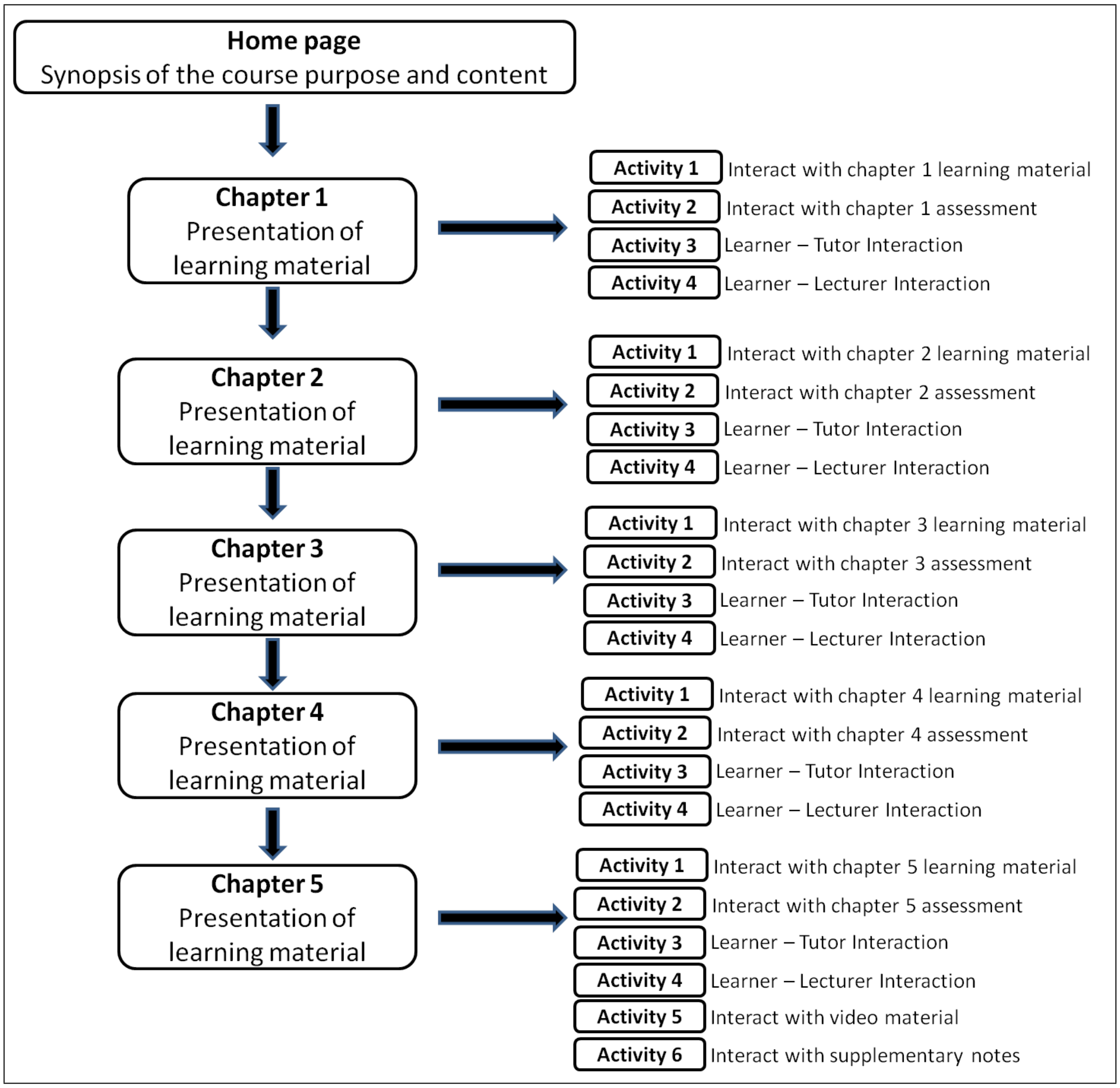


Figure 5.6: Example of a pedagogical plan for an online course with five chapters.

A pedagogical scenario is, according to Van Joolingen et al. (2007) is, *"an orchestrated set of activities that learners undertake to learn"*. Using the example of the pedagogical plan shown in Figure 5.6, a course designer can design various forms of pedagogical scenarios to indicate how the entire life cycle of a learning process should proceed. By using the CLPMA presented in Section 5.2, an example of how to model a pedagogy in the form of a learning process workflow based on the example of the pedagogical plan in Figure 5.6 is presented as follows:

- **Creating a modelling project** - Before modelling any pedagogy, the first task is to create a modelling project. A New Pedagogical modelling project can be created by selecting the menu item File => Create New => New Project and enter the project name (e.g., "Pedagogical Modelling Project") in the new project wizard. A new folder with the name of the new project ("Pedagogical Modelling Project") will be created inside the "Design Project Explorer" perspective.

- **Creating a learning process workflow** - A new learning process workflow can be created inside the new project folder by selecting the menu item File => Create New => New Process and enter a name for the learning process workflow (e.g., Mathematics-101). At this stage the palette (containing the graphical modelling notations) and editor tabs (containing the graphical modelling editor pane) perspectives are visible and enabled for use as shown in Figure 5.7.

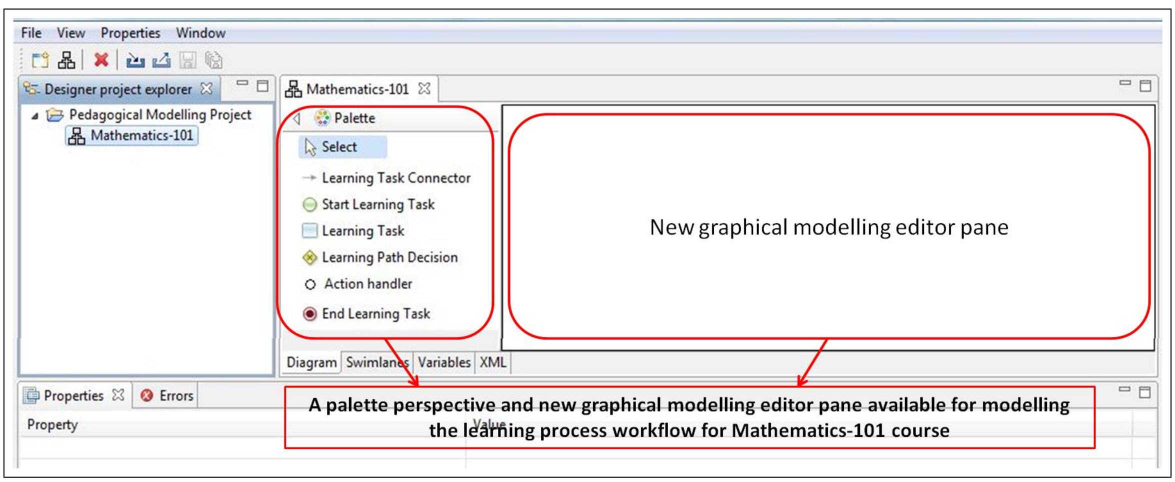


Figure 5.7: Graphical editor pane and palette perspectives.

- **Orchestrating learning activities around the learning materials** - This is where the whole modelling process begins by dragging and dropping graphical modelling notations from the palette into the graphical modelling editor pane. At this stage the whole modelling process becomes a bit more technical. There are five key technical areas of interest before a useful learning process workflow can be modelled.

1. **Connecting learning paths** - Creating learning paths involves a combination of "learning path decision" and "learning task connector" elements. In fact, multiple learning paths can be created seamlessly by adding more connector elements to a decision element as shown in Figure 5.8. In other words, the more the "learning task connector" elements on a single "learning path decision" element, the more the choice of learning paths that a learner can take to meander his/her way through the entire learning process. The ability to customise multiple learning pathways is another significant contribution of the new BPM-based architecture for learning process management.

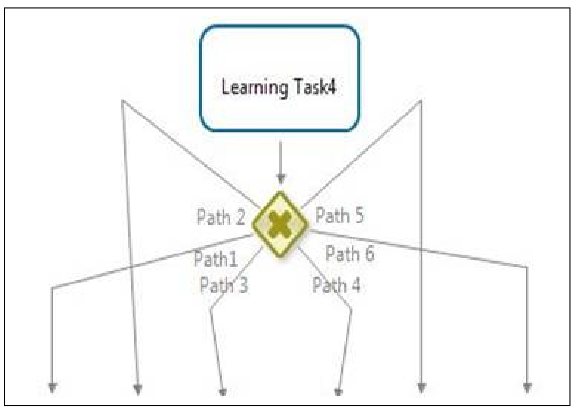


Figure 5.8: Example of a multiple learning paths.

2. **Adding group names (swimlane)** - A group name is a name assigned to a particular group that will be participating in a learning process of a particular course. Defining the group name is important to the modelling process as each learning task must be assigned to a particular group. Within the CLPMA, group names are treated as special variables that have to be created in a swimlane panel as shown in Figure 5.9. Once a "learning task" element is created, it must be assigned a group name by right clicking the "learning task" element and the

created group names will be available and can be added onto the "learning task" element.

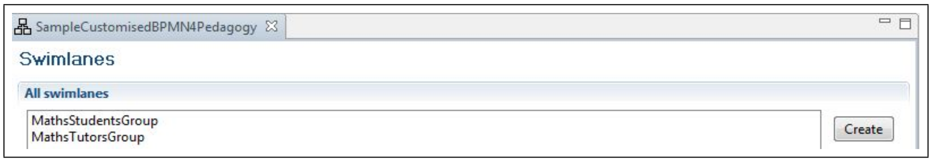


Figure 5.9: An example of swinlane variables.

3. **Defining learning variables** - Learning variables can be useful in making learning rules and decision. For example, it might be required to count the number of chapters in the entire learning materials before setting a deadline date for the completion of the learning process. Learning variables can be defined in the same way as the group name except that it is defined in a variable panel as opposed to the swimlane panel as shown in Figure 5.10.

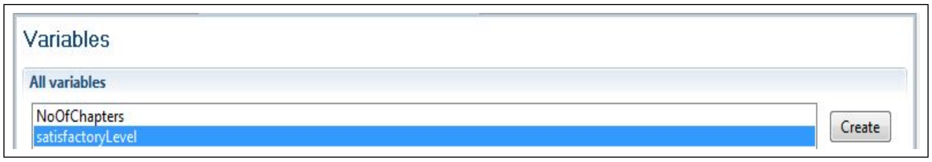


Figure 5.10: An example of learning variables.

4. **Defining learning rules** - This is another crucial area where the decision as to how progressions from one level to another are defined. If there is an assessment that has to be corrected by the system rather than a human, then, a decision rule has to be defined for that. If a learner is looping through a chapter without progression after a long period of days, weeks or months, then, a learning rule has to be defined in such a way as to whether the system should flag the tutor or lecturer for intervention. Learning rules are defined in an "if then else" statement using a graphical panel on every "learning path decision" element. Figure 5.11 shows an example of a definition of a learning rule - If satisfactory level is low

(based on the feedback option that is designed with the learning material) then the system should infer that the learner needs an assistance and other e-learning participant (e.g., tutor) can be notified. If the satisfactory level is not low then the learner can progress to the next learning task.

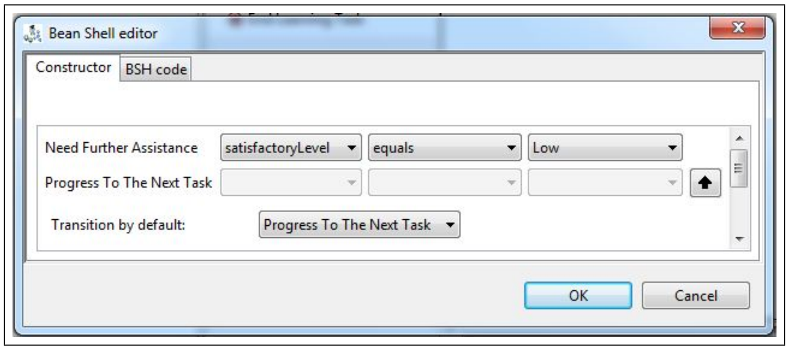


Figure 5.11: An example of a definition of a learning rule.

5. **Creating or integrating learning material into a "learning task" element** - Learning material can be created or added to a learning task by right clicking the "learning task" element and selecting the "create learning form" option from the dropdown menu. A new window with a WYSIWYG editor is opened and learning material and form can be inserted as shown in Figure 5.12.

By following these five key technical steps, orchestrating learning activities around learning materials is possible by dragging the BPMN elements from the palette on to the graphical modelling editor where they can be linked together to form a learning process workflow based on a desired educational pedagogy. Depending on the pedagogical approach, different learning process workflows can be modelled with the same pedagogical plan that is described in Figure 5.6. Based on the non-linear pedagogical plan, an example of a learning process workflow that is designed around a simple Mathematics course (called Mathematics-EE101) is shown in Figure 5.13 and the full modelled diagram of the learning process workflow is shown in Figure 5.14a.

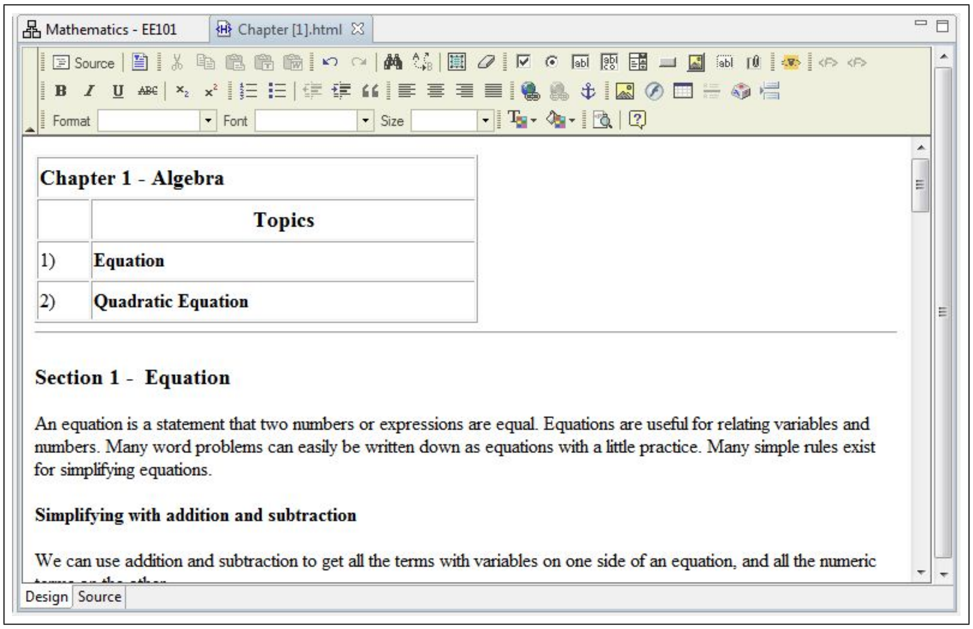


Figure 5.12: A sample learning material created in a WYSIWYG editor.

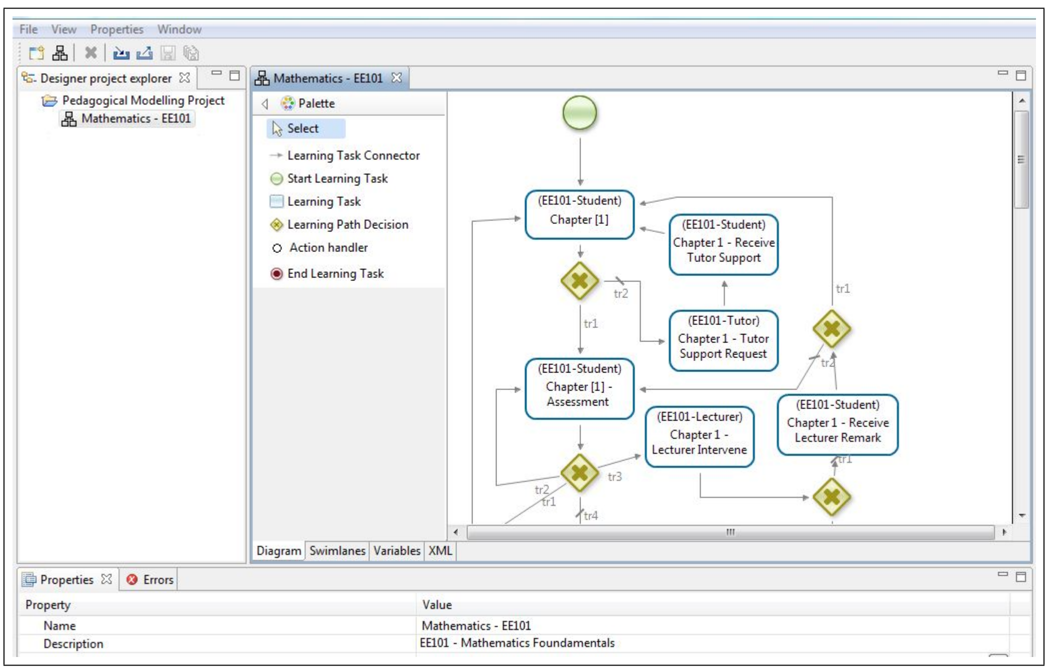
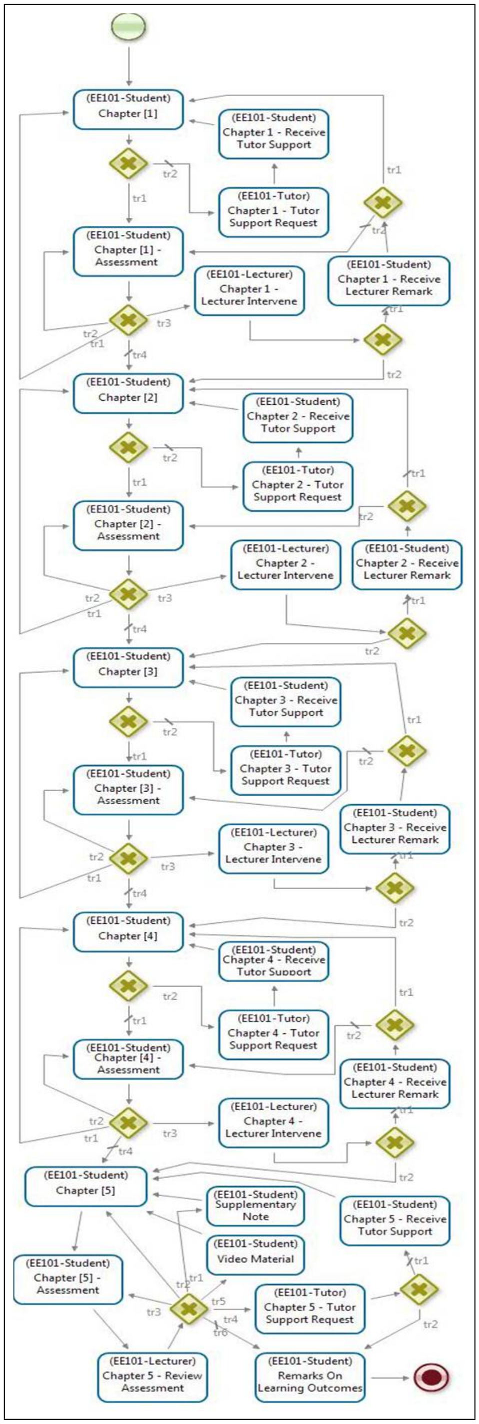
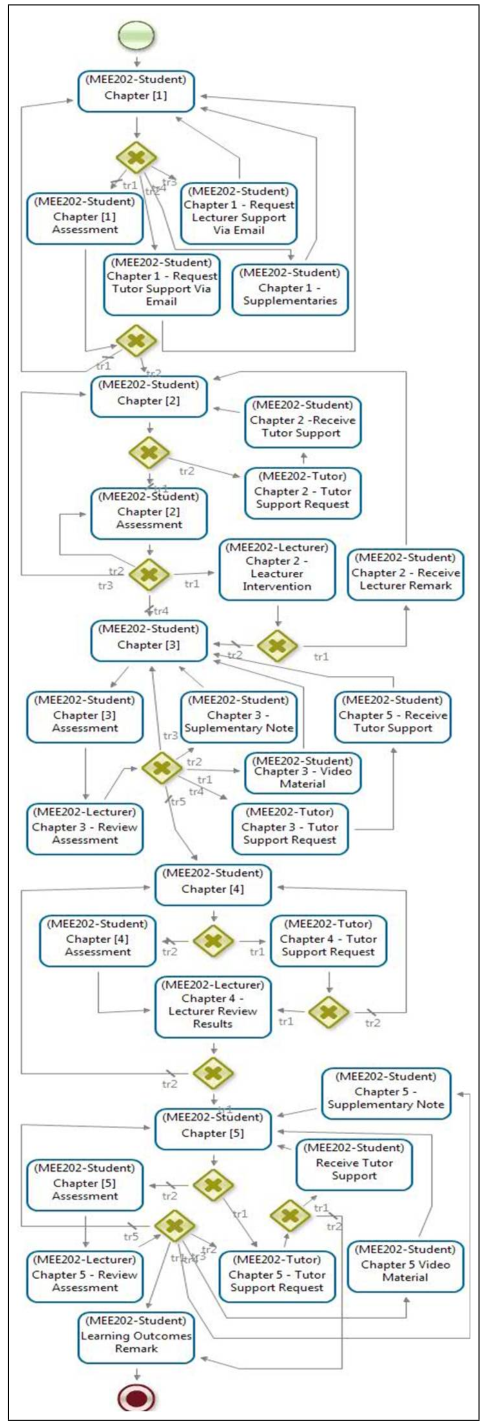


Figure 5.13: Graphical editor pane with the modelled Mathematics-EE101 learning process workflow.

The sample pedagogical plan and scenarios can be reused in different contexts. For example, Figure 5.14b shows the same pedagogical plan and scenarios used to model



(a) Full diagram of the modelled Mathematics-EE101 learning process workflow.



(b) A modelled Mathematics-EE202 learning process workflow using the same pedagogical plan but different pedagogical approach.

Figure 5.14: Full diagrams of examples of two modelled pedagogies in the form of learning process workflows based on the same pedagogical plan.

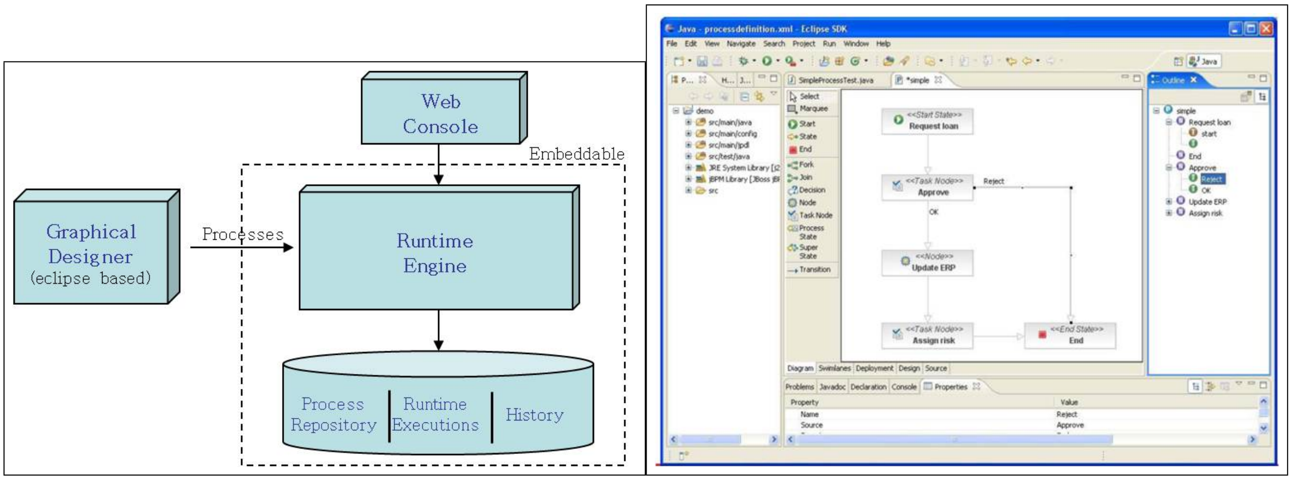
the Mathematics-EE101 learning process workflow is used to model a learning process workflow for a different Mathematics course (i.e., Mathematics-EE202 learning process workflow). It is also possible to apply the same modelled learning process workflow on a completely different course. A modelled learning process workflow can serve as a template for other courses. In other words, a modelled learning process workflow could be course agnostic - what changes is the underlying learning materials/objects. Thus, a pedagogic reuse is possible.

The pedagogical approach to the simple Mathematics-EE101 course is such that chapters 1 to 4 are designed with paths of similar interactive activities. Chapter 5 is designed differently with even more paths and activities. This is to demonstrate that different pedagogical scenarios can be modelled as course designers see fit. If a particular learning topic or task is considered to be advanced or complex, it is likely that the pedagogical scenarios around such learning task will be modelled in such a way that would aim to reduce the complexity. This could mean that more learning activities could be modelled around the learning task. The entire pedagogical design on the simple Mathematics course presented in this chapter is a simple example of a specific pedagogical approach to show that pedagogy can be modelled using a graphical modelling tool (i.e., the proposed BPM approach). However, it is also possible to model a complex pedagogy using the same BPM-based modelling approach.

With the example of the modelled learning process workflow in Figure 5.14a. The swimlanes (EE101-student, EE101-Tutor and EE101-Lecturer) in the overall diagram represent the groups that are responsible for various types of learning activities. Members of these groups form the human interactions that are required to advance the flow of the learning process. Learning each topic through the course material is modelled as a learning task needed to be fulfilled by a learner; learning outcome assessments and supports are modelled as an assisting task by the lecturer and/or tutor. Competence-based assessment is modelled as a testing task that aims to test a learner's competency on various topics; however, more complex assessment implementations are possible. Learners are provided with the option to seek alternative sources when difficulties arise. Again, the multiple branches (XOR gateway) represents the potential multiple learning pathways. Therefore, customised learning paths and interactive pedagogy within the model shown in Figure 5.14a are intertwined. In the modelled example, interaction with a tutor for support is possible, either through a manual process (learner can initiate need for support) or an automatic inference when learners progress lingered (in this case tutor support is invoked automatically). Consistent failure to answer questions correctly is modelled as a task for the lecturer to intervene as necessary. Where possible, lecturer intervention could be a face-to-face meeting with the learner. Where face-to-face meeting is required, this can be modelled formally, where the outcome of the meeting can be re-entered into the workflow process (e.g., the learner who requires contact with a lecturer would either need to repeat an element of the course work or be granted the permission to progress based on the outcome of the face-to-face meeting etc.). This is part of the process of capturing a full record of a learner's learning progress. In theory, it would be possible to automatically request inputs from other e-learning participants in a learning institute, such as generating a request for the student services department to assist a student with ongoing difficulties, so that the learning process could be fully integrated with the formal business processes of other functions within the learning institute.

5.3.1 The JPDL Implementation Version of a Modelled Pedagogy

In general, BPMN specifications are modelling specifications and not executable specifications. Consequently, the BPMN diagrams that are used to model pedagogy in the form of a learning process workflow described in Section 5.3 are not executable. Therefore, there is a



(a) Typical JBoss JBPM design components. (b) JPDL designer in Eclipse environment.

Figure 5.15: JBoss JBPM design environment.

need to transform them into an executable program language. While the design and modelling of learning process workflows is accomplished using the BPMN elements as described in Section 5.2, the execution of the modelled learning process workflow is based on the JPDL process execution language - a JBoss JBPM framework for process execution.

Typically, a JBoss JBPM suite provides its own Graphical Process Designer (GPD) as shown in Figure 5.15b for modelling a process workflow based on the JPDL constructs, but the graphical environment is not a standardised business process modelling environment. The JBoss JBPM design environment suite components, as shown in Figure 5.15, include: the GPD, Web Console, Runtime Engine, Process repository and Runtime Executions. Both the runtime engine and runtime execution components use the JPDL as the core executable process language.

Although, the JPDL framework is not a standard execution language, it is however possible to integrate the JPDL framework with the standardised BPMN modelling framework. The JBoss JBPM provides a JBoss BPMN converter module. It contains a wrapper framework that can translate BPMN into the JPDL execution language within the JBoss JBPM engine. This provides a significant benefit for the BPMN standard technology. This approach is compatible with the concept of business process orchestrations that usually begins with business process modelling in a BPMN environment and is subsequently translated into an execution language. Therefore, the JPDL framework is the adopted execution language for the prototype implementation of the proposed BPM-based architecture that is presented in this work.

The pedagogical modelling application of the VLPE implementation is designed and implemented as a standalone application and it is entirely based on the JBoss JBPM and BPMN frameworks. For the pedagogical modelling implementation purpose, the nodes, transitions and states of the JPDL constructs are implemented to represent the following key pedagogical modelling components: Start Learning Task; Learning Task; Learning Task Connector; Learning Path Decision; Learning Task Action Handler; and, End Learning Task. This implementation approach is just one possible solution that is intended to be used as a proof of concept that education pedagogy can be modelled using a BPM conceptual framework. The functional details of the key pedagogical modelling components are presented in Section 5.2 and how they can be used for pedagogical modelling purpose is presented in Section 5.3.

The translation of the BPMN elements into an executable process language is a complicated process; the process is automated and hidden from the user as a back-end process. The JPDL constructs are made up of nodes, transitions, and actions/states that jointly describe the manner by which an instance of a process should track the targeted corresponding graph. In the JPDL model, during execution the nodes are passed through as they are detected during the flow of a process definition instance. Transitions control the flow paths of a process definition, and implement an action to achieve a specific logic on a node when a transitional event occurred. When a process definition is modelled using process designer, a process archive ("*.par*") file can be generated using the JBPM tools. The generated process archive can then be deployed into the jBPM process runtime engine where it can be called or executed. The JBPM engine runs the graphical representation of the modelled process, and performs different operations that are defined within the JPDL constructs (nodes, transitions, and states).

The example of the modelled Mathematics-EE101 learning process workflow in Section 5.3, Figure 5.13 is converted into an equivalent JPDL version (the conversion process is not transparent to the course designers). However, the XML version of the JPDL can be viewed in the XML pane of the CLPMA editor tab perspective that is described in Section 5.2. An XML snippet of the JPDL version of the modelled Mathematics-EE101 learning process workflow is shown in Listing 5.1.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<process-definition name="Mathematics - EE101" xmlns="urn:jbpm.org:jpdl-3.2">
  <description><![CDATA[EE101 - Mathematics Foundamentals]]></description>
   <swimlane name="EE101-Student">
      <assignment class="com.jbpm.delegate.handler.AssignmentDelegate"
   </swimlane>
   <swimlane name="EE101-Lecturer">
      <assignment class="com.jbpm.delegate.handler.AssignmentDelegate" >
   </swimlane>
        ...
      <start-state name="Start">
         <task name="Start" swimlane="EE101-Student"/>
      </start-state>
      <decision name="Decision2">
         <transition name="tr1" to="Assessment 2"/>
            <transition name="tr2" to="Chapter 2 - Support"/>
      </decision>
       ...
  <task-node name="Chapter 1">
    <task name="Chapter 1" swimlane="EE101-Student"/>
    <transition name="tr1" to="Assessment 1"/>
  <end-state name="End"/>
</process-definition>
```

Listing 5.1: An XML snippet of the JPDL version of the modelled Mathematics-EE101 learning process workflow

5.3.2 Packaging a Modelled Learning Process Workflow into a Process Archive File (*.par*)

Once all the modelling is completed and error-free, the JBoss JBPM provides a process packaging framework that allows the executable JPDL version and all its dependent artifacts to be packaged into a process archive file with an extension "*.par*". The "*.par*" file can be deployed into the JBoss JBPM runtime engine and available as jBPM-jPDL services; where it can be invoked by a client - in this case by the web clients such as the e-learning participants that were defined in the BPMN swimlanes (learner and lecturer). Within the CLPMA, the JPDL version of the modelled Mathematics-EE101 learning process workflow can be exported into a "*.par*" package by simply clicking the export icon () in the menu bar; and, a packaged learning process workflow will be ready for export as shown in Figure 5.16.

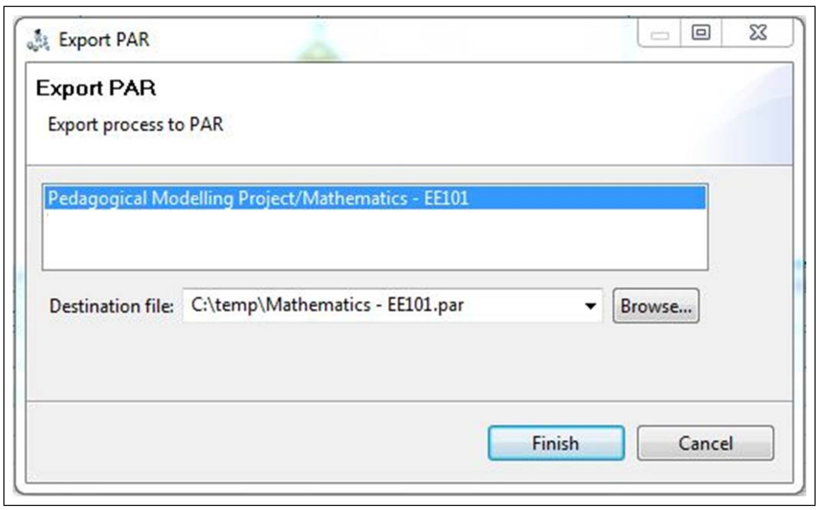


Figure 5.16: Exporting the JPDL version of the modelled learning process workflow in a "*.par*" package.

Similarly, existing modelled learning process workflows can be imported into the CLPMA simply by clicking the import icon () and locate the source of the "*.par*" file. The imported modelled process will be displayed and can be edited as necessary.

Once the learning process package has been exported in a process archive file, it can be deployed into a BPM Web-based application where it can be remotely accessed by clients and learning process management can be facilitated. This is the purpose of the next section - the BPM web-based implementation of the VLPE.

5.4 An Implementation of a BPM Web-Based Application as a Learning Process Management Environment

A deployed process archive (i.e., the Mathematics-EE101.par) on the Web application can only be processed on the server side of a web application that implements BPM technology. Therefore, the implementation of a BPM Web-Based Application as a learning process management environment involves the integration of some custom server side JBPM libraries and client side GWT/SmartGWT libraries. While the development of the CLPMA presented in Section 5.2 involves a refactoring of the modelling components of JBoss JBPM framework for pedagogical modelling purposes, the design and implementation of the BPM web-based application of the VLPE is quite different in several ways. There is no refactoring process involved - all codes are written from scratch (see Appendix A). The JBoss JBPM API, however, provides a number of programmatic interfaces for accessing relevant components for process deployment and management on a web interface.

The technical component-based software frameworks that are related to the BPM-based conceptual architecture presented in the previous chapter is shown in Figure 5.17. The BPM web-based learning process management application is part of the VLPE solution. It is based on a client-server architectural model with the client side implemented in a GWT/SmartGWT framework and server side implemented in Servlet, EJB, Hibernate and JBoss JBPM frameworks. One of the benefits of using the GWT framework is that it provides numerous communication protocols such as GWT Remote Procedure Call (GWT RPC), JavaScript Object Notation (JSON), Simple Object Access Protocol (SOAP), XMLRPC and REpresentational State Transfer (REST) between the client and server side as shown in Figure 5.18.

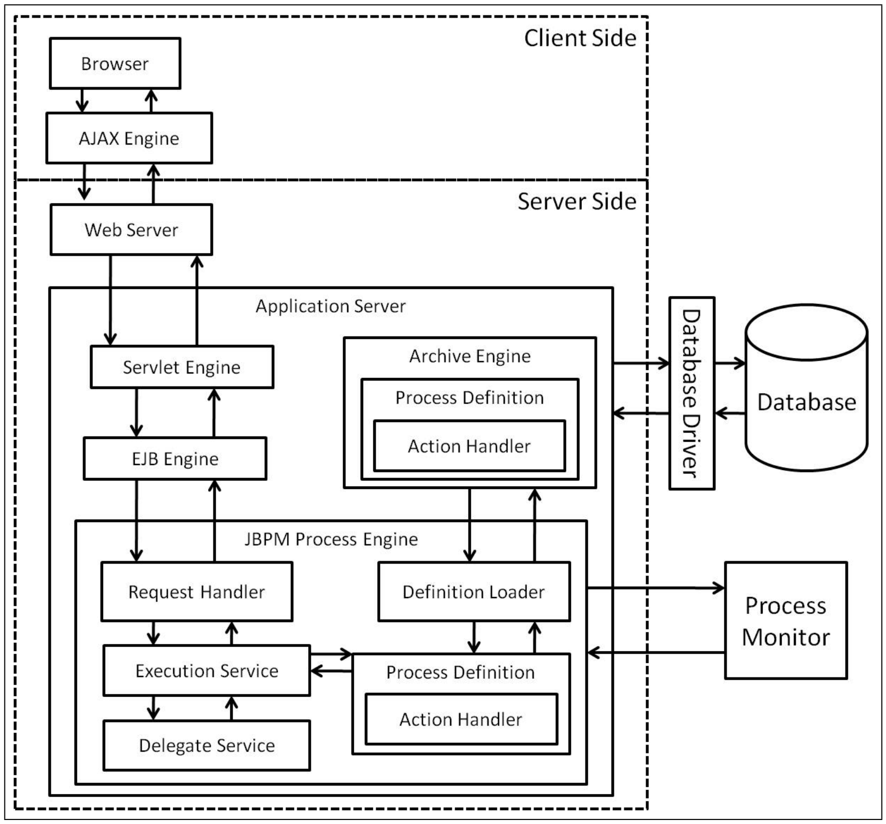


Figure 5.17: VLPE client-server architecture.

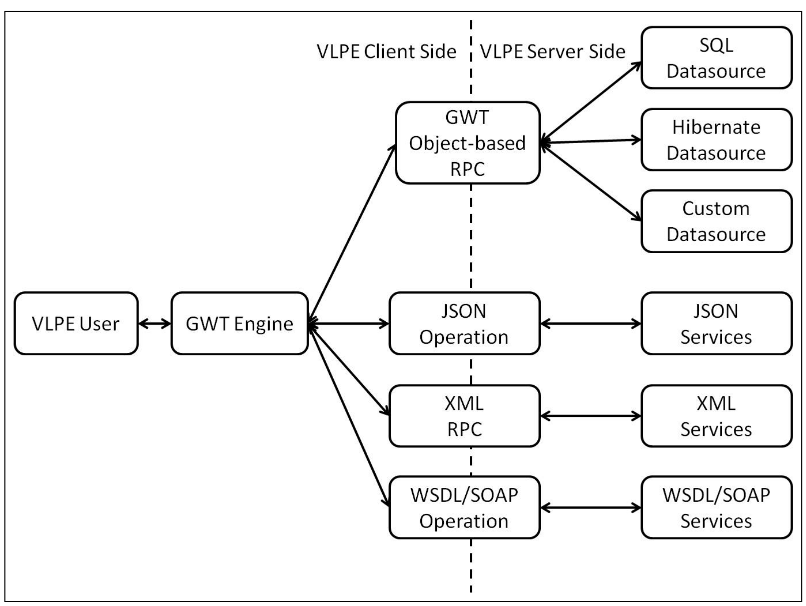


Figure 5.18: GWT communication protocols between the VLPE client-server side.

The GWT RPC uses the XMLHttpRequest object (the heart of AJAX) for asynchronous request-response message exchange and would be a suitable choice if server side is implemented in Java programming language. This is the case for the VLPE server side implementation (server side code is predominantly written in Java code). Therefore, except in the cases where web services request to heterogenous services are made, the VLPE client side integration with the server side is predominantly designed around the GWT RPC communication protocol and the standard architecture of the GWT RPC is shown in Figure 5.19. Each feature within the GWT design environment is called a module. For example, "Start Process" feature represents a "Start Process" module, "Execute Learning Task" represents an "Execute Learning Task" module e.t.c. A quick overview of the technical implementation of the server-client communication mechanism particularly with respect to the use of the GWT RPC protocol to interact and communicate with a module is presented in the next section.

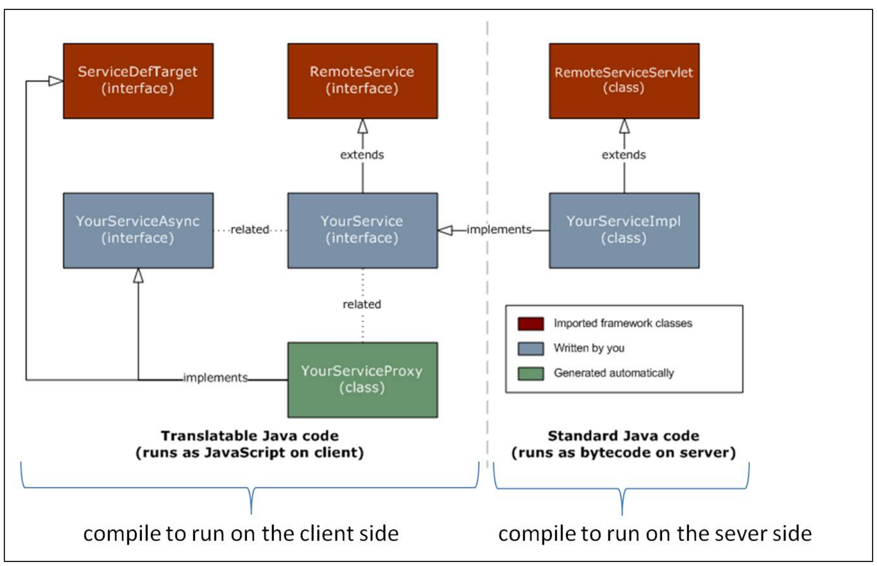


Figure 5.19: GWT RPC standard architecture overview. Source: (GWT 2010)

5.4.1 Server-Side Implementation of A BPM Application For Learning Process Management

Processing a modelled learning process workflow on the server side requires that every logical action that needs to be performed on a deployed process archive file must be treated as a remote service. For example, to start a process, start process must be implemented as a remote service (i.e., StartProcessService). This service is then controlled by a special remote service servlet that pushes a serialised result back to the client in an asynchronous way so as to avoid thread lock or blocking. Using a "Start Process" module as an example, this section briefly describes how the GWT remote service servlet (RemoteServiceServlet) can be used to implement a control service to a learning process instance. In GWT, the servlet implementation is called "service"; the remote procedure call to the server is called "use the service" and, the service used is the object which can be sent to the client (user interface) side. The VLPE "Start Process" module class diagram is shown in Figure 5.20. In this figure it is

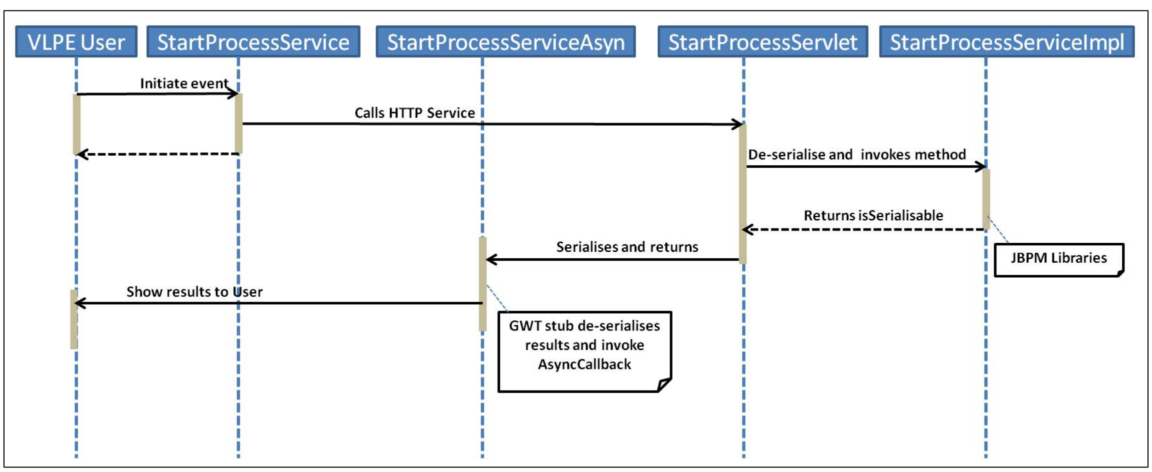


Figure 5.20: The class diagram of a GWT start-process module controlled in servlet.

worth pointing out that the DAO implementation using Hibernate is used to decouple the service controller (i.e., the servlet) from the service logic implementation (for modularisation purpose). The following steps are involved in the implementation of the GWT server side

"Start Process" module:

- **An implementation of a learning process service controller - extending a RemoteServiceServlet.** The first step is to define a service interface. The service interface must extent a RemoteService interface which shows the all service methods that will be exposed to the client. After defining the service interface, implementing the methods of the service is performed on the server side. The implementation of the controller for these service methods must be a class (Servlet) which extends RemoteServiceServlet and implements the service interface (StartProcessService) that contains the service methods as shown in Listing 5.2.

```
public class StarProcessServlet extends RemoteServiceServlet implements ↩
    StarProcessService{
...
return startProcessDTO;
}
```

Listing 5.2: GWT "Start Process" module controller class extends RemoteServiceServlet

- **An implementation of a learning process service logic - Using a DAO pattern.** A DAO design pattern is used with the Hibernate framework to facilitate the persistence of a StartProcessServiceImp object. The reason for using the DAO pattern is that it provides a fine grained abstract interface that hides both the database implementation and the mechanism or framework that is being used to persist data to the database. The implementation snippet of the "Start Process" module logic is shown in Listing 5.3. Within the code snippet, the two important objects of interest are the ProcessExecutorServiceDelegator and ProcessDefinitionServiceDelegator. Both of these objects are processed using the JBPM libraries so as to have access to the modelled learning process workflow. The StartProcessServiceImp DAO is now read as a service that can be controlled in the GWT servlet controller discussed previously.

```
public class StartProcessServiceImp {
   public StartProcessDTO executeStarProcess(HttpServletRequest request, long ↩
       processId){
      try {
         ProcessExecutorServiceDelegator executorDel = DelegateFactory.getInstance()↩
             .getExeServiceDelegator();
         ProcessDefinitionServiceDelegator procDef = DelegateFactory.getInstance().↩
             getProcessDefServiceDelegator();
         ...
      } ...
      startProcessDTO = new StartProcessDTO(hasStartForm, startSuccessful, processId↩
          );
      return startProcessDTO;
   }
}
```

Listing 5.3: StartProcessService implementation of the StartProcessServiceImp DAO object

5.4.2 Client-Side Implementation of A BPM Application For Learning Process Management

The client implementation includes several front-end features that provide crucial functionalities for the management of a web-based learning process workflow. This section aims to present briefly the technical implementation of client side of the "Start Process" module that is previously presented on the server side implementation.

The Entry point is the starting point for a GWT-client application. This is similar to the standard Java main method. Any GWT Java class that represents an entry point must implement the "com.google.gwt.core.client.EntryPoint" Interface. This Interface defines only one method - onModuleLoad(). VLPE class is the class that implements the EntryPoint interface of the GWT-client side as shown in Listing 5.4.

```
    public class VLPE implements EntryPoint {
        public void onModuleLoad() {
        ...
        }
}
```

Listing 5.4: VLPE GWT entry point

The process of calling a remote service (i.e., the StartProcessService) using a GWT RPC from the client involves five steps. The following are the steps involved:

- **Define a synchronous interface that extends RemoteService.** The first step in creating the VLPE "Start Process" service is to define the client StartProcessService interface. The interface should contain all the service methods that are needed to be exposed to the client and must extend the GWT RemoteService interface as shown in Listing 5.5.

```
@RemoteServiceRelativePath("StartProcessService")
public interface StartProcessService extends RemoteService {
  public StartProcessDTO doStarProcess(String userN, String pw, int ↩
      processId);
}
```

Listing 5.5: Synchronous StartProcessService interface extends RemoteService

- **Define an asynchronous interface that corresponds to the synchronous interface.** The Asynchronous interface to the client is based on the synchronous interface and must be created before a call can take place. The essential requirement of the asynchronous method calls is that the caller must provide a callback object (AsyncCallback). This callback object is called to inform it that the asynchronous call is complete. Asynchronous interface methods do not return any value, therefore, the method data type (i.e., method return type) must be void as shown in Listing 5.6. On completion of an asynchronous call, communication to the client is made via a callback object.

```
public interface StartProcessServiceAsync {
  void doStarProcess(String userN, String pw, int processId, AsyncCallback<↩
      StartProcessDTO> callback);
}
```

Listing 5.6: Asynchronous interface extends

- **Using the GWT.create() method to instantiate a service interface.** Before a service can be used within the client side, an instance of the service would need to be instantiated. The listing in 5.7 shows how to create an instance of the StartProcessService object.

```
StartProcessServiceAsync startProcService = (StartProcessServiceAsync) GWT.↩
    create(StartProcessService.class);
ServiceDefTarget endpoint = (ServiceDefTarget) startProcService;
```

Listing 5.7: Instantiate the service interface using GWT.create()

- **Using ServiceDefTarget to specify the service URL's entry point.** Once the service instance is created, the service implementation location or URL must be specified as shown in Listing 5.8. Destination URL's service must be in the same domain and port where the web page will be served.

```
endpoint.setServiceEntryPoint(GWT.getModuleBaseURL() + "StartProcessService"↩
    );
```

Listing 5.8: Instantiate the service interface using GWT.create()

- **Create an AsyncCallback so the client can be notified when the call is completed.** To notify a client of a call completion, an asynchronous object (AsyncCallback) as shown in Listing 5.9 must be created. The object is passed as a parameter to the RPC service call. When a call is made to the service, no value is returned instantaneously. This is because a client-server communication within the GWT framework is done asynchronously. As a result, service calls do not block the continuous running of the application (i.e., the Web browser). A GWT application therefore does not wait for a response from a service call before running or making a new service call. It will continue to run until asynchronous callback is received from the service. The callback notifies the GWT application that a service call is either successful or failed. An unsuccessful call to the service will call the onFailed method of the AsyncCallback object. A successful call to the service will call the onSuccess method of the AsyncCallback object.

```
startProcService.doStarProcess(new AsyncCallback<StartProcessDTO>() {
   public void onFailure(Throwable caught) {
      dialogBox.setTitle("Remote Procedure Call - Failure");
      dialogBox.show();
   }
   public void onSuccess(StartProcessDTO result) {
      setProcess(result);
         theProcess = result;
         createUserPanel(result);
            }
 }
```

Listing 5.9: AsyncCallback object for client notification

The GWT compiler is a key component of the GWT framework. It allows the AJAX applications written in Java code to be compiled into optimised JavaScript codes that are fully compatible with all popular browsers, as well as the iPhone and Android. Consequently, the VLPE client side implementation is compiled into JavaScript codes and is located in the web archive (war) folder where the application can be deployed on an application server (i.e., JBoss application server in the case of the VLPE application). The next section presents a running VLPE application and how it can be used to manage the process of learning.

5.5 Learning Process Management within the VLPE

Once the VLPE is deployed and running, it becomes accessible through the Web. It was necessary to test and verify its functionality, particularly, on how the learning process management might be facilitated within the specific context of accessing learning tasks and performing learning analytics through a visual tracking and monitoring of the learners' learning processes. The primary objective of this section is to present the VLPE key features and functionality that are crucial to the management of the process of learning.

Within the VLPE, there are several features that are designed specifically for the management of learning processes. A feature like the login process is a replicate of a function present in any VLE and while it is crucial for the purpose of session tracking, it is not an important issue with respect to the contributions within the proposed new BPM-base architecture.

Learners that are registered for any course within the system can login with their credentials (username and password). Lecturers who are registered as course designers can also access the system. Tutors whose role is to assist learners to understand a concept and to help address questions that might arise in the course of learners' learning processes can be registered within the system, especially if they are modelled as part of the learning process. Depending on the role of the user upon login, the system performs a check on the user' profiles for authentication and authorisation for the purpose of establishing what rights and permissions that the user have on certain VLPE features. In some cases, certain features will either be disabled or invisible to users with no right permission on such features. Each of the features has a uniform effect and is equally important to the way learning is experienced (by learners) and managed (by both lecturers and learners).

5.5.1 Managing Learning Process through the VLPE Features

Focusing on the Web aspect of the VLPE features, the life cycle of a learning process can be managed at different levels with the following core features:

Start Learning Process

This is a feature that allows the learners to launch a learning process on any course that they are registered for. Lecturers can also initiate the commencement of a learning process on the course they own if the pedagogy adopted requires such an action. The start learning process feature provide numerous functionalities as shown in Figure 5.21. A learning process workflow that is modelled and packaged using the pedagogical modelling tool that is presented in Section 5.3 would need to be deployed on the VLPE web application if it is to be used to facilitate the learning process. Therefore, the process deployment would be the first feature needed to do just that. It allows for a modelled learning process to be deployed on the web part of the VLPE. Using the example of the modelled learning process workflow (packaged as a *.par* file) discussed in Section 5.3.2, Figure 5.22 show how the deployment feature can be used to deploy the modelled process. Course designers and system administrators are the only group that have permission to the deployment feature and therefore invisible to other users.

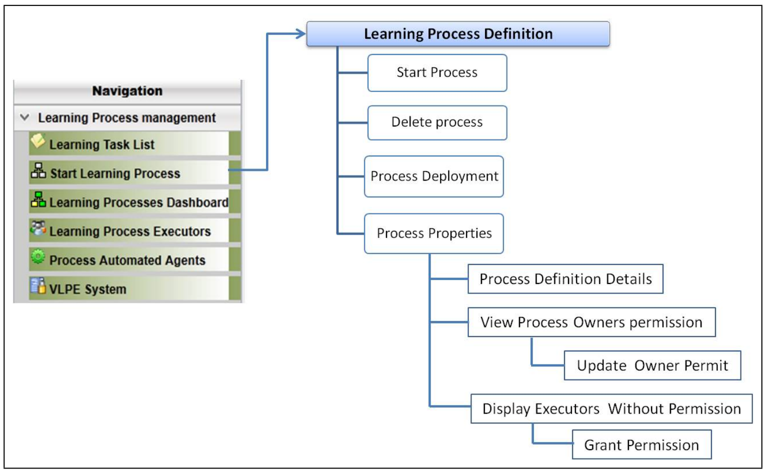


Figure 5.21: The "start learning process" features with numerous sub-features

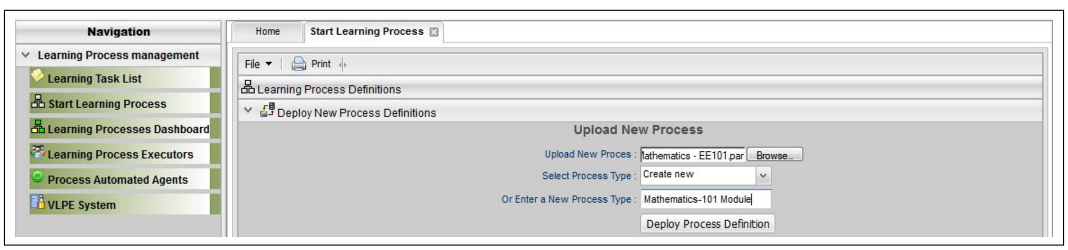


Figure 5.22: Deployment feature for a modelled learning process workflow.

Once a modelled learning process is deployed, its summary is visible in the "learning process definition section where the delete and start process features are also visible and enabled depending on the permission granted to the user on a particular modelled learning process. The process property feature is also visible and as shown in Figure 5.23, it allows the course designers to manage and grant several types of permissions to the users that will be involved in the entire life cycle of the learning process (i.e., who does what on which learning process workflow).

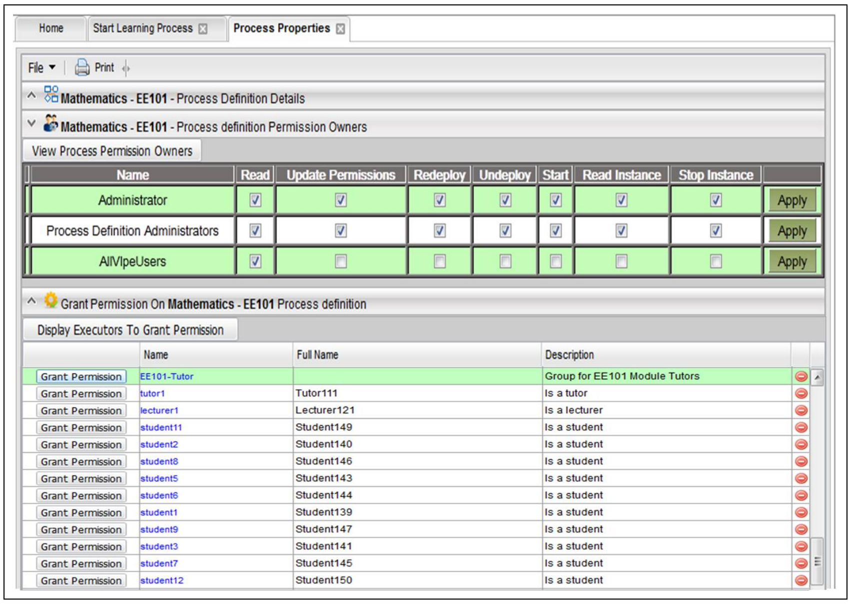


Figure 5.23: Property feature for course designers to manage permissions on a modelled learning process.

Once the course designers have completed the management of permissions on the deployed learning process, the course in which the pedagogy is modelled in the form of a learning process workflow will appear on the web pages of the learners that are registered for the course. Each learner can start learning through the course by simply clicking on the course title as shown in Figure 5.24.

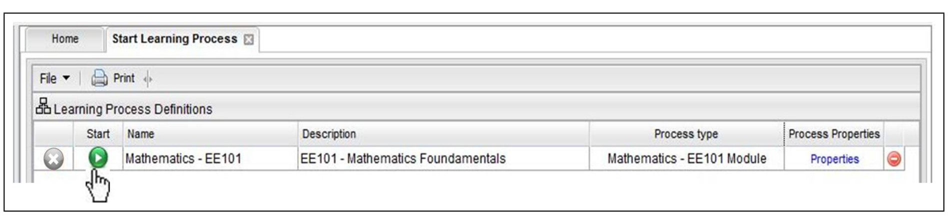


Figure 5.24: A learner starting the process of learning on a course - Mathematics-EE101.

Learning Task List

This is the learning process interface feature and it is available to all the e-learning participants that have been pre-defined and assigned a role within the learning process orchestration. This is where interaction between learners, content, lecturers and tutors takes place and this interaction is determined by the nature of learning task that is taking place. Once a learner clicks on the start button within the "start learning process" feature, the task list page is displayed. The tasks that must be fulfilled are equally displayed according to the flow of the orchestrated learning process workflow. For example, Figure 5.25 shows a learner on the 2^{nd} chapter of the mathematics-EE101 course. Within the Figure 5.25, the task list page provides the learner with: the topics and learning materials under the chapter; supplementary learning resources that can be used to access heterogeneous learning materials from learning service provides such as Google, Youtube and Dictionary; a rating form on the particular chapter where learners have the opportunity to express their satisfaction with the presentation of a particular chapter; and, the learner is presented with the option of either seeking support or progressing to the next learning task. Figure 5.25 also shows the corresponding segment of the graphical diagram of the modelled learning process on the chapter. Depending on the path chosen by the learner and the learning rules specified during the modelling process, the process flows to the next task list page.

The task list page is a common territory where the system facilitates dynamic interactions between the e-learning participants according to their tasks and responsibilities. For example, the lecturer and tutor task list page is similar to the learner's page except that the tasks for either the lecturer or the tutor are different. Figure 5.26 shows the stage of a learning process workflow task where a lecturer received a task. The lecturer's task, in this case, is to review a learner's assignment where answers/responses to such assignment are written ones and can not be assessed by the system. Upon assessment, a lecturer or tutor can

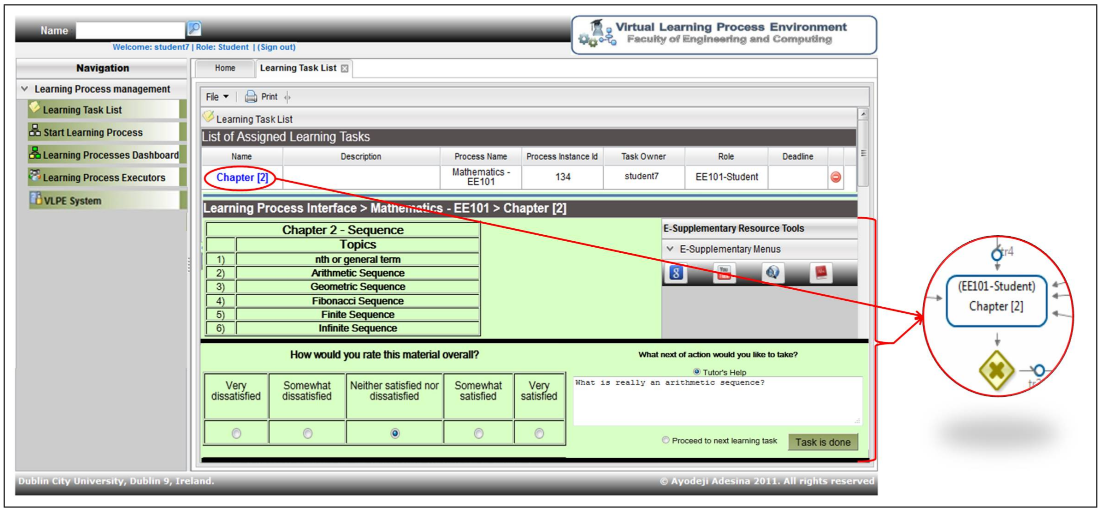


Figure 5.25: A learner on chapter 2 of the Mathematics-EE101 course.

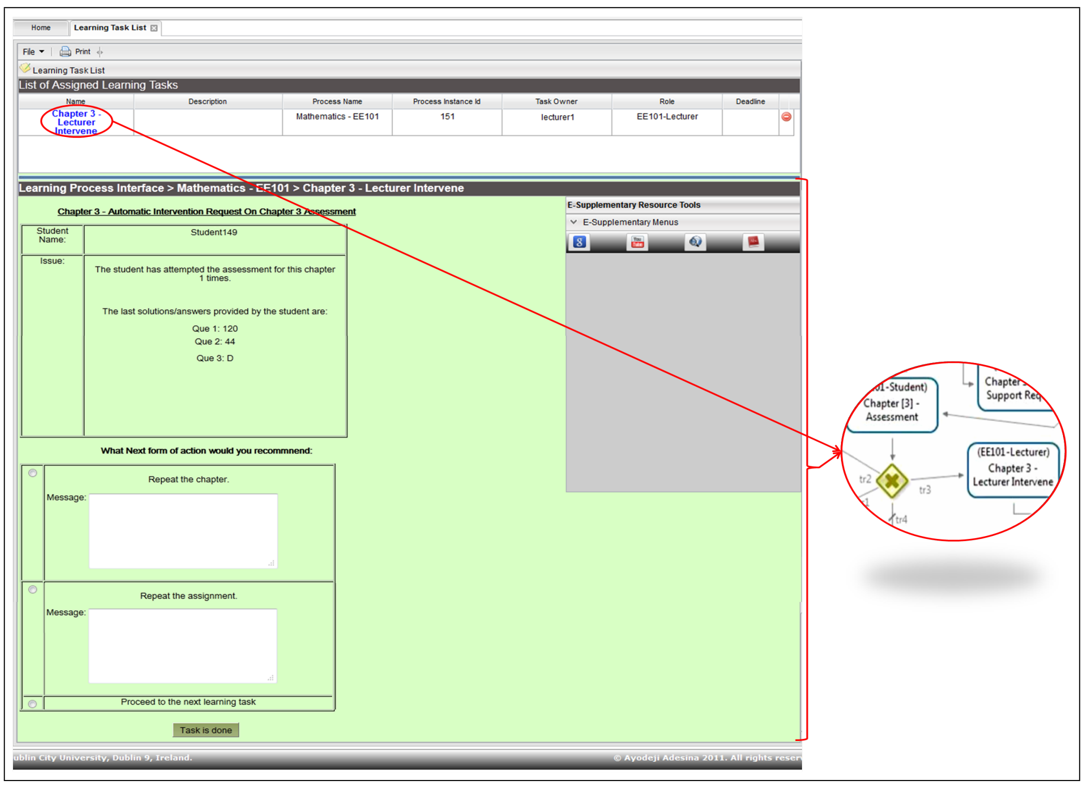


Figure 5.26: A lecture reviewing a learner's answers to assessment questions.

decide on the next path of learning progression with one of the following options: proceed to the next topic; repeat the lesson; read recommended books; read supplementary notes;

or engage in discussion forum on the topic. Any of these actions would change the learner's learning path. Different learners' responses would result in different actions, consequently, different path ways and yet the same learning outcome can be facilitated.

Learning Process Executors

This feature displays all of the e-learning participants and their roles within the VLPE. It also shows the various groups that each participant belongs to. Within the VLPE, there are two types of executor: the actor which refers to an individual and the group which refers to two or more actors associated with a common name. The group name is crucial as this is what the BPMN swimlane element uses to assign tasks within a modelled learning process. Depending on the user's role within the VLPE, the "Learning Process Executors" feature provides numerous functionalities as shown in Figure 5.27. This allows the user to perform various actions such as view, add, delete, create, update and remove existing participants within the VLPE. For example, Figure 5.28 shows a learning process executor definition panel - this is where an executor (actor/group) can be created. It also shows a summary of the existing executors within the VLPE. Figure 5.29 on the other hand shows an executor's management panel - this allows a permitted user to update information about an executor.

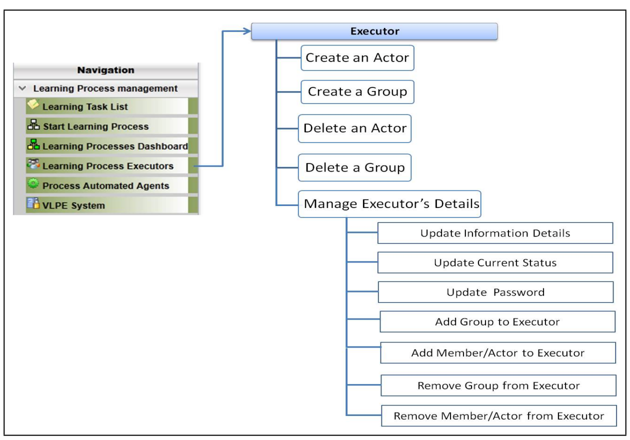


Figure 5.27: The "learning process executors" features with numerous sub-features.

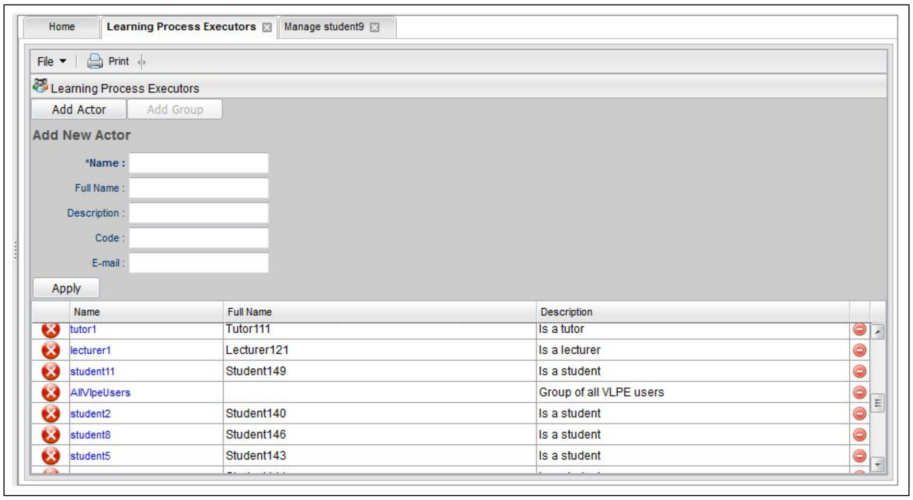


Figure 5.28: An learning process executor definition panel.

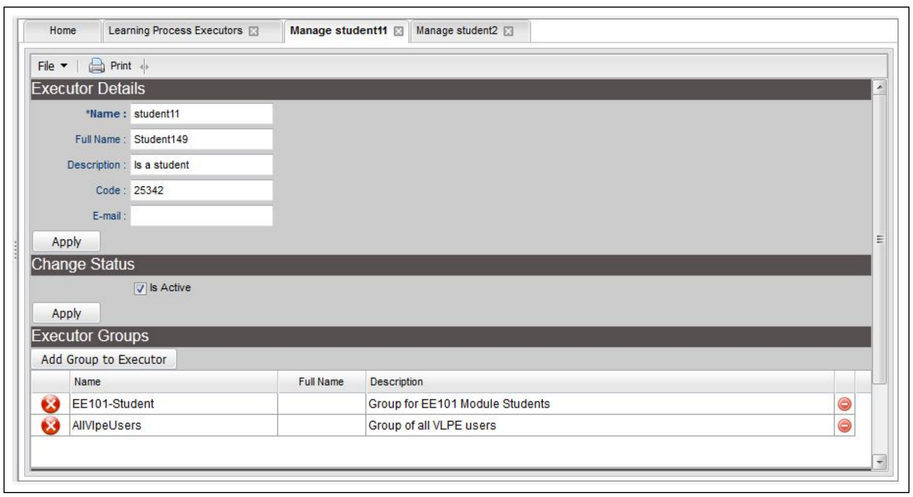


Figure 5.29: A management panel for the details information of an executor.

VLPE System

The feature displays the permission granted to all the e-learning participants within the VLPE system and depending on the user's role, updates on permissions can be made. The permissions that could be grated to any user including: "Read", "Deploy process", "Create/update/delete executor", etc. as shown in Figure 5.30. These permissions are not related to the types of permissions granted to users on a deployed modelled learning process workflow, they are mainly permissions on how the users interact within the VLPE system itself.

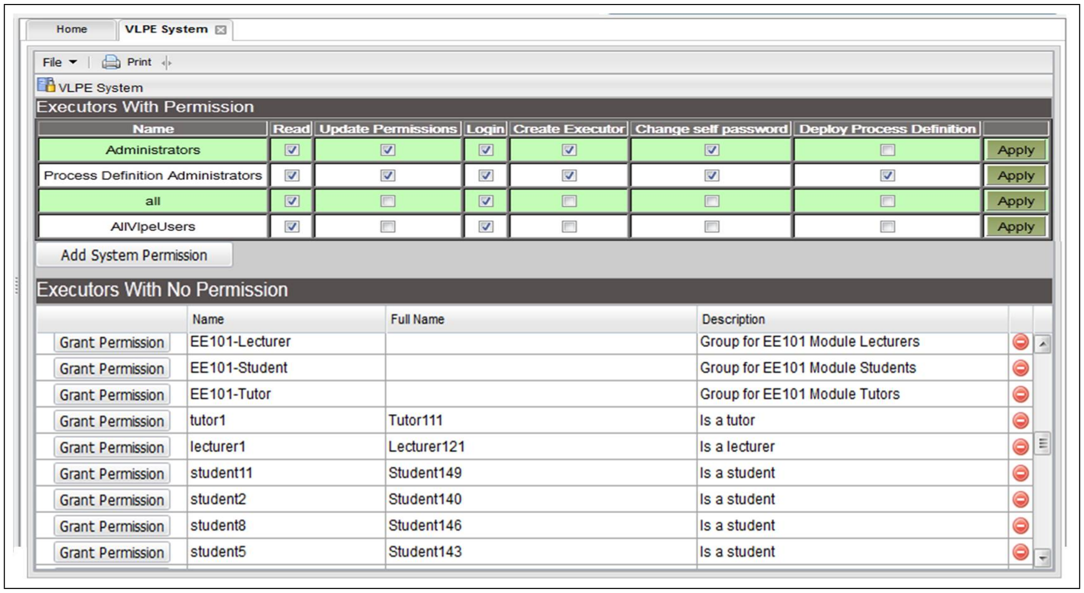


Figure 5.30: VLPE system permission management panel.

Learning process Agents

This feature is purely for administrators' usage. It allows for the deployment and management of the automated agents that are associated with the BPM technology. These automated agents are employed to perform data mining on learning process information. The design and deployment of automated agents are not part of a course designer's activities within the VLPE but are part of the IT configuration of the VLPE system.

E-supplementary Resource Tools

This feature is part of the learning process interface features. By harnessing the benefits offered by SOA and web services, the "E-supplementary resource tools" feature integrates different learning sources (i.e., Google, YouTube) externally to the VLPE system into a mashup menu as shown Figure 5.31. The feature provides users (learners in particular) the option of sourcing learning materials from external sources. For example, Figure 5.32 shows a learner watching a Youtube video on a topic of interest after sourcing the topic from the YouTube menu of the "E-supplementary resource tools" feature.

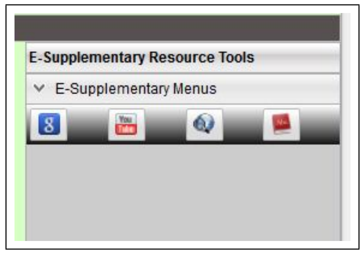


Figure 5.31: VLPE E-supplementary resource tool.

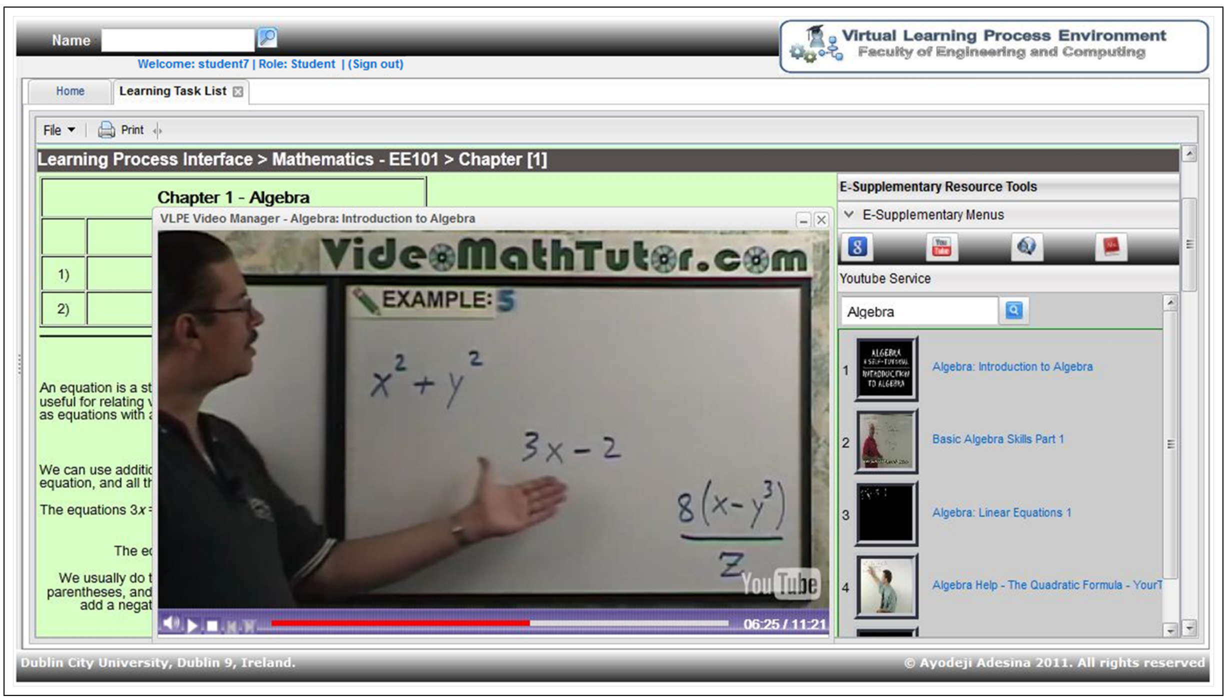


Figure 5.32: Using the E-supplementary resource tool to source a topic (Algebra) on YouTube.

Learning Process Dashboard

This is a crucial feature of the VLPE and indeed for the research work that is presented in this thesis. As shown in Figure 5.33, it's a feature that provides real time alerts based on learning process metrics when learning processes are in need of intervention. Course designers and/or tutors can analyse and detect in real time the: rate or lack of progressions; learning performances; frequency of supports; live feedbacks and completion rate. Individual learners can also use this feature to monitor and analyse their own learning process; and, can compare results anonymously with other learners. This feature is a marriage between data mining for learning activities and learning process intelligence gathering. The "Learning process dashboard" feature is extensively discussed in the next chapter as it is the feature that encapsulates all the learning process management results in a dashboard portal.

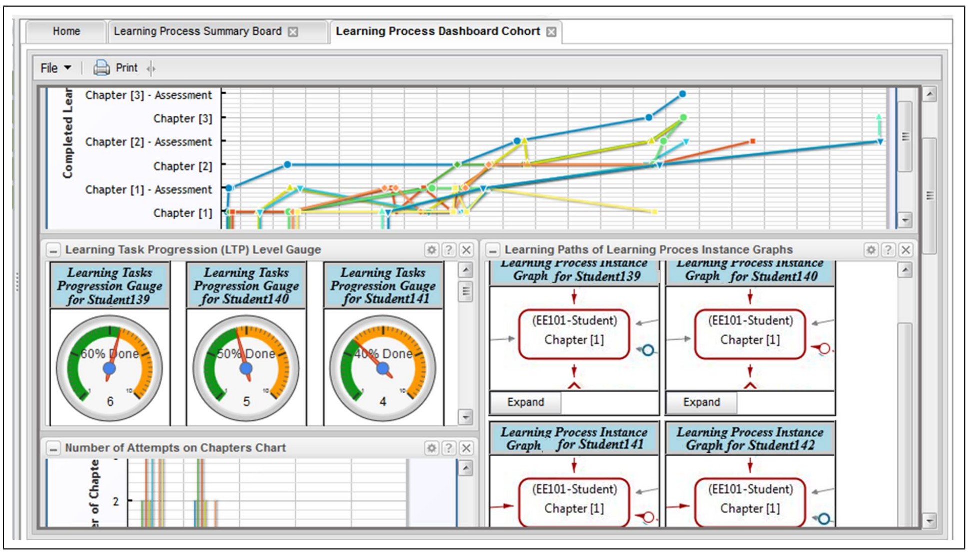


Figure 5.33: VLPE learning process dashboard.

5.5.2 VLPE Core Functionality

The educational values that the VLPE espouses and how it is unique from the current VLE can be realised from the functions of its features. These functions arise from the interaction with the features, content and users. For the purpose of the research work that is presented in this thesis, the core functionalities of the VLPE features that are described above can be categorised into five key functions.

1. **Pedagogy modelling** - With pedagogy at the heart of the VLPE implementation, a

pedagogical modelling tool (CLPMA) that is presented in Section 5.2 was designed and developed as part of VLPE system. Using the CLPMA, Section 5.3 demonstrates, as a proof of concept, how course designers can model various education pedagogies in the form of learning process workflows using the intuitive flow diagrams associated with the BPM elements. The modelled pedagogy can then be deployed into the VLPE web interface. An example of a modelled learning process workflow that is designed around a structured mathematics module (Mathematics-EE101) based on a non-linear pedagogical structure is present. The same learning process workflow can be instantiated by all the learners that are enrolled for the module, with each instantiation representing the learning process of an individual learner. Consequently, all instances can be used to visually track the learning processes and progressions of a cohort of learners as they learn through the course materials. Furthermore, the ability to visually track these learning processes would allow for the effectiveness of any adopted pedagogy to be evaluated with the potential to improve course design based on the analytical results.

2. **Learning as a task list** - Learning through each topic in the course material is modelled as task lists that need to be fulfilled by all the learners. Once the learning process on any module (e.g., the Mathematics-EE101) is instantiated, course content are systematically displayed as a task list (i.e., "chapter", "assessment", "validate assessment", "approve or reject progression" etc.) and interaction with the learning materials by the e-learning participants can take place within the learning process interface. Therefore, course materials are not made readily available for immediate download. Instead, learning materials are an integral part of the learning process workflow designed (i.e., learning objects are embedded into the process as a task list). Learner has to go through each part of the learning activities within the process. This way the learner's digital learning footprints can be tracked and monitored. Download of course materials is automatically made available to learner who has gone through the lifecycle of a lear-

ning process. The learning process interface also contains tools for accessing external heterogeneous learning resources (i.e., Google, YouTube, Dictionary Services etc.).

3. **Customised learning paths** - Customised learning paths through course materials are based on the number of nodes/branches that are created within the orchestrated learning process. The more the nodes in the learning process workflow, the more optional paths are available for learners to meander through. Learning path construction is limited to imagination and resources. The conventional hyperlinks enabled by the existing technologies such as SCORM, LD, LAMS, Moodle and even Blackboard can be used to provide learners with multiple alternative hyperlinks to choose from or iterate/browse through. However, one significant difference between the construction of pathways using a BPM toolset and conventional hyperlinks is that BPM provides a run-time rules engine that can influence learners' learning pathways. A complex learning scenario that warrants an adaptive learning pathway can be constructed seamlessly by using a BPM toolset. For example, a learner might click on a button to progress and the BPM rule engine might actually return the learner to a pending assignment that is due to be submitted. In other words, each learner's run-time behaviour in a learning process can be used to determine the path for progressing through course materials. This scenario can be programmed within the current e-learning systems using a lot of hard-coded low-level programming that goes beyond the conventional use of hypertext linkage. However, BPM provides a high-level toolset that can be adapted to orchestrate learning pathways in a much easier way and adaptive way.

4. **Enhanced human interactive pedagogy** - The CLPMA modelling tool of the VLPE can be used to design and implement an enhanced interactive pedagogy in a learning process through course materials; this is achieved by orchestrating interactions between learning services (learning objects and competence-based assessment)

and human-task services (learner, tutor and lecturer). Using the modelling tool, course designers are able to sketch the mode and extent in which a learning process workflow enables flexible and adaptive interactive pedagogy through the course material. The implementation of an interactive pedagogy in a learning process within the system encompasses an approach where a general learning outcome is the ultimate goal but individual learner's learning behaviour within a learning process determines the level of interactivities in achieving the desired learning outcome. The broad and partially overlapping categories that are implemented are: Customised interaction; learning object; content delivery; and, finally, customised support. Learners are provided with the option to seek alternative interactive support (e.g., tutor's support, lecturer's support etc.) when difficulties arise. In the example of the modelled learning process workflow discussed in Section 5.3, interaction with tutors for support is possible, either through a manual process (learner can initiate need for support) or an automatic inference when learners progress lingered (in this case tutor support is invoked automatically). Consistent failure to answer questions correctly is modelled as a task for the lecturer to intervene as necessary. Lecturer intervention could be a call for a face-to-face meeting with the learner. Importantly, such a face-to-face meeting can be modelled formally, where the outcome of the meeting can be re-entered into the workflow (e.g., the learner requires contact from a course tutor, needs to repeat an element of the course work etc.) so that a full record can be a captured of a learner's progress.

5. **Learning analytics** - What cannot be measured can neither be improved, nor managed. Therefore, measuring the learners' learning processes in a real time manner provides the monitor-ability, manageability and improve-ability of learners' learning experiences through assessment and intervention by a lecturer and/or tutor where and when necessary, based on the monitored data as learners learn through course material. The capturing, monitoring and measuring of the learners' learning processes lifecycle

in a transparent manner would require a learning process dashboard so that course designers/lecturers, learners and tutors can keep track of the learning processes. A BPM approach to managing learning process workflow through learning analytics is facilitated through the persistent management of various learning interactions and events. In other words, every click of a button/link is automatically persisted continuously throughout the entire lifecycle of the learning process workflow. Who does what and when is also persisted on a continuous basis during the learning process. Every client side user action is stored on the server side as learning process data. Depending on how a learning process workflow is modelled, the outcome of the processed data can be feed back to the BPM learning process model in a way that can help to adapt learning pathways in a unique way for an individual or group or learners. The same feature could be hard-coded into a traditional VLE, albeit with significant effort. However, this capability is built-in to the BPM model and the tools required for aggregating data are also inherently present within BPM implementations, as are other tools for dealing with features of BPM, such as multiple process pathways. Again it is possible to build these analysis tools without BPM, but it would be difficult to implement them within a traditional VLE. So for example, with relative ease, BPM with the availability of learning process data, further statistical computation (e.g. calculation of distribution of marks to spot outliers, to get completion rate, total scores, etc.) and regression analysis (establishing cause and effect relationships) can be performed on the server-side, with the analytical results made available in real-time within a learning process dashboard. This provides the means for lecturers and/or tutors to intervene in a learning process in real-time based on the monitored data, rather than detecting problems at semester-end/major assessments. This is the motivation for the next chapter. The next chapter discusses how the VLPE implementation was used to facilitate learning analytics.

5.6 Summary

In this chapter, using the BPM and GWT technological frameworks, a prototype implementation (VLPE) of the proposed BPM-based architecture for learning process management through the possible modelling of education pedagogies is presented. The VLPE solution is made up of two systems:

1. CLPMA is a custom BPMN standalone application specifically designed and implemented as a pedagogical modelling tool for course designers to be able to use an intuitive flow diagram to graphically model their educational pedagogies in Section 5.2. Using the CLPMA, Section 5.3 demonstrates, as a proof of concept, how pedagogies can be modelled and an example of a pedagogy model based on an example of a pedagogical plan on a Mathematics-EE101 course is orchestrated in the form of a learning process workflow.

2. A BPM Web-based Application as a Learning Process Management Environment is designed and implemented in Section 5.4. It is a web interface that allows a modelled pedagogy to be deployed, run and managed by course designers. Once a modelled pedagogy (i.e., Mathematics-EE101) is deployed on the web, course designers/lecturers can manage groups of learners around the modelled learning process workflow. Learners can instantiate/execute a learning process workflow against the course that they are registered for.

Some of the core features and functionality of the VLPE solution are also presented. In particular, VLPE provides the following key features: start learning process; learning task list; learning process executors; learning process agents and e-supplementary resource tools. All of these features provide the means to facilitate the management of a learning process. VLPE also provides the following key functionalities: pedagogical modelling; learning as a task list; customisation of multiple learning paths; enhanced human interactive pedagogy; and, learning analytics. All of these are important components for effective management of learning processes within an online virtual learning environment.

The VLPE prototype solution that is presented in this work is not a perfect system; for example, several useful learning activities such as emailing services, learning objects integration services, chat room services, discussion forum services; and, higher level technical modelling interfaces for many other learning activities that are vital to learning managements are not part of the VLPE features and functionality. Consequently, VLPE is not deployed for a much larger user level testing as it would be difficult for course designers to objectively respond in the absence of such features and functionality. Ideally VLPE would have all of the features that are present in today's VLEs, but it is not possible to achieve this within the timeframe of this work as these features would have to be rewritten from first principles. However, it is believed that the VLPE solution that is presented thus far merits the proof of concept for the proposed BPM-based architectural solution for learning process management. As a result, the next chapter presents the results of the functional and user level testing from learning analytics perspective of the VLPE solution based on the example modelled learning process workflow.

Chapter 6

VLPE: Learning Analytics Testing, Results and Discussion

6.1 Introduction

Apart from testing the VLPE functionality for its pedagogical modelling capability as presented in Chapter 5, the chapter also discusses the functionality that facilitates the gathering of learning process statistics for a cohort of learners with a view to providing the information necessary for learning analytics. The actual analysis of the statistics is beyond the scope of this research. It is expected that different cohorts' learning processes will generate different learning statistics. Thus, different interpretations will abound, especially from course designers' point of view. However, it is reasonable, for the purpose of the research that is presented in this thesis, to present a user level testing of the VLPE with the view to validate the learning analytical offerings of the BPM-based architectural solution. Therefore, a group of 10 participants were invited (following a face-to-face interview) to voluntarily participate in a short Mathematics course. Upon their acceptance to participate in the study, each participant was given a unique username and password needed to gain access to the VLPE system. The 10 participants (male and female) are between 18 and 20 years of age (detail of a consent letter, that was made retrospectively is in Appendix C). The participants' personal details or data are not used within the VLPE as they are not relevant for the purpose of this research. Therefore, their actual names, age, gender etc. are not recorded or stored within the VLPE system. The short Mathematics course (see Appendix B) was designed by the author of this thesis, hence, assuming the role of a lecturer and tutor.

The 10 participants were used to carry out user level testing of the VLPE implementation as a proof of concept that by using a BPM-based solution to model education pedagogies, real time quantitative learning process information can be gathered in a way that can assist course designers to improve on their pedagogical choices. Table 6.1 presents the virtual usernames and roles given to the learners within the VLPE. It is also worth mentioning that the VLPE is an example of a prototype implementation (i.e., one possible implementation approach) of the proposed BPM-based architecture and not the ultimate full-fledge BPM-based e-learning system that could be deployed for production. In fact, the implementation and design of a full-fledge BPM-based e-learning system based on the proposed BPM-based architecture presented in Chapter 4 would require many person year's effort - this is beyond the scope of this research. Therefore, as a proof of concept, the user level testing is performed on a smaller group of learners as an example of the learning process statistics that can be gathered for learning analytics and pedagogical re-evaluation.

Upon the deployment of the modelled learning process workflow on the VLPE web system, it was necessary to test and verify the functionality of the feature (i.e., the learning process dashboard) that provides real time alerts based on learning process metrics. Particularly, with regard to the real time statistical gathering and analysis aspect of the learning process information that can be used for learning analytics and pedagogical evaluation. Therefore, using the example of the modelled learning process workflow discussed in Chapter 5, this chapter presents possible examples of learning analytics that can be performed based on

Learners' User-Names	Learners' Roles	Learners' Groups
Student139	Student	EE101 Module Students
Student140	Student	EE101 Module Students
Student141	Student	EE101 Module Students
Student142	Student	EE101 Module Students
Student143	Student	EE101 Module Students
Student144	Student	EE101 Module Students
Student145	Student	EE101 Module Students
Student146	Student	EE101 Module Students
Student147	Student	EE101 Module Students
Student148	Student	EE101 Module Students

Table 6.1: Learners' names, roles and groups for learning process management within the VLPE.

the learning process information results that are gathered from the cohort of learners (i.e., the 10 voluntary participants) that have engaged in learning processes within the VLPE prototype solution. The results presented in this chapter are meant to demonstrate how a BPM-based e-learning solution can be used to facilitate learning analytics and assist course designers/lecturers to benefit from real time statistics gathering of up to a very large cohort of learners' learning processes through the ability to monitor and analyse statistical learning process information on a learning process dashboard. One of the significant features of the VLPE prototype implementation is the Learning Process Analytics Dashboard (LPAD) which allows the course designers/lecturers to do just that. Learners can also benefit from the use of the LPAD to monitor, analyse and manage their learning process workflow if they are allowed to access their statistical learning process information on the LPAD.

The statistical and analytical results of the learners' learning processes that are presented in this chapter are based on the example of the non-linear pedagogical structure that is modelled as a learning process workflow shown in Figure 6.1. The same diagram shown in Figure 6.1 can be instantiated (i.e., start a learning process workflow) by as many lear-

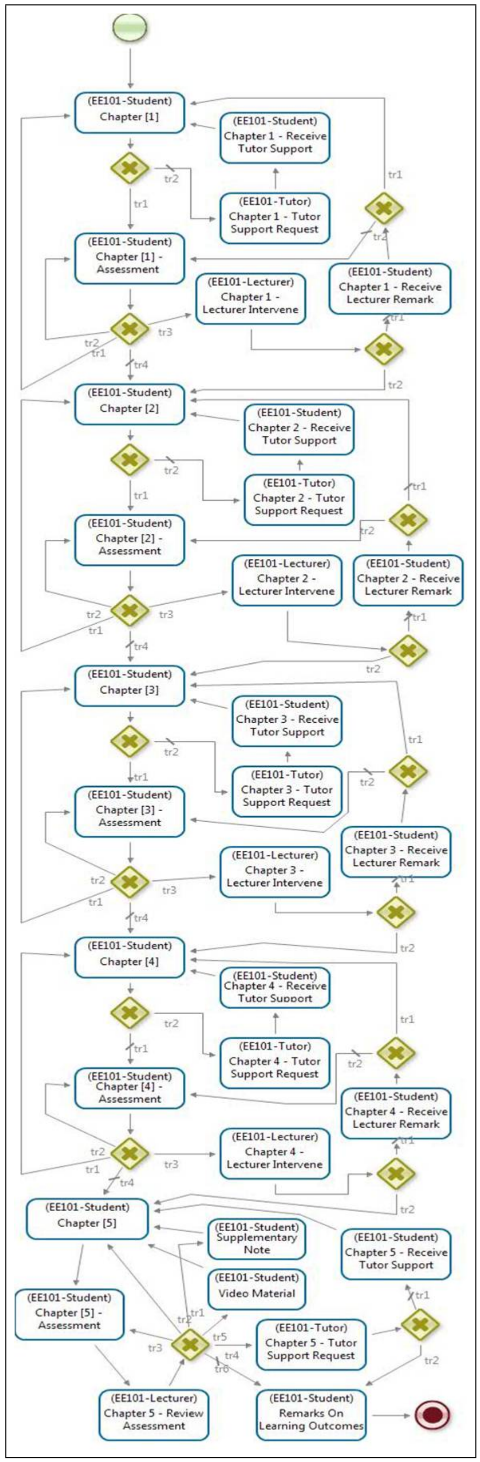


Figure 6.1: Full diagram of the modelled Mathematics-EE101 learning process workflow.

ners as possible, with each instantiation representing the learning process of an individual learner. Consequently, all instances can be used to visually track the learning processes and progressions of a cohort of learners as they learn through the course materials. Furthermore, the ability to visually track these learning processes would allow for the effectiveness of any adopted pedagogy to be re-evaluated with the potential to improve course design based on the analytical results.

One of the over-arching benefits of using BPM technologies is the volume of quantitative learning process data that can be gathered during the process of learning. The quantitative learning process data can be captured and processed for the Key Performance Indicators (KPIs) analysis on the cohort learning processes. KPIs are quantitative or qualitative measurements and evaluations of the effectiveness, efficiency and quality of a business process, which reflect the overall process success factors or success of a particular activity within the entire process and address the performance of the business process (Liu et al. 2008a). Within the example of the modelled learning process workflow that is shown in Figure 6.1 above, the non-linear pedagogical approach is such that the KPIs are measured against the learners': successful learning outcomes through the formative process of assessing their competencies on every chapter; attrition rate; progression rate; mathematical problem solving skills; frequency of supports; feedback; and, completion rate. While these KPIs are applicable to the example of the modelled pedagogy, they may or may not apply to a different pedagogical construct. In other words, KPIs measurements are dependent on the pedagogical choice by the course designer.

6.2 Learning Analytical Results and Discussions

Within the VLPE prototype implementation, there are two types of LPAD. The first type is the aggregated Cohort Learning Process Dashboard (CLPD) which provides the analytical

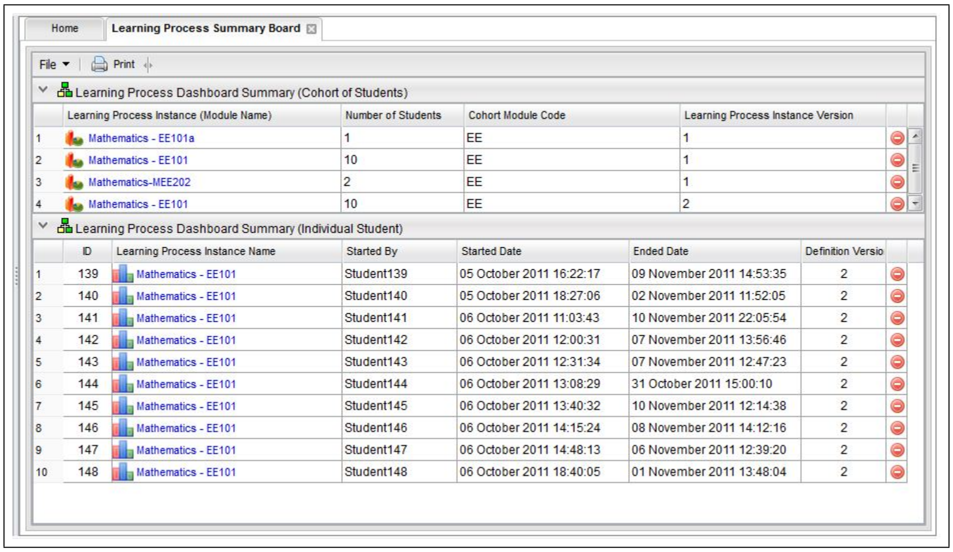


Figure 6.2: Summary panel of the VLPE learning process dashboard.

means to view the entire cohort learning processes in a single dashboard interface. The second type is the Individual Learning Process Dashboard (ILPD) which provides the analytical means to drill into an individual learner's learning process. Both the CLPD and ILPD can be accessed through the summary panel of the VLPE learning process dashboard shown in Figure 6.2.

For effective analysis of learning processes, the LPAD is made up of several analytical charts:

- Learning Task Progression Chart.
- Learning Task Progression Level Gauge.
- Learning Process Instance Graph (Learning Paths graph).
- Number of Requests for Tutor's Support Chart.
- Number of Requests for Lecturer's Support Chart.
- Number of Attempts On Chapters Chart.

- Number of Attempts On Assessments Chart.
- Student's Satisfaction Level Chart.
- Popular Learning Task Supporter Chart.

Each of the charts has two versions - the cohort and individual version. These are the basic charts that are implemented within the VLPE to measure learning task progressions and how learning resources (human supports) that are available to assist learners during their learning process are being used. There are multiple paths that learners can take to complete their learning tasks. However, learning task progressions are only measured against two core learning tasks - reading of chapters or sections of learning materials and completing the assessment tests that are available on each chapter or section of the learning material. In other word, a learning task progression counter increments on the completion of either a chapter/section or assessment test that follows each chapter/section. Learner's marks for assessment tests are recorded on the "Number of Attempts On Assessments" chart (see Section 6.2.2, Figure 6.13). Each of the charts provides different statistical metrics and graphical information on how the cohort or individual learning progressions and performances can be intuitively comprehended by the course designers/lecturer, learners, and tutors.

Learning process analysis can be performed at any stage of an instantiated learning process. This section presents the analytical results of the learning processes of the 10 learners that are presented in Table 6.1 based on the example of the modelled learning process workflow. The results are based on a five-week period of analysis in which the cohort's learning progressions and performances were closely monitored (i.e., tracking who is doing what at a particular time) within the LPAD for learning analytics purpose. It is worth pointing out that while the cohort of learners is made up of 10 learners in total, the ability to display a very large cohort (i.e., 100 learners) in a chart depends on the data visualisation design approach. BPM already provides a persistence mechanism for which every event and action of the user is persisted. Data mining and data aggregation are also generally part of a BPM larger initiative of business intelligence solution. Therefore, two possible design solutions for loading and displaying a very large data set into a dashboard component (chart or table) are suggested. (1) For medium-size data sets (e.g., 20 learners), dashboard components can be designed to scale through a zoom in/out feature that allows small to medium-size data to be scaled up and down in order to make it easier to read. In fact, this is the data visualisation design approach that is adopted for the entire charts that are presented within the LPAD. (2) For a very large data set (i.e., > 20 learners), one possible solution is a chart pagination that controls/limits the size of data sets per view. A pagination chart provides control buttons or pagination arrows that allow users to render a very large data set on a chart in an incremental fashion by clicking the pagination arrows.

6.2.1 LPAD: Cohort and Individual Analytical results for Learning Processes

The results presented in this section provide different statistical and graphical information on how the learning progressions and performances of the cohort and/or an individual learner can be intuitively comprehended by the course designers/lecturers and tutors. Detailed and real time analyses on the levels of learner-content, learner-tutor and learner-lecturer interactions can be performed at any stage of an instantiated learning process. For example, using the CLPD and ILPD components and charts, this section presents two sets of analytical results. The first set is based on the analytical results of the cohort learning processes into the third week of starting the learning processes on the example of the modelled pedagogy. The second set is based on the final analytical results of the cohort learning processes at the end of the entire cohort's learning processes (i.e., after every learner has completed a learning process cycle). By drilling into the details of individual learners, this section also provides examples of the types of statistical and graphical information on how the learning progressions and performances of an individual learner can be viewed and analysed at any stage of an instantiated learning process. The detailed learning process result of an individual learner can be extracted from each set of the cohort learning process results by clicking on the individual's name. This will open the ILPD components and charts panel and lecturer or tutor can be able to drill down and perform a detail analysis on an individual's learning process.

By comparing an individual's learning process results against the cohort's, the heterogeneous nature of an individual learner could provide a significant clue as to the disparity between an individual learner's learning progressions and performances and the rest of the cohort's. This may give more credence to the belief that an individual learner is different and that *one-size-fit-all* does not actually fit all. If such is the case, then, an online pedagogical approach would need to be such that target and adequately meet the heterogeneous needs.

To analyse the effect of an online pedagogical approach, it was important to observe and monitor the learning process information on a learning process dashboard, hence, the CLPD feature in the prototype implementation. Based on the observable real time monitored learning process information on the CLPD components and charts shown in Figure 6.3 to Figure 6.9 in the middle of the learning process (i.e., three weeks into the learning process life cycle) and at the end of the cohort learning processes, analyses on the cohort learning progressions and performances can be deduced. This way the course designer/lecturer can re-assess the entire cohort performances with the view to improve a modelled pedagogy if need be.

By using the CLPD components and charts, learning progressions and performances can be analysed based on the patterns or trends that can be identified and interpreted as either positive or reasonable or negative assessments of learning outcomes of learning processes. For example, the more negative and zero slopes on the learning progression chart (i.e., a line chart) then the more the evidence of an anemic learning progression. An ideal reasonable learning progress should show more positive slope on the learning progression chart. Also, periodic patterns on the learning progression chart would be good indication of the frequency of repetition of learning tasks. For example, the periodic pattern around the first chapter and the assessment that follow as shown in Figure 6.3a would indicate numerous repetitions of the learning tasks. In other words, learner(s) are going back and forth between learning tasks (in this case a chapter and the subsequent assessment). Therefore, it could indicate that learners were struggling to get through the chapter and the assessments that follow before they were either satisfied or just manage to meet the requirements for progression. The length of time the entire cohort spent to complete each learning task and the learning process as shown in Figure 6.3b could provide an insight into a reasonable measure of how long it takes to complete a learning task and how long should the course duration last for. Figure 6.3c shows the variation of an individual learning task progression chart at the end of the learning process cycle.

Figure 6.4 is a learning process gauge on the level of progressions on the entire learning tasks. It should give an accurate account of the level of progress each learner had made thus far on the entire course material. Should all of the learning process level gauges give 100% reading as shown in Figure 6.4b, this would indicate that the entire cohort have completed the learning process cycles. Otherwise, the indication would be that at least a learning process is still in progress.

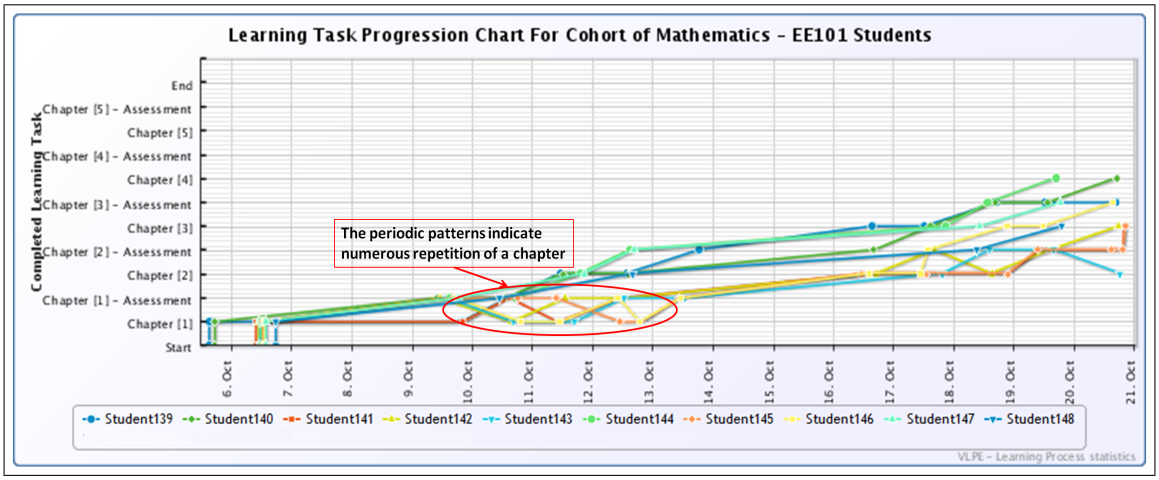
The number of times the learners had read through each of the chapters can be captured and analysed as shown in Figure 6.5a - with each bar chart representing each of the learners on each chapter. For example, Figure 6.5a shows the level of learners' engagements with the chapters in the third week of the learning process. The number of times the learners read or viewed each chapter could indicate that such chapter is either difficult to understand or the presentation could be improve. However, the level at which the learners are performing and the desired level of achievements can be verified in the assessment chart shown in Figure 6.6. This is because the learning progression or lack of thereof is largely determined by learners' performances on the assessments that followed each of the chapters. The correlation between the levels of interactions with the learning tasks or chapters shown in 6.5b and the number of times the learners had to repeat assessment tests that follow the learning tasks or chapter shown in Figure 6.6b should provide significant insight into the learning tasks or chapters that are more challenging for the learners and that would probably need to be revamped (structurally or presentation wise) in the future. Since the example of the modelled pedagogy was orchestrated in such a way that no learner is allowed to progress unto the next learning task unless the learner has successfully completed the assessments that follow a particular learning task, it becomes obvious on how a particular learning task can be deemed easy or difficult for the learners by the number of times they had attempted the assessments. The more the learners have to attempt the assessments, the more likely that they are struggling to understand the material that is being presented. By extracting an individual's learning performance from the rest of the cohort as shown in Figure 6.5c, the average number of times the individual attempted to read or view the entire chapter can be analysed and possibly compared with the rest of the cohort.

Another significant indicator of how learners are faring in terms of the difficulties experienced on each learning task is the number of requests for support made on each of the chapter as shown in Figure 6.7. Figure 6.7a and Figure 6.7 show how requests for tutor support can vary from time to time. Depending on the overall number of requests for support received by the tutor, course materials may either need to be overhauled or additional human resources (i.e., more tutors) would need to be increased in the future so as to accommodate demands for supports. The adopted learning rule on the modelled pedagogy is such that the system initiates a lecturer's support on a particular learner once the system detects that it is unlikely for such learner to make reasonable progress. The system can detect unreasonable progress if a learner continuously repeats an assessment without any success. In other words, as part of the pedagogical approach, the learning process workflow is modelled in such a way that the lecturer should be automatically alerted when progression is anemic or stalled on chapter 1, 2, 3, and 4 (i.e., learners do not have the option to initiate or seek support directly from the lecturers). Figure 6.8 shows the levels of support that the lecturer provides where needed. The last chapter, in particular, was modelled as a pedagogical scenario that involve the lecturer manually correcting the final assessments on chapter 5, hence the high level of the lecturer activities as shown in Figure 6.8b. On an individual level, Figure 6.7c and Figure 6.8c show how much supports an individual learner received throughout the entire learning process cycle. The average request for support could provide a clue as to how the individual learner is actually struggling to cope with the course material. Overall support popularity between the lecturer and tutor is 48.9% and 51.1% respectively.

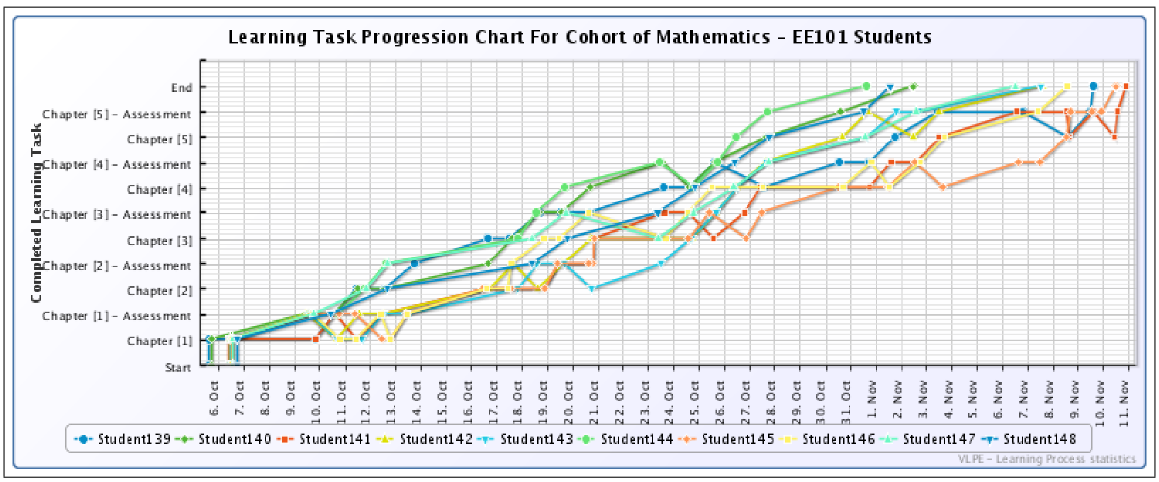
Figure 6.9 could even be interesting for the lecturer as it gives a direct feedback on how learners perceived the presented course materials as their satisfaction levels were captured and presented. Opinions on each chapter can differ across the board; however, learning task or chapter with significant level of "somewhat dissatisfactions" or "very dissatisfied" would confirm the need to restructure and/or improve such learning task. Consequently, prompting a real time feedback to the lecturer on the effectiveness of each course material's structure or presentation.

Using the CLPD, it is possible to observer the learning pathways taken by each learner to meander through the full learning process cycle. Figure 6.10 shows the examples of how individual learners' learning process paths can be graphically captured. The Figures (6.10a to 6.10c) show different learner's learning process pathways (paths captured and shown in red colour). The learning resources, supports sought, repetitions made and most popular paths taken by each learner can help to inform on the learner's learning behaviour and style.

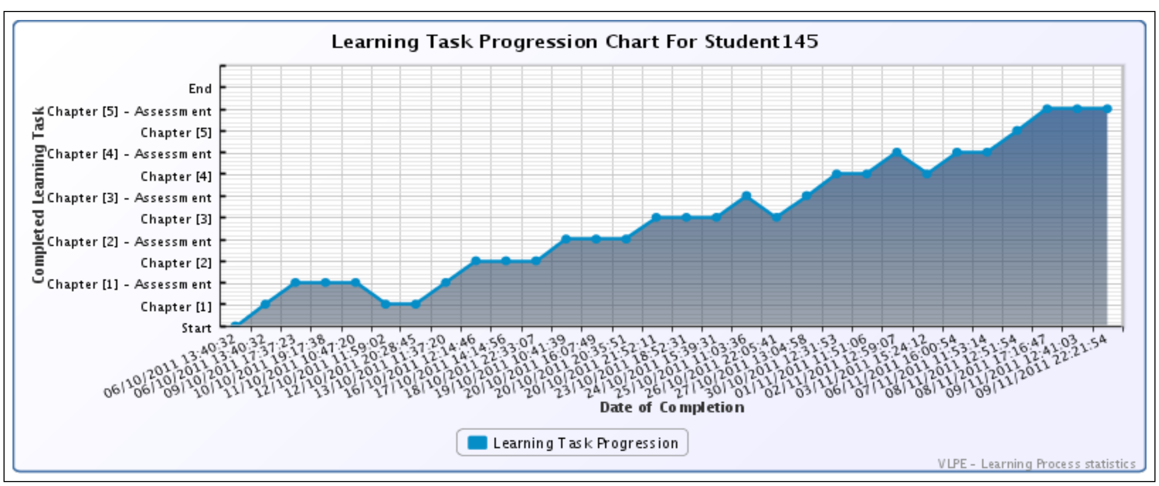
The analyses can be conducted on a continuous basis and interventions can be made where and when needed accordingly since the cohort digital learning footprints were been monitored live. This mimics and provides a similar experience that would normally be experience in the classroom settings.



(a) Cohort learning task progression chart in week 3.

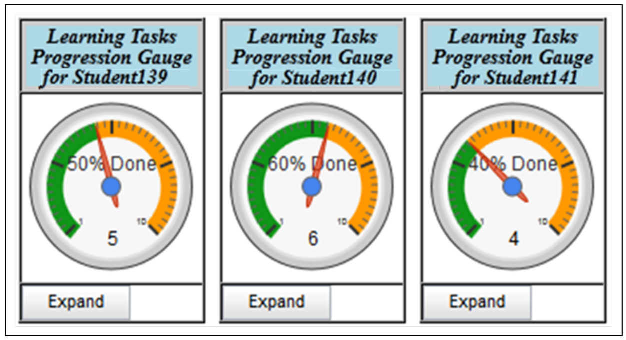


(b) Cohort learning task progression chart at the end of the learning process cycles.

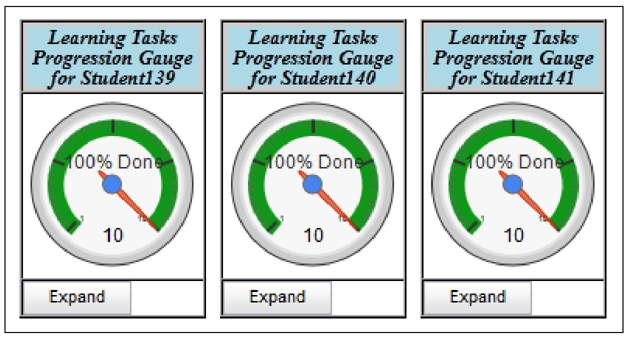


(c) Individual learning task progression chart at the end of the learning process cycle.

Figure 6.3: Cohort and individual learning task progression charts.

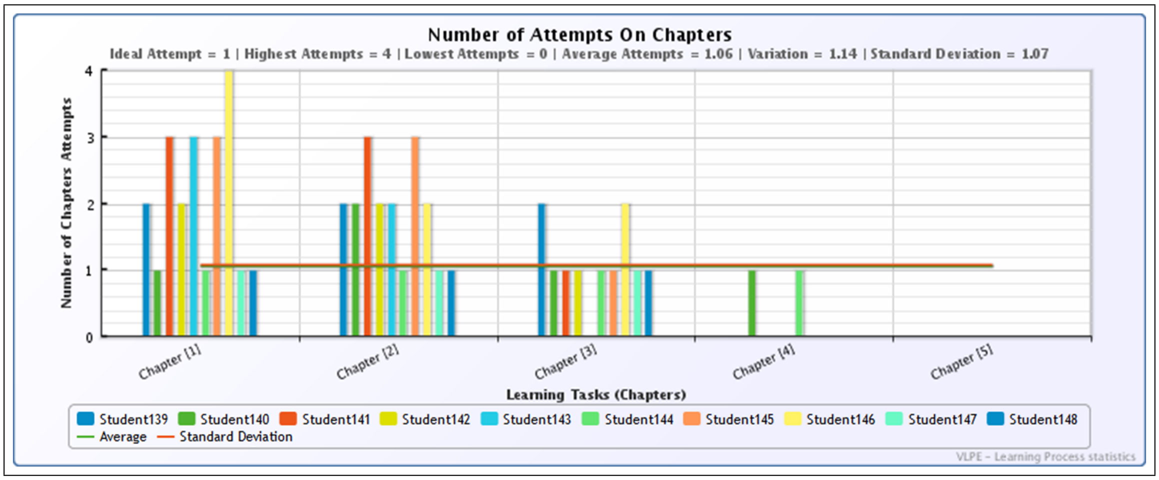


(a) Cohort learning task progression level gauge in week 3.

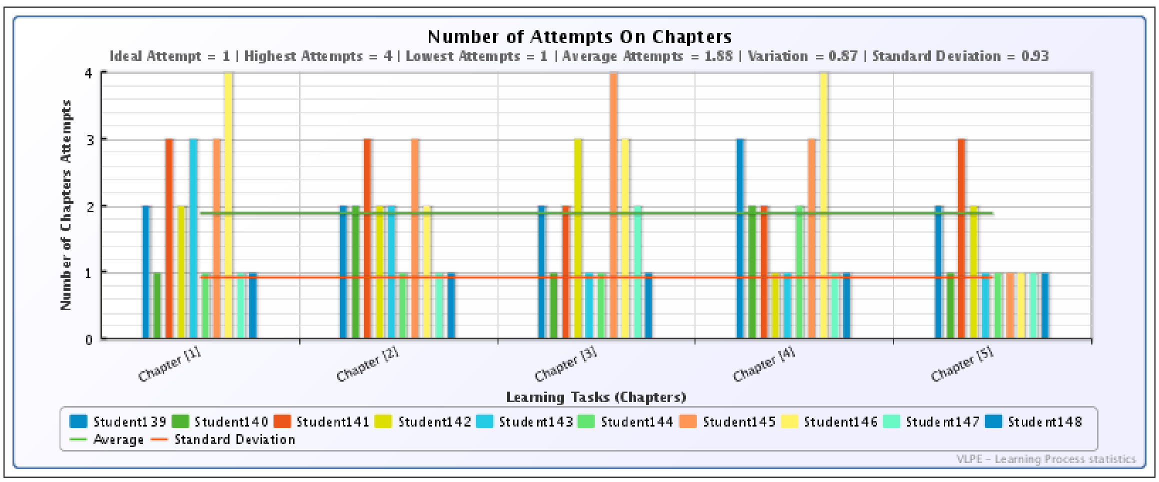


(b) Cohort learning task progression level gauge at the end of the learning process cycles.

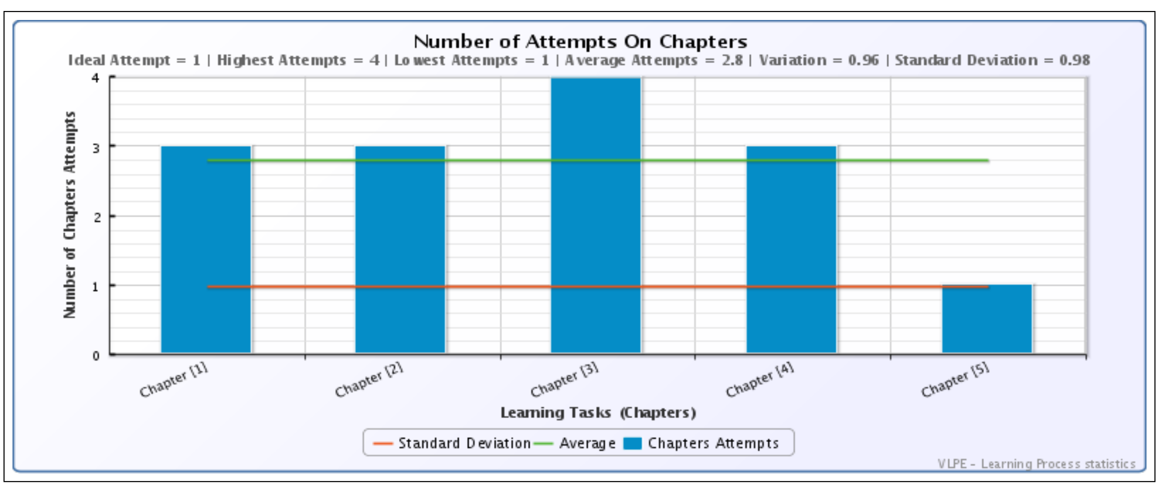
Figure 6.4: Cohort learning task progression level gauge.



(a) Number of times cohort attempt reading chapters in week 3.

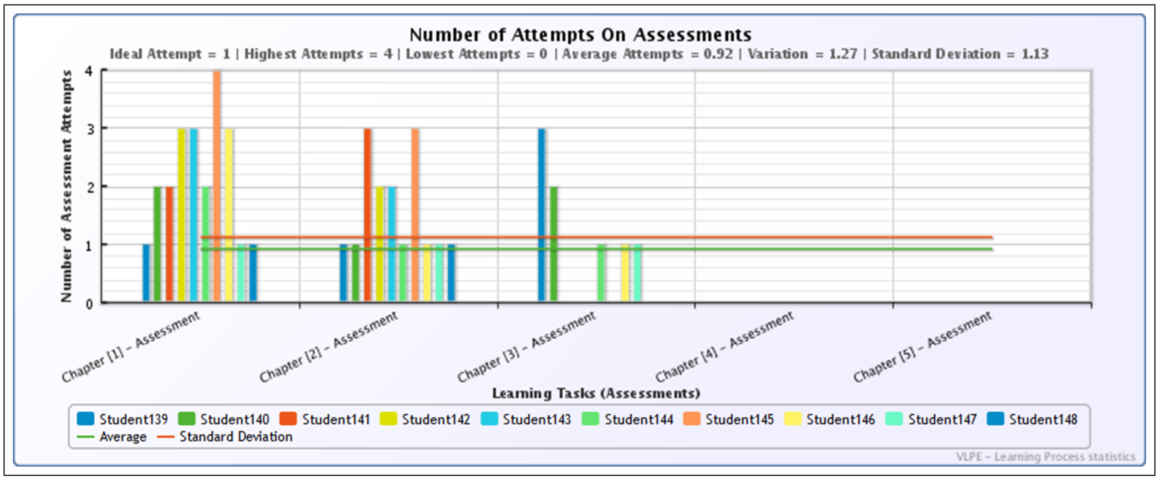


(b) Number of times cohort attempt reading chapters at the end of the learning process cycles.

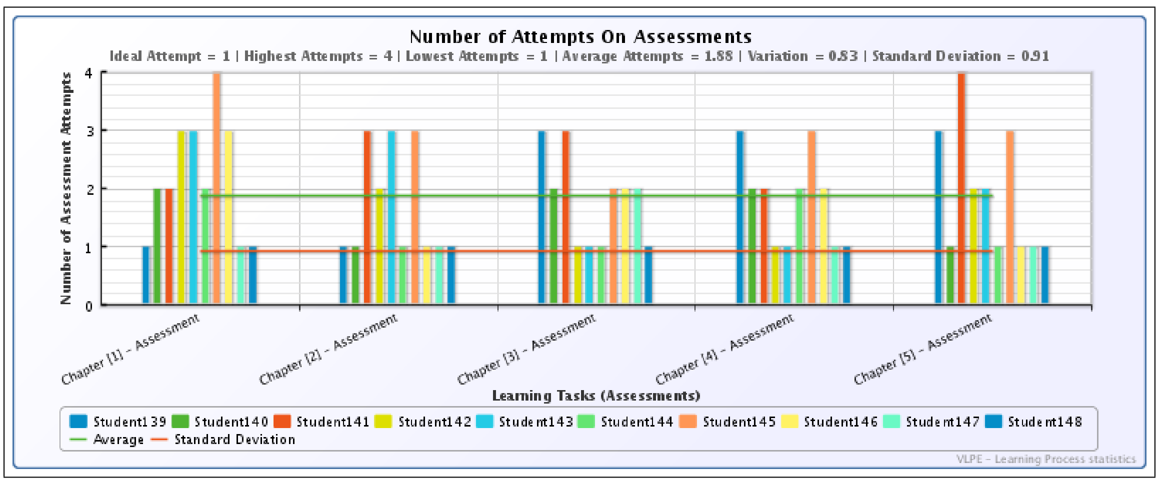


(c) Number of times an individual learner attempts reading chapters at the end of the learning process cycles.

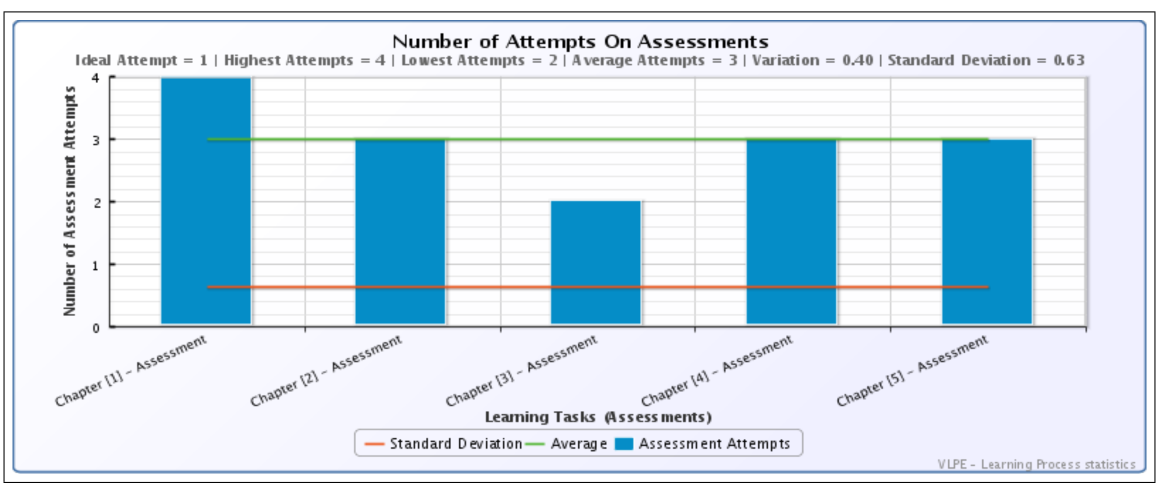
Figure 6.5: Number of times the cohort and an individual learner attempt reading chapters.



(a) Number of times cohort attempt the assessments on chapters in week 3.

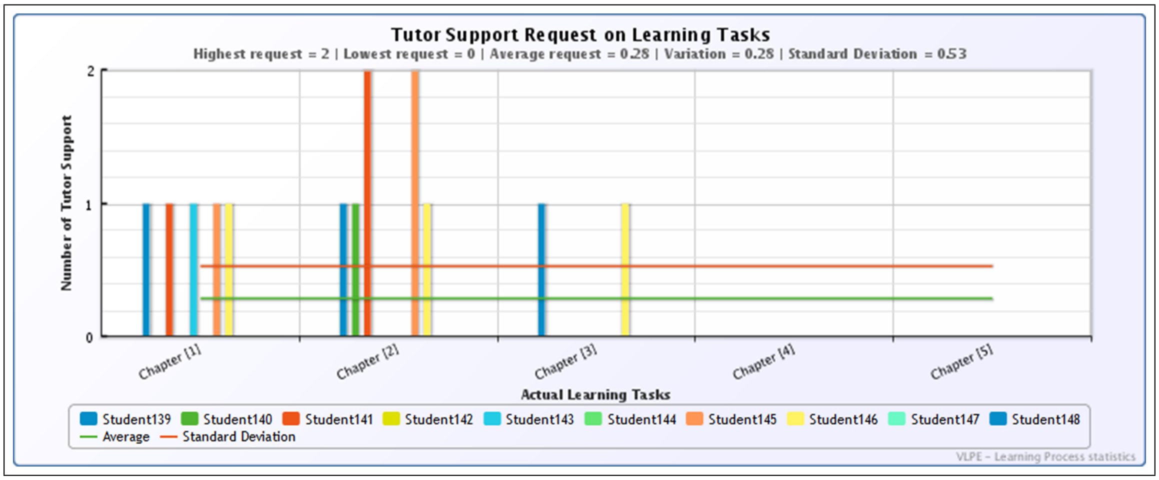


(b) Number of times cohort attempt the assessments on chapters at the end of the learning process cycles.

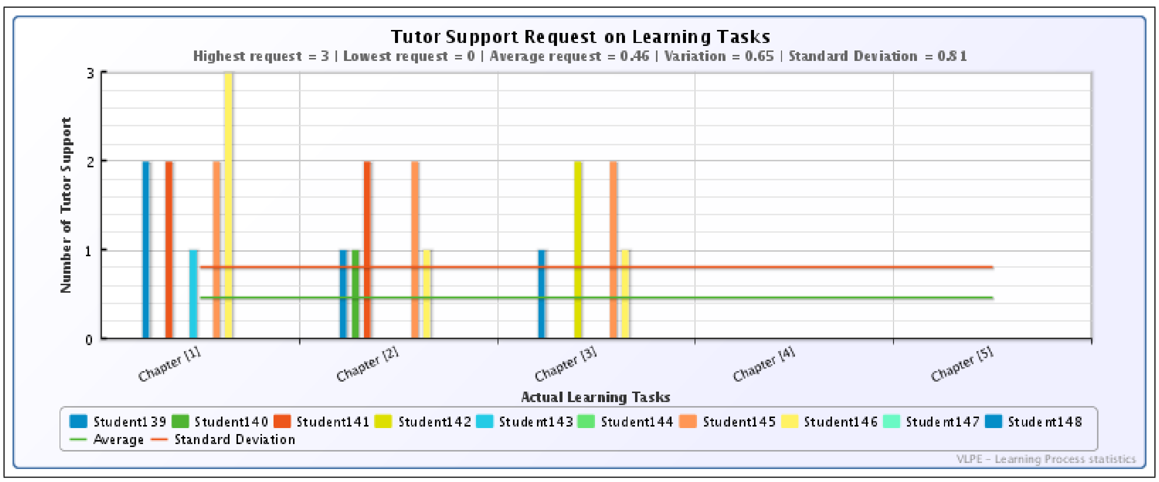


(c) Number of times an individual learner attempts the assessments on chapters at the end of the learning process cycles.

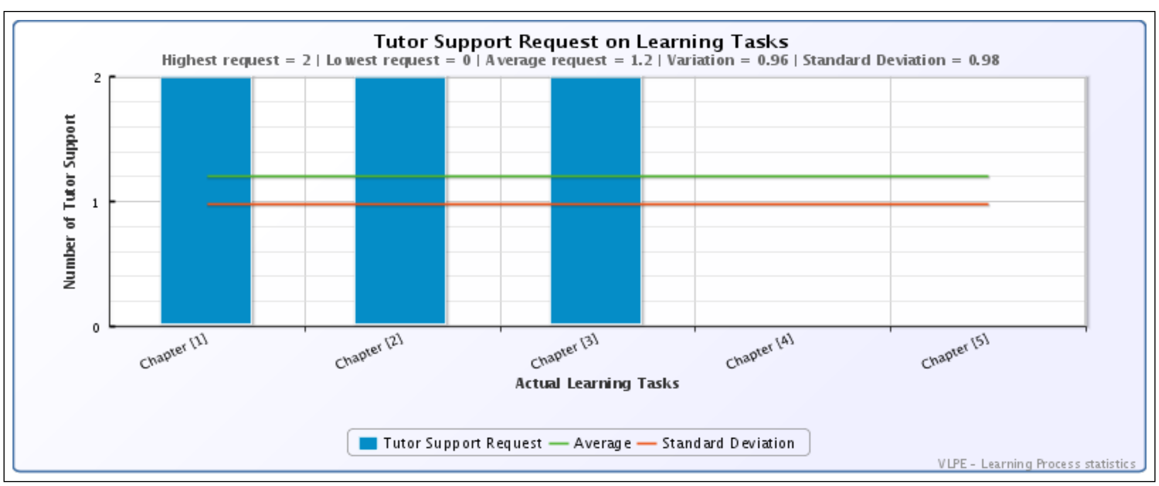
Figure 6.6: Number of times cohort and an individual learner attempt the assessments on each chapter.



(a) Number of tutor supports requested by the cohort in week 3.

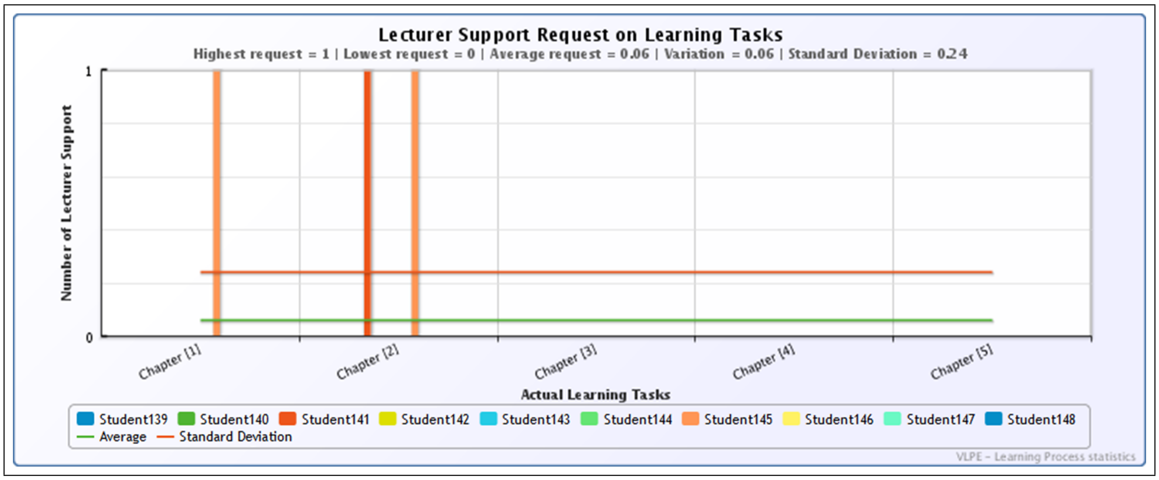


(b) Number of tutor supports requested by cohort at the end of the learning process cycles.

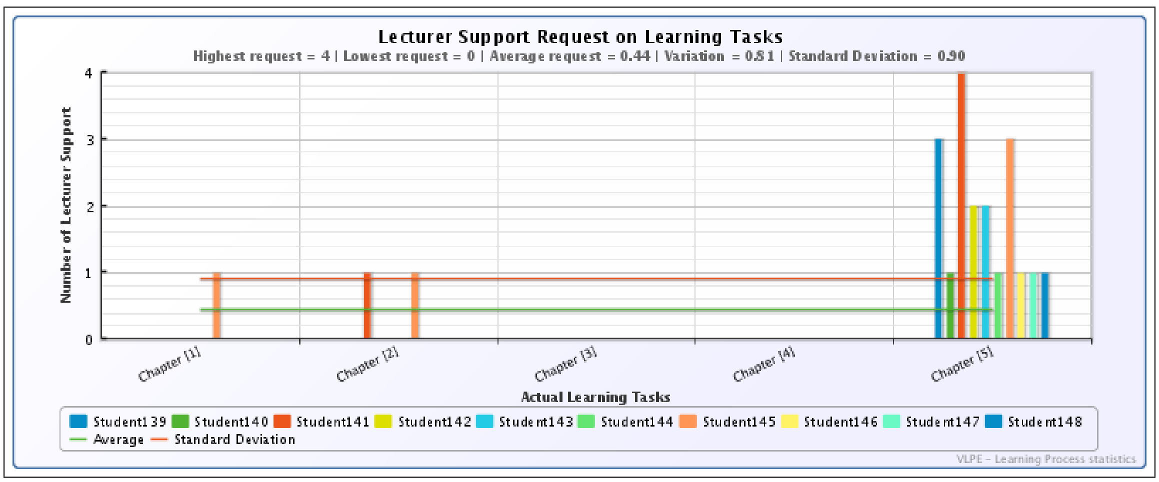


(c) Number of tutor supports requested by an individual at the end of the learning process cycles.

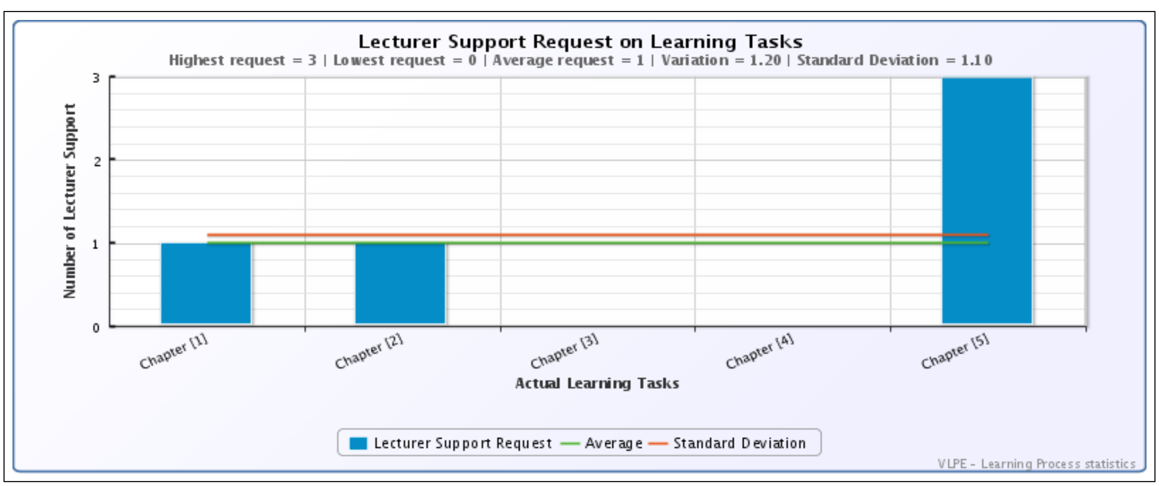
Figure 6.7: Number of tutor supports requested by cohort and an individual learner.



(a) Number of lecturer supports requested by the cohort in week 3.



(b) Number of lecturer supports requested by cohort at the end of the learning process cycles.



(c) Number of lecturer supports requested by an individual at the end of the learning process cycles.

Figure 6.8: Number of lecturer supports requested by the cohort and an individual learner.

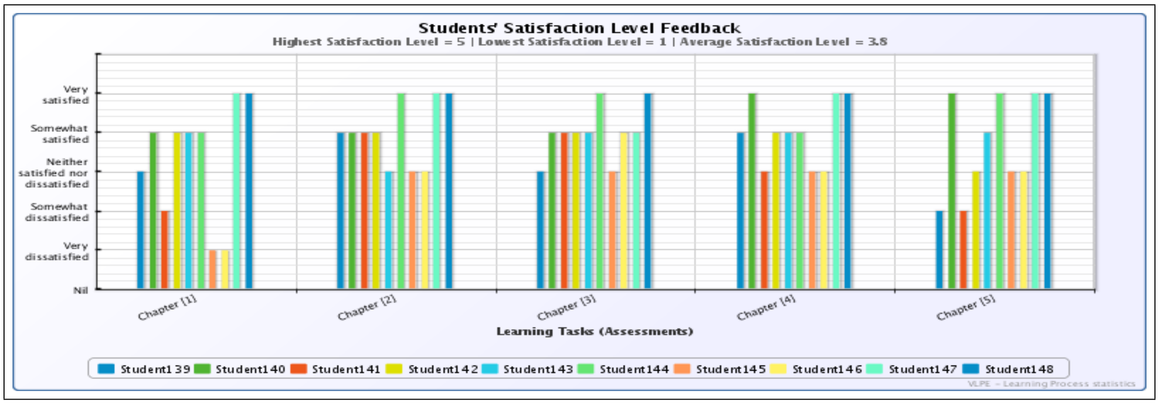
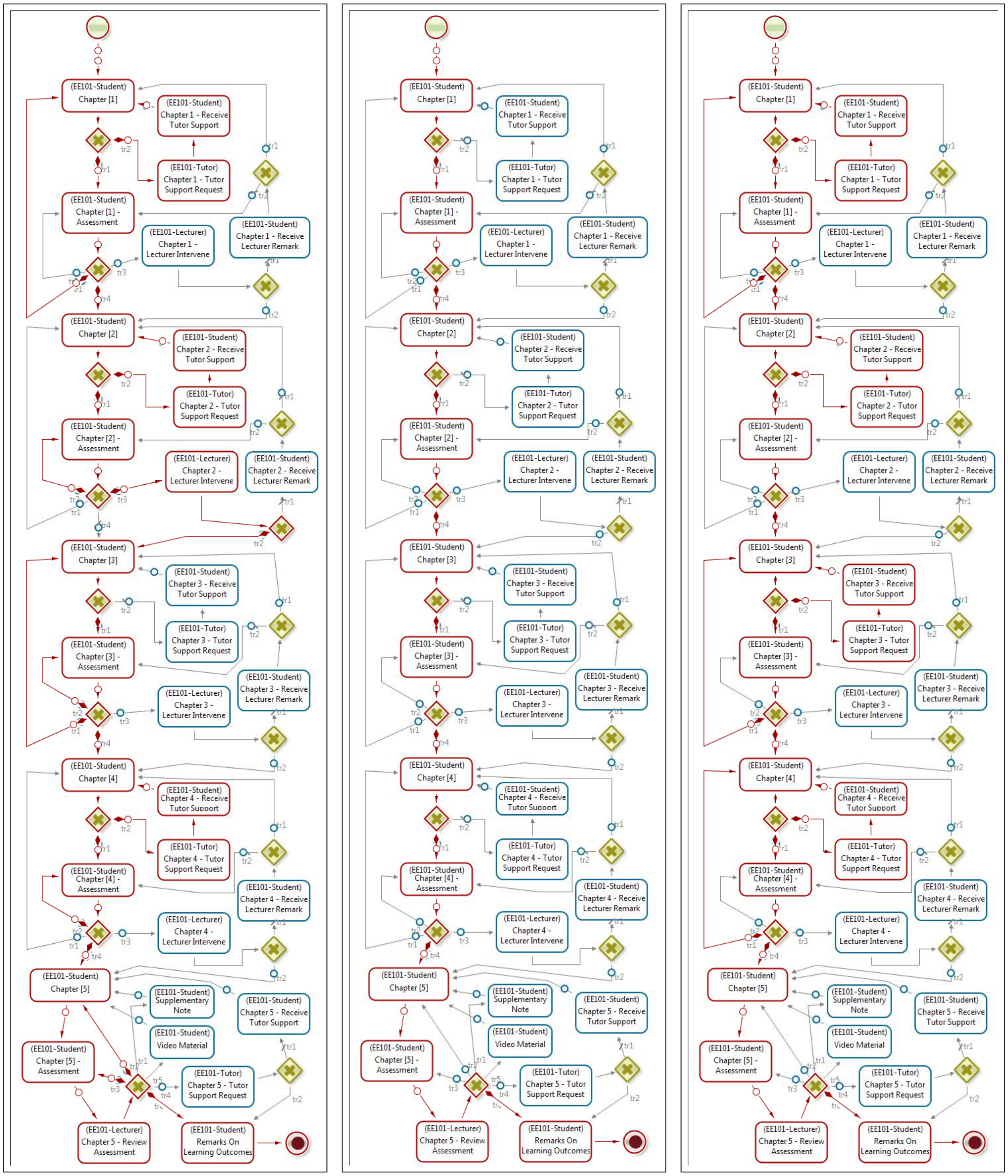


Figure 6.9: Cohort feedback on satisfaction level on each chapter at the end of the learning process cycles.



(a) The learning path of Student141 - captured and shown in red colour.

(b) The learning path of Student148 - captured and shown in red colour.

(c) The learning path of Student146 - captured and shown in red colour.

Figure 6.10: A set of the Learners' learning process paths (captured and shown in red colour) at the end of the learning process cycles.

6.2.2 ILPD: Personal Analytical results for Learning Process

Personal analytics is about analysis from an individual learner's perspective. One of the benefits of the proposed BPM-based architecture is that it also facilitates individual learners in monitoring and analysing their own learning performances in comparison to their peers in a real time anonymous manner through a personal analytics learning process dashboard. Using the ILPD feature within the VLPE, an example of how basic learning statistical information can be viewed and used by an individual learner to perform personal analytics on own learning performances is presented in this section.

Using the example of the modelled pedagogy presented in Chapter 5, the analytical results of a sample of the cohort of learners is presented. The analytical results on the learner can be assessed by the same learner that is performing the learning task and the examples of what could be analysed are:

- Personal learning task progression;
- learning level gauge;
- number of chapters completed;
- number of assessments completed and scores on each assessment;
- frequency of tutor supports; and,
- frequency of lecturer supports.

Each of these analysable outcomes is presented in a chart as shown in Figure 6.11 to Figure 6.15. Each chart provides basic statistical information such as the lowest, highest, average, variation and standard variation of any interaction with the learning task (i.e., chapter/assessment) or of any interaction with other participants (i.e., tutor/lecturer). While these are just some of the examples of what an individual could analyse with the VLPE, it is however possible to provide many other types of learning information that could help to improve personal learning analytics. Personal analytics can be performed in real time at any stage of the learning process and the learning statistical data on the personal analytics is juxtaposed with the rest of the cohort learning statistical data for comparison and contrast. For example, Figure 6.11 shows the trends of progression by Student145 on learning tasks (i.e., chapter/assessment). It also shows what learning task is done, when a learning task is done, how long it tasks to complete a learning task and the learning tasks that are outstanding.

Figure 6.12 allows Student145 to analyse, in more details, how he/she is progressing on every individual chapter of the module. For example, it can be observed by Student145 in Figure 6.12 that in the third week, 3 out of 5 chapters has been completed when compared to the average of 4 out of 5 completion by the cohort. It is observed that Student145 has either attempted to read or view a chapter at least 4 times, compared with highest attempt of 4 amongst the entire cohort. The 0 lowest attempt on chapter indicates that at least there is still a chapter that has not been read or viewed at all, this is also the case when compare with the entire cohort in the third week of the commencement of the learning process. Other significant statistical information are the average number of attempts, variation of attempts and standard deviation on the number of times Student145 has read or viewed the entire chapters. With an ideal number of attempt set to 1, the average number of attempts by Student145 so far is 1.4 and 1.06 by the cohort. The variation of attempts by Student145 is 1.84 and 1.14 by the cohort and 1.36 standard deviation by Student145 when compared with 1.07 by the cohort. In this example, depending on the pace of how Student145 may or may not process and retain information (i.e., cognitive strength), Student145 can deduce that he/she is either not too far away from the ideal attempt (as the average suggests) and therefore be happy with the progression thus far or that the comparable statistical results with the cohort is an indication that progression can be improved.

In the example of the modelled pedagogy, the rate of progress from one chapter to another is largely determined by the rate of performance on the subsequent assessment test that follow each chapter, where problem solving skills of the individual learners are put to test. Figure 6.13 allows Student145 to analyse how he/she is performing on the assessment tests that follow each chapter. The statistical results can also be compared with the cohorts'. Student145 can observe in Figure 6.13 that in week 3, so far, assessments on chapter 1 and 2 have been completed with 100% (i.e., 3/3) and 67% (i.e., 2/3) scores respectively. Other statistical results when compared to the cohort's result show that wile two chapters' assessments have been completed by Student145, an average total of three chapters' assessments have been completed by the cohort. Student145 highest number of attempts on any assessment is 4 times (i.e., chapter 1 assessment as shown in Figure 6.13) and the highest number of attempts amongst the cohort is also 4 times. Average of attempts is 1.4 and 0.92 by Student145 and the cohort respectively. Variation of attempts by Student145 is 3.4 when compared with 1.27 by the cohort. Also, the standard deviation of attempts is 1.74 and 1.13 by Student145 and the cohort respectively. It is worth noting that the average, variation and standard deviation are calculated on all of the available assessments on chapters (i.e., chapter 1 assessments to chapter 5 assessments). Therefore, the statistical results change with each completed assessment.

The statistical representation of the interactive context with tutor and/or lecturer can provide learners with the knowledge of the level of engagement. An individual learner can describe if he/she is learning alone or is fully engage with other in the learning process especially when support is needed. Although, any individual can choose to learn solitarily, one of the benefits of been able to analyse ones interactive history with others is that is gives the learner a sense of engagement especially when compared with the entire cohort interactive history. Figure 6.14 and Figure 6.15 show the interactive history and statistics of Student145 with a tutor and lecturer respectively. In Figure 6.14, the statistics on the interactions between Student145 and a tutor are shown. In the third week of Student145's learning process, a total number of 3 requests for supports were logged, this compares to a total number of 14 that were logged for the entire cohort. The highest number of request for tutor support on a particular chapter by Student145 is 2, same as the highest number of request by any member of the cohort. The average, variation, and standard deviation of the number of request for support by Student145 are 0.6, 0.64 and 0.80 respectively, compared to 0.28, 0.28 and 0.53 by the cohort respectively. Therefore, significant level of interactive support with the tutor is observed. The option to enhance the level or quality of interactive supports is part of the pedagogical approach in the example of the modelled pedagogy that is used to perform the learning analytics on the learner's learning process.

Since lecturer's support is modelled as an automatic call when system detects continuous and repetitive attempts on assessment tests, Figure 6.15 shows that the system invoked lecturer support for Student145 once on chapter 1 and 2 as he/she had repeatedly attempted the assessment tests 4 and 3 times respectively as shown previously in Figure 6.13. The statistical results of the interactive support with a lecturer show that so far in the third week of Student145's learning process, he/she as received from the lecturer 2 times compared with a total number of 3 supports for the entire cohort. The highest number of support on any particular chapter is 1, same when compared with the cohort. The average, variation and standard deviation of supports for Student145 is 0.4, 0.24 and 0.49 respectively and 0.06, 0.06 and 0.34 respectively for the cohort.

Conclusions on personal analytics are by and large dependent on how an individual learner perceived his/her progress and performance especially when compared with the cohort's learning progress and performance data. The examples of the learning statistical information that are presented in this section for personal analytics on learning are not a total picture of every possible element of learning statistics. The examples, however, provide a snapshot on the kind of learning data that can be captured as a result using BPM tool for pedagogical modelling. Within the current VLEs, certain learner's learning data (e.g., learner's login and

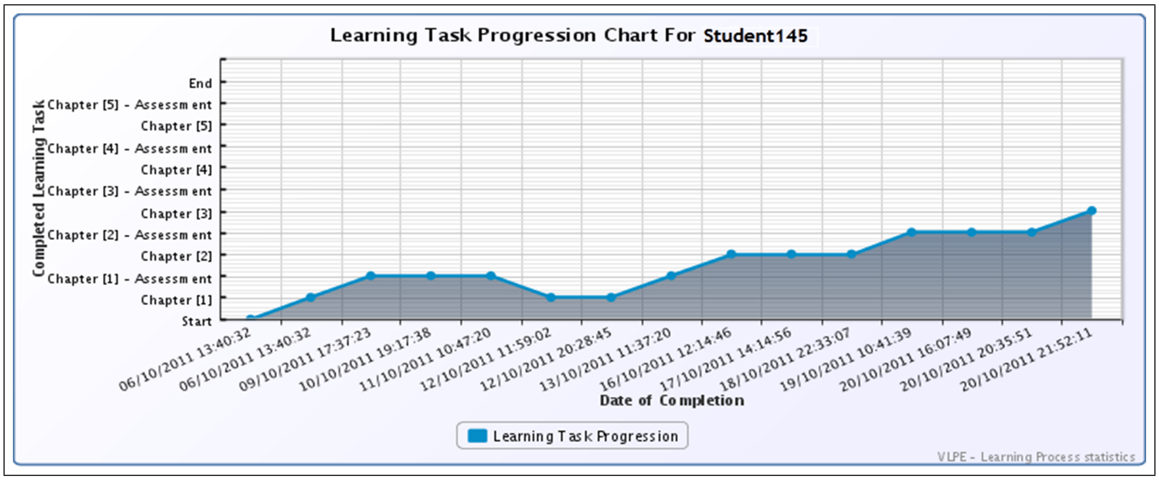
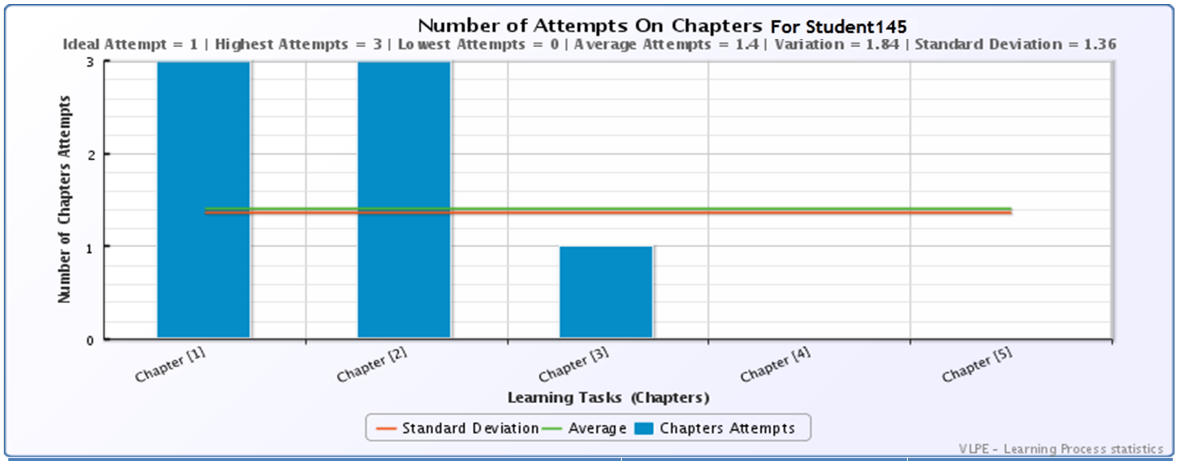


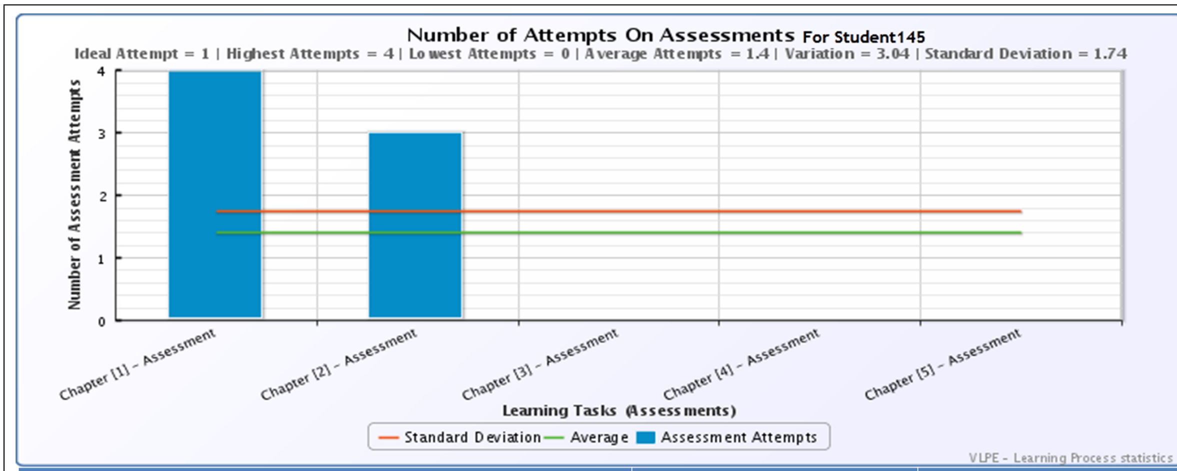
Figure 6.11: Student145's learning task progression chart in week 3.

logout, learner's assessments/exams results) can also be captured and analysed. However, the level of learner's transition from one learning level to another (i.e., from topic A to topic B often based on a simple HTML links) or the level of learner's interaction with peers, tutor and lecturer can be difficult to analyse. One of the key success factors in learning is the nature and quality of interactions. By adopting a suitable technological framework (i.e., the BPM in the case of the research work presented in this thesis), interactive pedagogy can be enhanced and quantitative learning data can be captured, monitored and analysed seamlessly.



	Personal Statistics	Cohort Statistics
Total # of Completed Chapters	3	4
Ideal # of Attempts	1	1
Highest # of Attempts	3	4
Lowest # of Attempts	0	0
Average of Attempts	1.4	1.06
Variation of Attempts	1.84	1.14
Standard Deviation	1.36	1.07

Figure 6.12: Statistics on the number of times that Student145 attempts reading chapters in week 3 - compared with the cohort.



	Personal Statistics	Cohort Statistics
Total # of Completed Assessments	2	3
Ideal # of Attempts	1	1
Highest # of Attempts	4	4
Lowest # of Attempts	0	0
Average of Attempts	1.4	0.92
Variation of Attempts	3.4	1.27
Standard Deviation	1.74	1.13

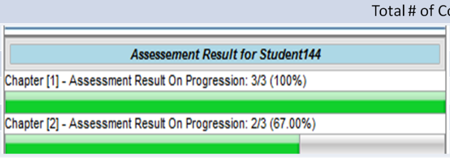
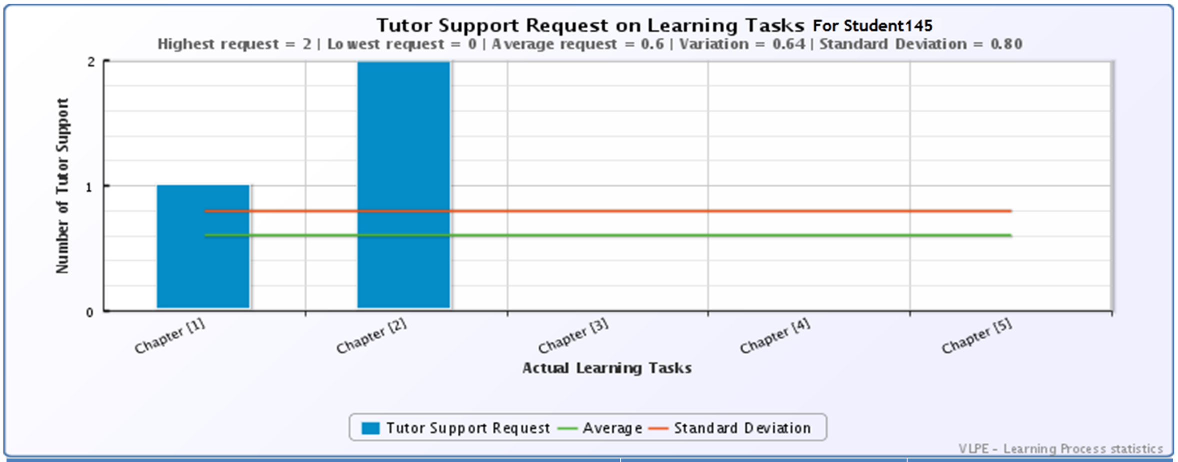
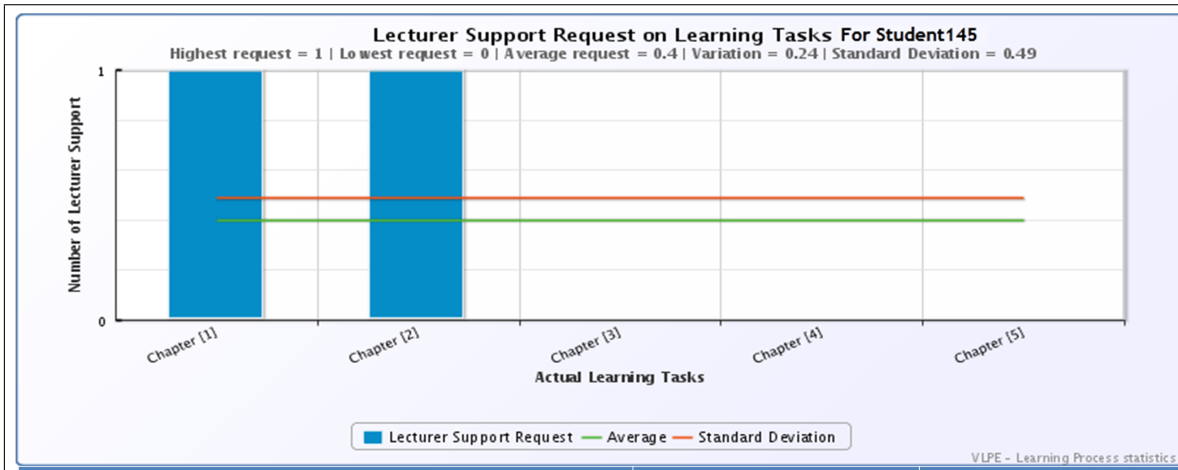


Figure 6.13: Statistics on the number of times that Student145 attempts the assessments (with scores) on each chapter in week 3 - compared with the cohort.



	Personal Statistics	Cohort Statistics
Total # of Supports	3	14
Highest # of Supports	2	2
Lowest # of Supports	0	0
Average of Supports	0.6	0.28
Variation of Supports	0.64	0.28
Standard Deviation	0.80	0.53

Figure 6.14: Statistics on the number of times that Student145 had sought tutor's support in week 3 - compared with the cohort.



	Personal Statistics	Cohort Statistics
Total # of Supports	2	3
Highest # of Supports	1	1
Lowest # of Supports	0	0
Average of Supports	0.4	0.06
Variation of Supports	0.24	0.06
Standard Deviation	0.49	0.24

Figure 6.15: Statistics on the number of times that Student145 had sought lecturer's support in week 3 - compared with the cohort.

6.3 Summary

Learning analytics are beginning to gain traction and will continue to play a significant role for future education, particularly within the online learning environments. Learning analytics deals primarily with the use of learning data to model analytical capabilities for tracking, monitoring, analysing and predicting learner's learning progression and performance. As a proof of concept, the capability for learning analytics is presented in this chapter as part of the proposed BPM-based architectural offerings that allow learning analysts (i.e., course designers/lecturers) to evaluate in real time the effectiveness of their chosen pedagogy using a live interactive learning analytics dashboard. With the aid of a learning analytics dashboard, learning analytics results can be presented to all e-learning stakeholders - where course designers/lecturers, learners and tutors can visualise and analyse various learning activities in a way that could contribute to or provide a better pedagogical approach for course designers/lecturers and better learning outcomes for the learners. The use of BPM approach helps facilitate the ability to auto-generate, collect and aggregate learning data for course designers/lecturers and learners so as to gain vital information on learning progression and performance in a real time manner.

In this chapter, examples of learning analytics from a course designer/lecturer and individual learner point of views are presented. The analytical results are based on the example of the modelled pedagogy that is orchestrated in the form of a learning process workflow which is presented in Chapter 5. Quantitative learning process information are gathered from a group of learners (10 learners) and samples of learning data (i.e., when learners complete learning task, who offer learning supports, the frequency of supports, how often do learners repeat or access a particular learning task etc) that can be used to perform learning analytics are auto-generated - one of the benefits of the proposed BPM-based architecture. The auto-generated learning data are further computed for statistical analysis (i.e., the average, variation, standard deviation etc). The learning analytics results are categorised into two parts - the cohort learning analytics presented in both the CLPD and ILPD; and, personal learning analytics presented in the ILPD.

The example of the modelled pedagogy is deployed and used to examine and analyse the progressions and performances of the cohort learning process as well as an individual learner's learning process. Because the proposed BPM-based architecture which the prototype implementation was built upon can deal with learning data in a real time manner, learning analytics on the instantiated learning processes can be performed at any stage of the learning process. For example, the cohort learning analytics that are presented in this chapter are based on two sets of learning analytics. The first set of the analytical results are performed on the outcomes of the cohort learning performances and progressions in the third week of starting the learning processes and the second set of the results is based on the final analyses of the learners learning processes upon completion of the learning processes. The analytical results presented are from the view point of the course designers/lecturers. As a result of the analysis, course designers are able to evaluate in real time the effectiveness of their chosen pedagogy.

An additional contribution of the prototype implementation of the proposed BPM-base architecture is that individual learners can also benefit from the use of both the ILPD to manage their learning processes through personal analytics. In this chapter, the same example of the modelled pedagogy is used to present an example of a personal analytics of an individual learner which can be observed from the view point of the individual learner. For example, the personal analytics results as observed by an individual learner into the third week of learning process are captured, monitored and analyse for his/her own learning progressions and performances in comparison with his/her observable peers' progressions and performances in a real time anonymous manner through a personal analytic learning process dashboard.

Depending on the goals and objective of the course designers/lecturers, the conclusive analytical results will obviously differ from case to case. Therefore, the results that are presented in this chapter is a demonstration of how real time online learning analytics can be made possible within the proposed BPM-based architecture for learning process management and not a demonstration on the merit for a particular pedagogical strategy or approach. In fact, by gaining access to quantitative information about the effectiveness of a particular pedagogical approach, areas of improvement can be discovered for future pedagogical designs.

Chapter 7

Conclusions and Further Research

7.1 Conclusion

Thanks to the advances in ICT, e-learning is here to stay and its significance in the 21^{st} century education system cannot be overemphasised. However, research has shown that the future demand and sustainability of online education will be driven by continuous improvements to the existing methods, tools and technologies that would bring about educational value for all of the e-learning stakeholders. Therefore, the current ways of managing online learning and educational pedagogy within the virtual learning environments need to improve.

7.2 Research Contributions

Most of the current e-learning systems solutions examined in Chapter 2 provide several advantages for online learning management through content management solutions. Based on further research investigations in Chapter 3, it becomes obvious that this approach to learning management is limited, as learning is considered to be a complex process that involves several factors. Some of these factors include: the level and quality of interactions among the e-learning participants and interactions between participants and content; learning behaviours and styles; cognitive (thinking) variations; and, the pedagogical principles that underpin learning processes. Following this line of research, there is a need to devise an alternative approach to the ways in which online learning is managed vis-à-vis the underlying pedagogy that is being adopted. IMS LD describes a XML-based metadata specification for learning design that can be used for various pedagogical purposes. However, one of the significant limitations of the IMS LD is the lack of support for reflexive cycle (closed-loop) learning activities (König and Paramythis 2010, Santos et al. 2008). In other words, once a learning task/activity is complete, the activity cannot be revisited even thought the ability to revisit and revise learning activity more than once can help to improve learning. As discussed in Chapter 2 Section 2.3.5, LAMS (an IMS LD tool) is also limited by the lack of support to perform the same activity more than once as shown in Figure 2.13. LAMS supports an acyclic sequence of activities and learners can only traverse an activity once. The ability to construct loops around learning activities using a BPM framework is an important difference with regard to the IMS LD specification. By using the BPM framework, it is possible to advance learning processes from an acyclic sequence of activities to a more complex web of interrelated activities with loops that allow learners to revisit and revise previously completed activities as many times as they like.

7.2.1 Major Contributions

The contribution of this work is a new e-learning architecture (BPM-based architecture for Virtual Learning Environments) that is proposed and presented in Chapter 4.1. This architecture is a novel and innovative e-learning architecture, which is based on Business Process Management (BPM) concepts. BPM is a methodology by which the efficiency and effectiveness of business processes can be optimised through the possible modelling, development, automation, deployment, management, monitoring and analysis of the operation of such processes in a way that involves humans, applications, organisations and other sources of information.

It is believed that by adopting the BPM concept, principle and technology, the requirements for an ideal state-of-the-art e-learning system solution, discussed in Chapter 3 - particularly, on learning process management through the modelling of an online educational pedagogy, can be developed as a potential blueprint for future designs and implementations of online learning environments.

As a proof of concept, Chapter 5 presents a prototype design and implementation of the proposed BPM-based learning process management architecture - Virtual Learning Process Environment (VLPE). Within VLPE, a standalone BPM-based pedagogy-specific modelling tool (for pedagogical modelling purpose) and a BPM web-based application (for learning process management) are presented. The prototype itself does not aim to solve all of the issues associated with the current Virtual Learning Environments that are discussed in Chapter 2, but rather, it provides one possible implementation of the new architecture in a way that can serve as proof that the proposed new architecture can be used to facilitate the management of online learning processes including graphical modelling of an online educational pedagogy. This approach to online learning management has two major consequences for course designers in their pedagogical practices.

1. In Chapter 5, it is demonstrated that by using the BPM approach, course designers can use intuitive graphical flow diagrams to model their chosen educational pedagogies in the form of learning process workflows. Consequently, course designers are able to monitor, analyse and evaluate in real time the effectiveness of their chosen pedagogy. Although the LAMS framework provides the use of graphical flow diagrams to design a sequence of learning activities, LAMS is still limited by the limitations of the underlying IMS LD specification. The most obvious one is the lack of support for cyclic navigations that could allow multiple repetition of a learning activity more than once as discussed

previously. On the other hand, current BPM standard specifications provide not only a closed-loop capability that enables the entire system to be monitored for continuous improvements but also a loop around a specific activity is possible. Thus, learning activities can be revised for as many times as learners' desire. The BPM approach is a process-oriented and event driven approach. Therefore, by using the BPM framework, an online educational pedagogy can be orchestrated in the form of a non-linear learning process workflow with several interrelated learning activities that are event-driven (i.e., an activity could be triggered by real time learning event like "posting a new topic in a discussion forum" or "extension of assignment submission deadline"). An orchestrated learning process workflow is deployed into a process run time engine where is can be run and executed in an automated fashion.

2. In Chapter 6, it is demonstrated that by using the BPM approach, it is possible to capture quantitative learning process information. Consequently, course designers can perform learning analytics on a modelled learning process workflow using a live interactive learning analytics dashboard. The captured learning data can be computed for statistical analysis that could inform the need for pedagogical intervention on an ongoing learning process and/or a possible future pedagogical reform. In other words, once a course delivery is complete the collated quantitative information can also be used to make major revisions to pedagogy design for the next iteration of the course. Within the LAMS framework, it is possible to monitor a linear sequence of learning activities is shown in Figure 7.1. However, learning analytics with statistical metrics is lacking. Within the VLPE, learning analytics is enabled on two levels. It enables course designers to monitor learning paths, progressions and performances using an advance learning process analytical dashboard (described in Chapter 6). The analytical dashboard consists of graphical learning process workflow diagrams (each representing an individual learner's learning pathway), and various statistical charts that provided

in-depth information on various aspects of the cohort and individual learning processes.

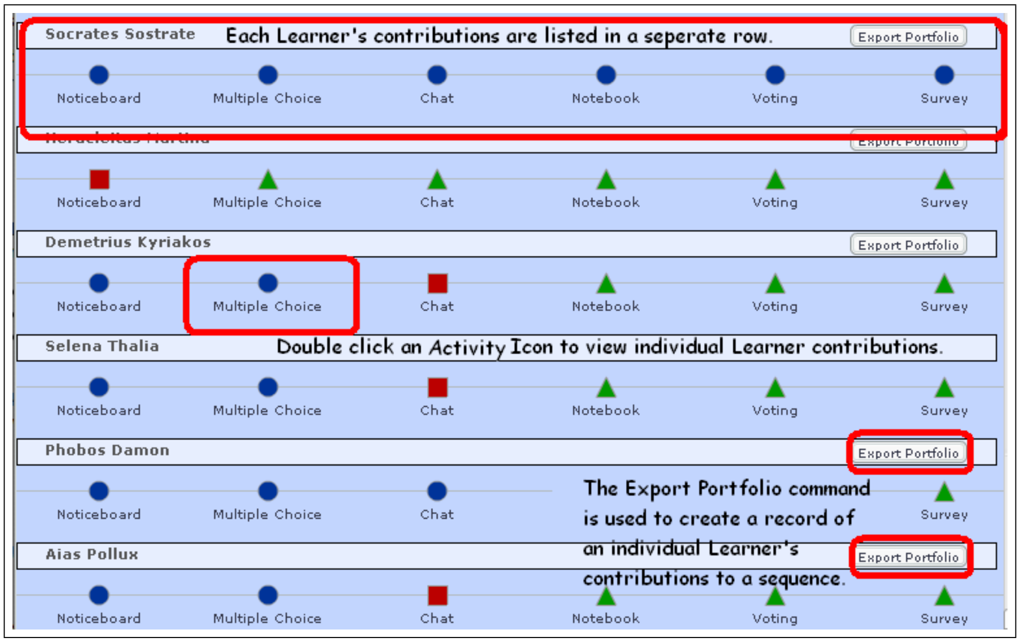


Figure 7.1: Monitoring capability with LAMS framework.
Source: (Dalziel 2008)

An additional contribution of this work is that this new architecture facilitates individual learners in monitoring and analysing their own learning performances in comparison to their peers in a real time anonymous manner through a personal analytics learning process dashboard. An example of a modelled learning process workflow and how it can be used to enhance and increase the information available for learning analytics is presented in Chapter 4 and 6.

7.2.2 Minor Contributions

Other contributions of this work include the possibility for course designers to be able to use BPM intuitive graphical flow diagrams to:

- Create flexible customised multiple learning pathways for the cohort of learners - Customised learning paths through course materials is based on the number of nodes/-

branches that are created within the orchestrated learning process. Learners' pathways are guided by a combination of constraints that are based on learning rules and choices. Although, multiple learning pathways can be constructed using HTML hyperlinks within the current VLEs, BPM takes away a lot of hard coded low level programming and allows a higher-level toolset to be adapted for the orchestration of multiple learning pathways easily. LAMS provides a higher-level toolset that can also be used to design learning pathways. However, it is demonstrated that by using the BPM approach, complex multiple pathways can be orchestrated. In particular, a loop back to previously completed learning tasks/activities is possible and learners can repeat learning activities as many times as they like. This is not currently possible within the LAMS framework. With the BPM architecture, learning path construction is only limited to imagination and resources.

- Define and model an enhanced interactive pedagogy by defining explicitly the group of users (students, tutors and lecturers) that are responsible for performing particular learning tasks. This is made possible through the use of the swimlane feature of the modelling tool to orchestrate the interactions between learning services (learning objects and competence-based assessment) and human-task services (learner, tutor and lecturer). Since it is widely believed that one of the key success factors in learning is the nature and quality of interactions, by using the modelling tool, course designers are able to sketch the mode and extent to which a learning process workflow enables a flexible and adaptive interactive pedagogy through the course material. The implementation of an interactive pedagogy in a learning process within the VLPE encompasses an approach where a general learning outcome is the ultimate goal but individual learner's learning behaviour within a learning process determines the level of interactivities in achieving the desired learning outcome.

7.3 Current Challenges and Limitations of a BPM Approach

The VLPE solution that is presented in Chapter 5 is a prototype demonstration of the proposed new BPM-based learning process management architecture and is not a complete fully fledged VLE. However, this research found that BPM technologies can be re-purposed in a meaningful way to produce tools and a runtime environment that may be useful in the target learning technology domain (module and programme level management, analytics etc.). The research also found that the adoption of a BPM approach is not without its challenges and limitations. From a technical point of view, one of the drawbacks of a BPM approach lies in the complexity of its frameworks and specifications. This concern is also shared across the enterprise industry where a BPM approach is widely adopted. There are fewer open-source frameworks to support the complex undertaking of the implementation of a full fledge BPM software system. Therefore, a BPM approach can be an expensive undertaking. The specifications of the BPM technologies are very much enterprise oriented - as the name suggested. Hence, the specification constructs do not cover areas of educational disciplines, such as pedagogy. Although BPM is domain agnostic, extending its specifications and standards to areas of educational models will significantly influence its adoption as a learning technology.

For academic staff, such as course designers and lecturers, the use of a BPM software system can be a challenging exercise. The learning curve (i.e., to have academics learn more how to use BPM tools to manage their courses) is very steep. There would be a significant training cost involved. Getting the maximum benefits from the use of BPM software systems can and will increase the workload for academics. For example, improvement on subsequent pedagogical models will involve a significant analysis and evaluation of the effectiveness of the previous pedagogical models.

7.4 Future Directions For Research

In spite of the challenges facing a BPM approach, the result (from a pedagogical modelling and learning analytics point of view) of the VLPE (prototype implementation of the BPM-based architecture) is significant and encouraging. Therefore, as the open-source BPM frameworks, on which this research relies, are only beginning to gain traction, it is expected that the level of complexity will reduce over time through the addition of more assistive and visual design tools. The drawback mentioned in Section 7.3 forms part of the future direction of this research. That is, as the open-source frameworks continue to improve, it is hoped to advance an open-source implementation and deployment of the proposed architecture, with a view that the BPM approach would be integrated into current VLEs such as Moodle and Sakai; albeit, this would require a significant refactoring of the Moodle system. This is because of the significant differences between the technological platforms of these VLEs and BPM-based system.

Furthermore, future work will be directed at extending the structure and scope of the new architecture with the view to integrating the current e-learning content standards. That is, upon completion of the investigation into the exploration of the IEEE LOM and IMS LOM standards, the extensions of these standards could be adopted and integrated within the proposed architecture in order to enhance pedagogical modelling and customisation of individual learning processes. The IEEE LOM and IMS LOM standards that would be further investigated include:

- assessment standards like IMS QTI (Question & Test Interoperability);
- IEEE PAPI (Public and Private Information) - to define a 'portable' learner;

- IMS LIP (Learner Information Profile) - in part, been derived from the PAPI;
- IMS LD (learning design) - for content design; and,
- IMS CP (content packaging) - used to export, import, aggregate and disaggregate content packages between multiple systems.

Appendix A

VLPE (BPM web-based) Class Diagrams

Within an integrated design environment (i.e., an eclipse IDE), the VLPE directory structure in GWT design environment is divided into three core sections: the client side, the server side and the compiled code for deployment as shown in Figure A.1. Some of the class files that make up some of the components of the VLPE application are shown in Figure A.2 to Figure A.20.

The client side directories represent the implementation of the VLPE client user interface (UI) and the interface engines that allow communication with the server side. It is written entirely in Java language. However, GWT provides a compiler that converts GWT Java client code to browser-readable codes (usually in JavaScript codes). The server side directories contain the implementation of the core application logic codes (i.e., the logic codes that are related to learning process management and persistence logic). The deplorable directory represents the hierarchical directory structure of the standard web application archive (WAR) as shown in Listing A.1. It contains the combination of the compiled client codes (JavaScripts and other corresponding files like the CSS), the server codes and other misc files that can

Appendix A – VLPE (BPM web-based) Class Diagrams

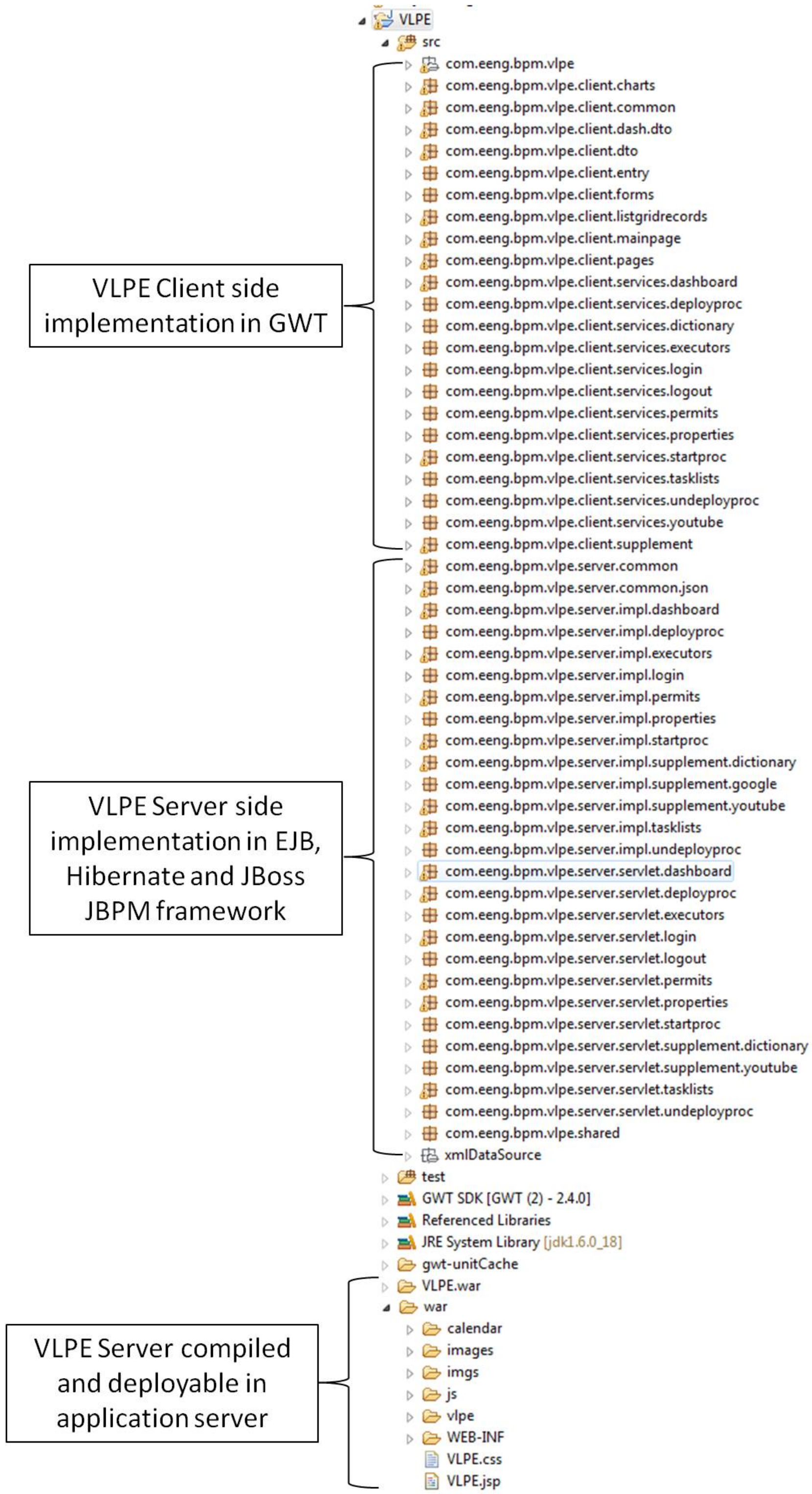


Figure A.1: VLPE directory structure in GWT design environment.

deployed in a production application server - the VLPE is configured to run on a JBoss application server.

```
MyHellowWorld.war
   index.html
   *.jsp
   WEB-INF/
      web.xml
      lib/
      classes/
   META-INF/
   images/
```

Listing A.1: Standard WAR structure

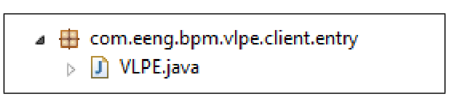


Figure A.2: VLPE main entry class.

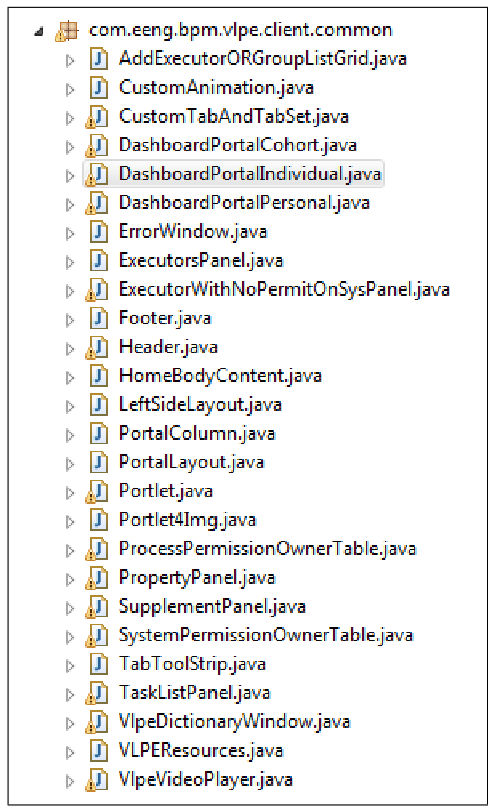


Figure A.3: VLPE: some structure classes (client common).

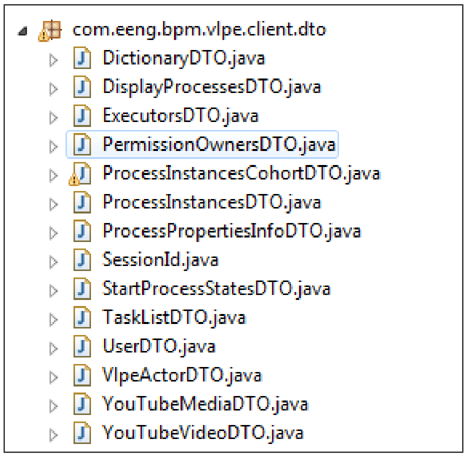


Figure A.4: VLPE: some structure classes (client DTO).

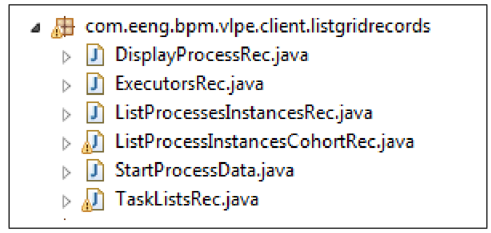


Figure A.5: VLPE: some structure classes (grid record).

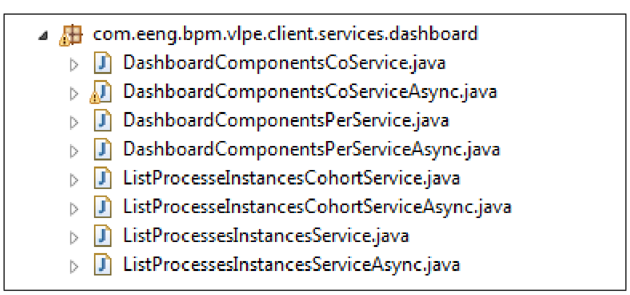


Figure A.6: VLPE: some structure classes (dashboard service).

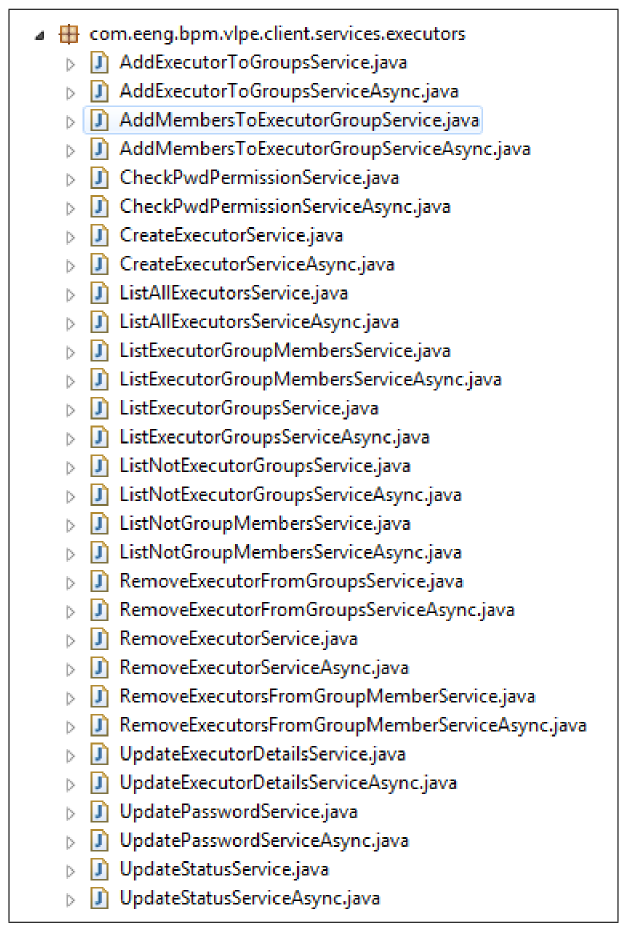


Figure A.7: VLPE: some structure classes (executor service).

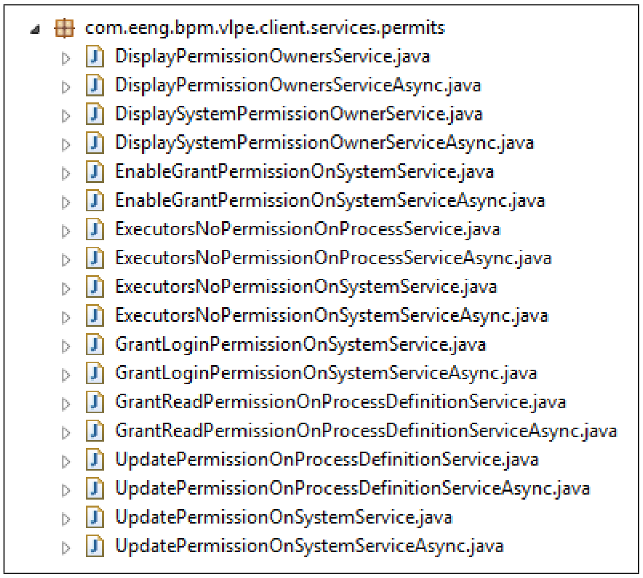


Figure A.8: VLPE: some structure classes (permission service).

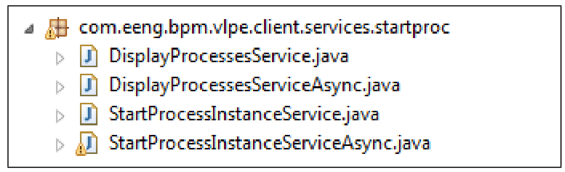


Figure A.9: VLPE: some structure classes (start process service).

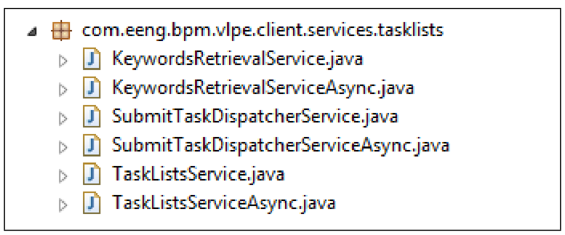


Figure A.10: VLPE: some structure classes (tasklist service).

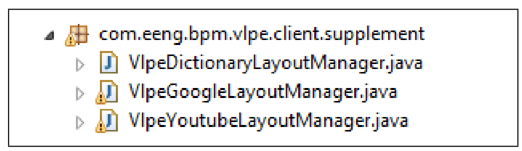


Figure A.11: VLPE: some structure classes (supplementary services).

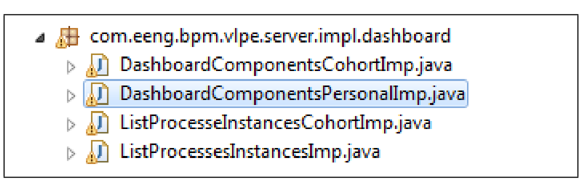


Figure A.12: VLPE: some structure classes (dashboard implementation).

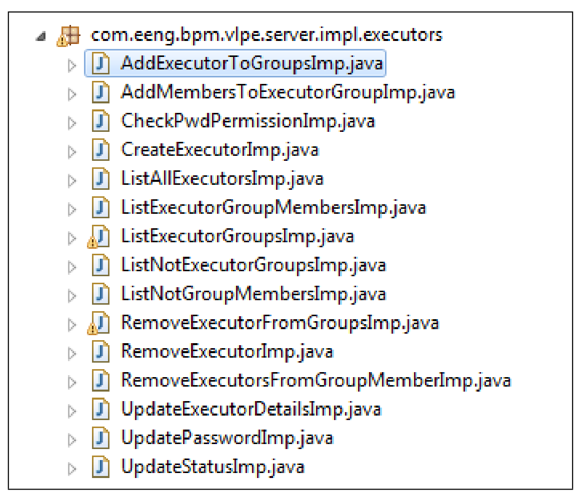


Figure A.13: VLPE: some structure classes (executor implementation).

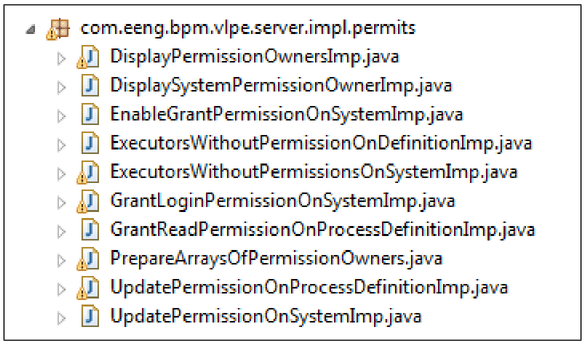


Figure A.14: VLPE: some structure classes (permit implementation).

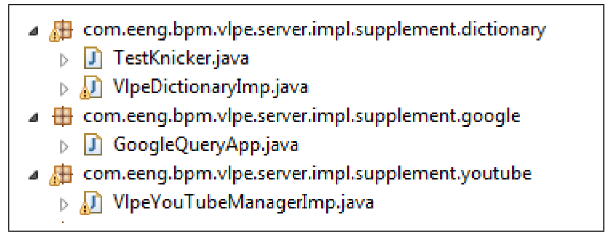


Figure A.15: VLPE: some structure classes (supplementary implementation).

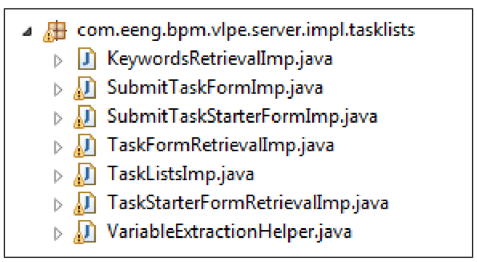


Figure A.16: VLPE: some structure classes (tasklist implementation).

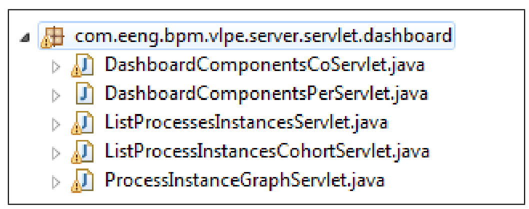


Figure A.17: VLPE: some structure classes (servlet dashboard).

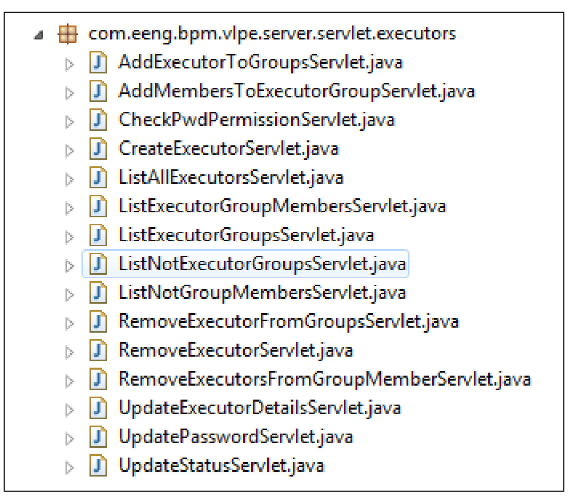


Figure A.18: VLPE: some structure classes (servlet executor).

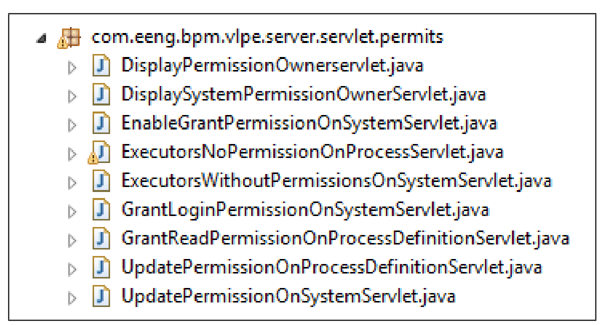


Figure A.19: VLPE: some structure classes (servlet permit).

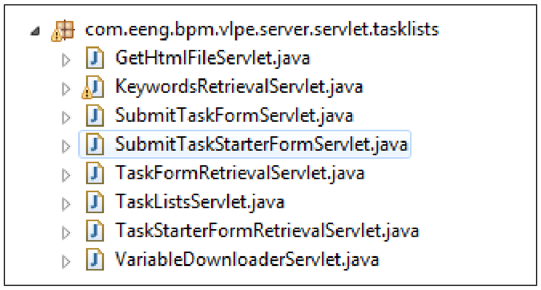


Figure A.20: VLPE: some structure classes (servlet tasklist).

Appendix B

Content of the Mathematics-101 Course

Using the example of the pedagogical plan shown in Figure 5.6. Pedagogy was modelled around a Mathematics-101 course in the form of a learning process workflow. The course content covers:

Chapter 1 - Algebra

- Equation.
- Quadratic Equation.

Chapter 2 - Sequence

- nth or general term.
- Arithmetic Sequence.
- Geometric Sequence.
- Fibonacci Sequence.
- Finite Sequence.

- Infinite Sequence.

Chapter 3 - Series

- Summation Notation.
- Series.
- Finite Series.
- Infinite Series.

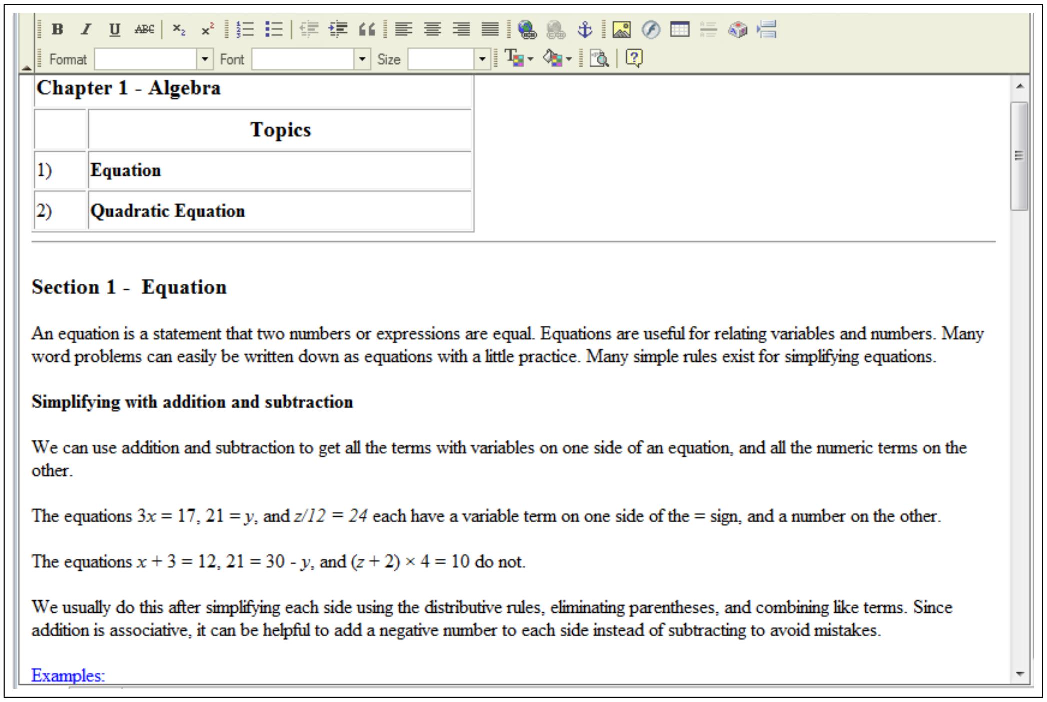
Chapter 4 - Differentiation

- General Formulas.
- Product Rule.
- Quotient Rule.
- Chain Rule.
- Power Rule.

Chapter 5 - Integration

- Integration of Basic Functions.
- Integration by Substitution.

Within the VLPE, the Custom Lightweight Pedagogical Modelling Application (CLPMA) is used to create or add learning materials/content within learning task elements using an integrated WYSIWYG editor tool. Figure B.1 to Figure B.5 show chapters of the content of the Mathematics-101 course created in different learning task elements.



Chapter 1 - Algebra

	Topics
1)	Equation
2)	Quadratic Equation

Section 1 - Equation

An equation is a statement that two numbers or expressions are equal. Equations are useful for relating variables and numbers. Many word problems can easily be written down as equations with a little practice. Many simple rules exist for simplifying equations.

Simplifying with addition and subtraction

We can use addition and subtraction to get all the terms with variables on one side of an equation, and all the numeric terms on the other.

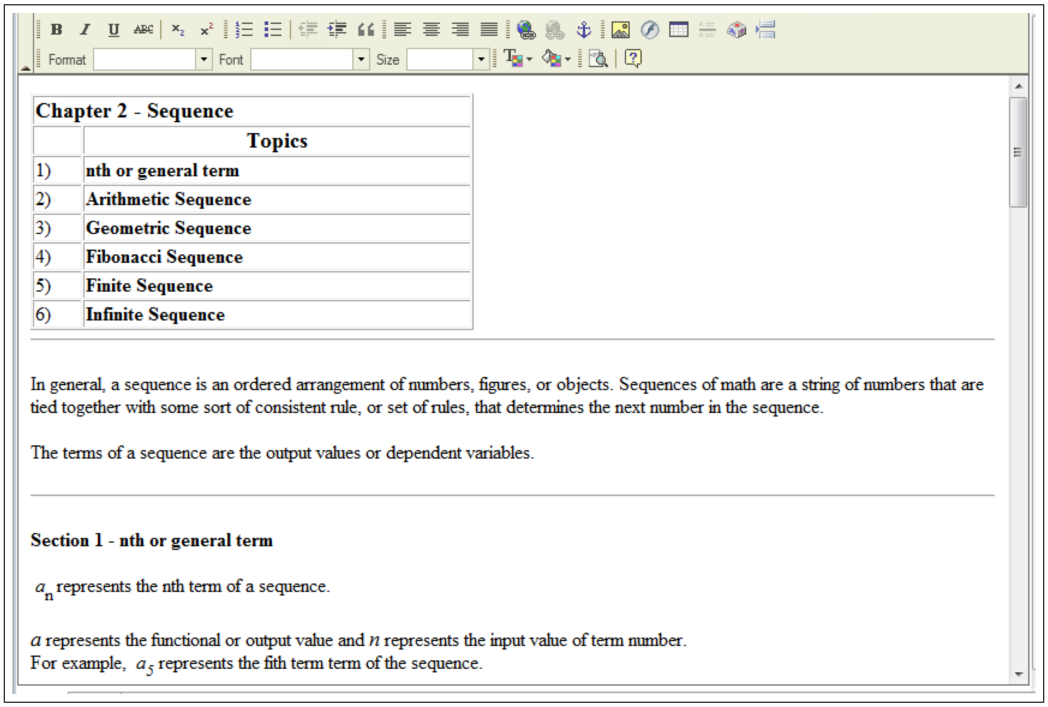
The equations $3x = 17$, $21 = y$, and $z/12 = 24$ each have a variable term on one side of the = sign, and a number on the other.

The equations $x + 3 = 12$, $21 = 30 - y$, and $(z + 2) \times 4 = 10$ do not.

We usually do this after simplifying each side using the distributive rules, eliminating parentheses, and combining like terms. Since addition is associative, it can be helpful to add a negative number to each side instead of subtracting to avoid mistakes.

Examples:

Figure B.1: Chapter 1 content.



Chapter 2 - Sequence	
	Topics
1)	**nth or general term**
2)	**Arithmetic Sequence**
3)	**Geometric Sequence**
4)	**Fibonacci Sequence**
5)	**Finite Sequence**
6)	**Infinite Sequence**

In general, a sequence is an ordered arrangement of numbers, figures, or objects. Sequences of math are a string of numbers that are tied together with some sort of consistent rule, or set of rules, that determines the next number in the sequence.

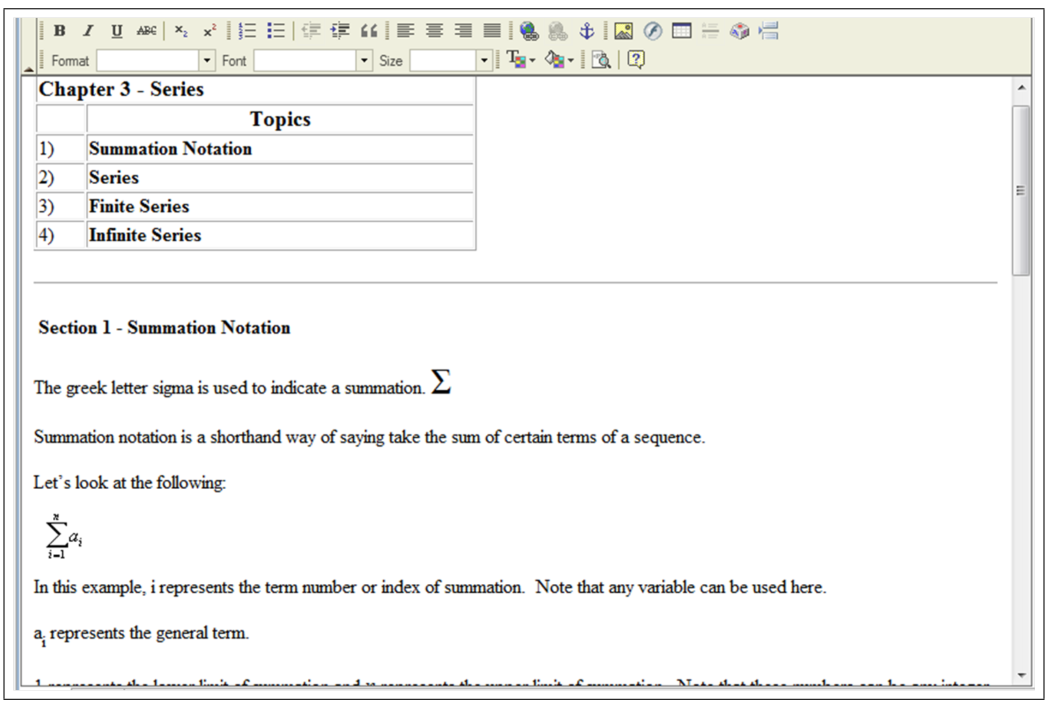
The terms of a sequence are the output values or dependent variables.

Section 1 - nth or general term

a_n represents the nth term of a sequence.

a represents the functional or output value and n represents the input value of term number.
For example, a_5 represents the fith term term of the sequence.

Figure B.2: Chapter 2 content.



Chapter 3 - Series	
	Topics
1)	**Summation Notation**
2)	**Series**
3)	**Finite Series**
4)	**Infinite Series**

Section 1 - Summation Notation

The greek letter sigma is used to indicate a summation. Σ

Summation notation is a shorthand way of saying take the sum of certain terms of a sequence.

Let's look at the following:

$$\sum_{i=1}^{n} a_i$$

In this example, i represents the term number or index of summation. Note that any variable can be used here.

a_i represents the general term.

Figure B.3: Chapter 3 content.

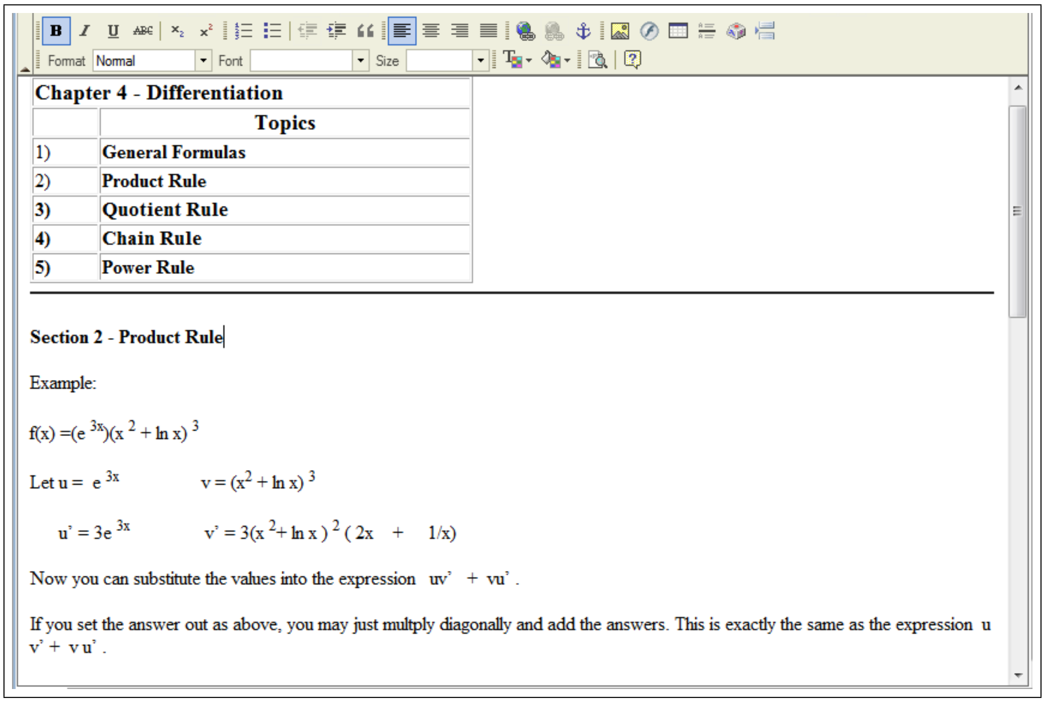


Figure B.4: Chapter 4 content.

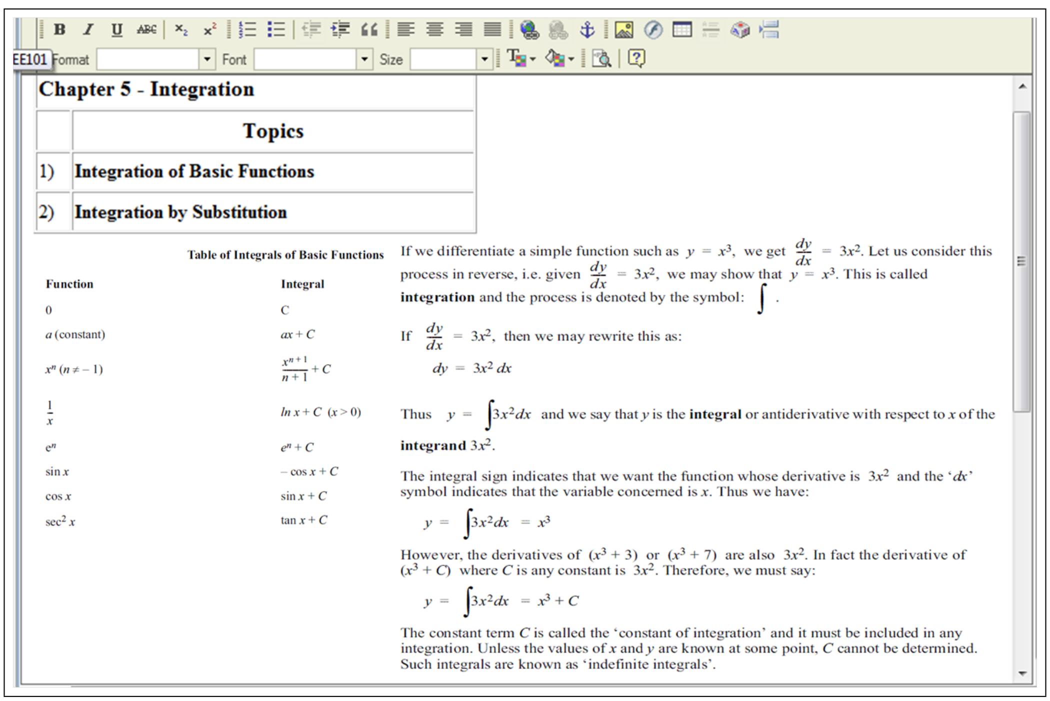


Figure B.5: Chapter 5 content.

Appendix C

Consent letter to participants

For user level testing, 10 participants (between the ages of 18 and 20) were invited to voluntarily participate in a short introductory course on Mathematics. They were invited by face-to-face discussion and a verbal agreement was the basis for consent. It became apparent during the viva voce examination that there was an oversight in that this agreement should have been in writing even though no personal data was captured in the testing. To remedy this oversight, the DCU Research Ethics Committee (REC) was consulted for advice. It was advised that the participants should be contacted and retrospectively provided with a copy of the letter of consent that they should have been asked to sign. In addition to providing this letter, the participants were offered the option to 'opt out' of the experiment. Should any of the participants have chosen to opt out, that participants data would have been removed from the experiments and the results would have been regenerated within the thesis document and observations would have been adjusted. A copy of the Consent Letter that was distributed retrospectively is presented herewith:

Appendix C – Consent letter

Dear Participant,

My name is Ayodeji Adesina and I am a PhD research student at the school of electronic engineering, Dublin City University. My research is titled "Virtual Learning Process Management: A BPM-Based Learning Process Management Architecture" and it is under the supervision of Dr. Derek Molloy.

The purpose of this research is to explore and investigate the viability of adopting the concepts of Business Process Management as a new and innovative architectural solution for an e-learning system. Particularly, to gain a better understanding of the intricacies of learning processes through learning analytics for the purpose of improving online pedagogical practices. Therefore, a prototype solution – VLPE (Virtual Learning Process Environment) – is implemented. One of the key functions within the prototype system is the ability to monitor learning processes in real-time.

Your participation will involve the following:

- **Taking a short course on Mathematics**

You are invited to participate in a free online short course on Mathematics covering 5 topics (Algebra, Sequences, Series, Differentiation and Integration). During learning process, you will have the opportunity to do the following: have access to learning materials; ask a tutor and/or instructor any questions with regard to the learning material by using the interactive tool (question box) provided within the system; have access to a learning process dashboard that would allow you to monitor and compare your learning performance and progression with the rest of the learning group anonymously.

Privacy

There is no privacy issue associated with your participation. Upon the receipt of your consent, you will be provided with a unique username and password. These are the only online credentials needed to access VLPE system and no personal data (name, gender, age etc.) is needed nor used within the VLPE system or the research report. However, if during the course of your learning you are concerned with the issue of privacy, you can stop at anytime and discontinue your learning process.

Benefits of Your Participation and Incentive

Your participation can help to enhance online pedagogical practices through learning analytics and thus, substantiate the viability of the BPM offerings in this respect. You will not receive any financial incentive for participating.

Voluntary Participation

Taking part in the short Mathematics course is totally voluntary. You may refuse to participate or withdraw from the study at any time.

Participant Consent
I have read this consent letter and was given the opportunity to ask questions.

I, ……………………………. (Participant name) consent to participate in a short online course within VLPE system.

Participant's signature …………………………………………… Date: ……………………………………

Researcher’s signature ……………………………………………. Date: ……………………………………

*If you have any questions, please do not hesitate to contact me at Ayodeji.adesina@mail.dcu.ie

Bibliography

Adesina, A. and Molloy, D. (2010). Capturing and monitoring of learning process through a business process management (BPM) framework. *3rd International Symposium for Engineering Education*. University College Cork, Ireland.

Adesina, A. and Molloy, D. (2011a). A business process management based virtual learning environment: Customised learning paths. *Proceedings of 3rd International Conference on Computer Supported Education (CSEDU 2011)*. Noordwijkerhout, Netherlands.

Adesina, A. and Molloy, D. (2011b). A business process management based virtual learning environment: The human interaction management system. *Proceedings of the Red-Conference: Universita della Svizzera italiana, Lugano (Ascona, Switzerland)*. [ISBN: 978-88-6101-010-9].

Adesina, A. and Molloy, D. (2012a). Virtual learning environment versus virtual learning process environment. *IADIS International Conference e-Learning, part of the IADIS Multi Conference on Computer Science and Information Systems (MCCSIS 2012)*. Lisbon, Portugal.

Adesina, A. and Molloy, D. (2012b). Virtual learning process environment: Cohort analytics for learning and learning processes. *Proceedings of International Conference on e-Education and e-Learning, ICEEEL*. Amsterdam, Netherlands. Accepted for a journal publication with the International Journal of Social and Human Sciences (Vol. 6. 2012).

Agostinho, S., Bennett, S., Lockyer, L., and Harper, B. (2004). Developing a learning object metadata application profile based on lom suitable for the australian higher education context. *Australasian Journal of Educational Technology*, 20(2):191–208.

Aldazabal, A., Baily, T., Nanclares, F., andChristian Hein, A. S., Esser, M., and Ritter, T. (2008). Automated model driven development processes. In *Proceedings of the ECMDA workshop on Model Driven Tool and Process Integration*.

Allert, H., Dhraief, H., and Nejdl, W. (2002). How are learning objects used in learning processes? instructional roles of learning objects in lom. In *In ED-MEDIA 2002, World Conference on Educational Multimedia, Hypermedia & Telecommunications*, pages 40–42.

Alonso, F., López, G., Manrique, D., and Soriano, J. (2004). Instructional methodology for e-learning content development. *IADIS International Conference e-Society*, pages 954–959.

Amsel, A. (1989). *Behaviorism, neobehaviorism, and cognitivism in learning theory: Historical and contemporary perspectives / Abram Amsel*. L. Erlbaum Associates, Hillsdale, N.J.

Anderson, T. (2003). Getting the mix right again: An updated and theoretical rationale for interaction. *The International Review of Research in Open and Distance Learning*, 4(2).

Andersson, A. and Grönlund, Å. (2009). A conceptual framework for e-learning in developing countries : A critical review of research challenges. *Electronic Journal of Information Systems in Developing Countries*, 38(8):1–16.

Anido, L. E., Fernández, M. J., Caeiro, M., Santos, J. M., RodrI, J. S., and Llamas, M. (2002). Educational metadata and brokerage for learning resources. *Computers & Education*, 38(4):351 – 374.

Ardimento, P., Boffoli, N., Convertini, V., and G.Visaggio (2011). Decision table for adaptive e-learning systems. *Education in a technological world: communicating current and emerging research and technological efforts*. Retrieved April 25, 2012 from http://www.formatex.info/ict/book/127-134.pdf.

Au, W. T., Sadiq, S., and Li, X. (2009). Learning from experience: Can e-learning technology be used as a vehicle? *In: Florin Salajan, 4th International Conference on e-Learning, Toronto, Canada*, pages 32–39.

Awang-Shuib, A.-R., Oii, B., and Ali, A. J. (2011). Multicultural awareness for better ways of life: A scale validation among malaysian undergraduate students. 2nd International Conference on Business and Economic Research (2nd ICBER 2011) Proceeding 2011-234, Conference Master Resources.

Bach, S., Haynes, P., and Smith, J. L. (2006). *Online Learning and Teaching in Higher Education*. McGraw-Hill, Inc., New York, NY, USA, 1 edition.

Banks, B. (2001). Learning theory and learning objects. *FD Learning Ltd*. Retrieved January 3rd, 2011 from : http://myweb.tiscali.co.uk/benadey/NEW%20FDLWEBSITE/html/company/papers/l-theory-l-objects.pdf.

Barker, P. (2005). What is IEEE learning object metadata / IMS learning resource metadata? Retrieved January 3, 2010 from http://wiki.cetis.ac.uk/images/8/82/WhatIsIEEELOM.pdf.

Beldagli, B. and Adiguzel, T. (2010). Illustrating an ideal adaptive e-learning: A conceptual framework. *Procedia - Social and Behavioral Sciences*, 2(2):5755 – 5761. Innovation and Creativity in Education.

Bentley, T. and Miller, R. (2004). Personalisation; creating the ingredients for systematic and society-wide change. *Personalised Learning Conference, London*. Chapter 8.

Bernstein, B. (2000). *Pedagogy, Symbolic Control and Identity - Theory, Research and Critique*. Rowman Littlefield Publisher Lanham, Maryland, USA. p.78.

Billett, S. (2002). Workplace pedagogic practices: Co-participation and learning. *British Journal of Educational Studies*, 50(4):457–481.

Boghossian and Peter (2006). Behaviorism, constructivism, and socratic pedagogy. *Educational Philosophy and Theory*, 38(6):713–722.

Bosilj-Vuksic, V., J. V. and Popovic, A. (2005). Business process change and simulation modelling. *Systems Integration*, 29.

Brambilla, M., Butti, S., and Fraternali, P. (2009). WebRatio BPM: A tool for design and deployment of business processes on the web. *Eclipse IT Conference - 4th Italian worshop on eclipse technologies*, pages 5–16. Eclipse Italian Community, Bergamo, Italy ISBN: 978-88-904388-0-6.

Bramming, P. (2007). An argument for strong learning in higher education. *Quality in Higher Education*, 13(1):45–56.

Britain, S. and Liber, O. (2004). A framework for the pedagogical evaluation of elearning environments. Technical report.

Brookhart, S. (2001). Successful students' formative and summative uses of assessment information. *Assessment in Education: Principles, Policy and Practice*, 8(2):153–169.

Brooks, C., Epp, C. D., Logan, G., and Greer, J. (2011). The who, what, when, and why of lecture capture. In *Proceedings of the 1st International Conference on Learning Analytics and Knowledge*, LAK '11, pages 86–92, New York, NY, USA. ACM.

Brooks, C. and McCalla, G. (2006). Towards flexible learning object metadata. *International Journal of Continuing Engineering Education and Life-Long Learnin*, 16:50–63(14).

Browing, P. and Lowndes, M. (2001). Jisc techwatch report: Content management systems, technical report tsw 01-02. *Joint Information Systems Committee*. Retrieved December 28, 2010 from http://fzki.uniag.sk/11ICT/02Informations/CMSRelated/tsw_01-02_CMS.pdf.

Brown, S. C. (2010). From VLEs to learning webs: The implications of web 2.0 for learning and teaching. *Interactive Learning Environments*, 18(1):1–10.

Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User Modeling and UserAdapted Interaction*, 6(2-3):87–129.

Brusilovsky, P. (2003). Adaptive navigation support in educational hypermedia: the role of student knowledge level and the case for meta-adaptation. *British Journal of Educational Technology*, 34(4):487–497.

Brusilovsky, P. (2004). Adaptive navigation support: From adaptive hypermedia to the adaptive web and beyond. *PsychNology Journal*, 2:7–23.

Brusilovsky, P. and Nijhavan, H. (2002). A framework for adaptive e-learning based on distributed re-usable learning activities. In *Proceedings of World Conference on E-Learning, E-Learn 2002*, pages 154–161.

Bunis, D. (2003). Commentary. *College and University, Fall.* v.78, n.2.

Cardinali, F. (2003). *Learning objects from cultural and scientific heritage resources.* Salzburg Research ; University of Glasgow, [Salzburg, Austria] : [Glasgow, Scotland].

Carliner, S. (2005). Course management systems versus learning management systems. *Learning Circuits*, 6(11). Retrieved January 6, 2011 from http://www.astd.org/LC/2005/1105_carliner.htm.

Chen, J.-H., Chang, H.-B., Shen, C.-Y., Wang, T.-H., and Chang, W.-C. (2009). Developing the immersive learning environment by integrating the interactive video and ubiquitous technologies. In *Proceedings of the first ACM international workshop on Multimedia technologies for distance learning*, MTDL '09, pages 39–48, New York, NY, USA. ACM.

Chen, L., Xu-peng, D., and Zheng-qiu, Y. (2010). Research of modern enterprise intelligent system based on rule engine and workflow. In *Intelligent Computing and Intelligent Systems (ICIS), 2010 IEEE International Conference on*, volume 1, pages 594 –597.

Childs, S., Blenkinsopp, E., Hall, A., and Walton, G. (2005). Effective e-learning for health professionals and students - barriers and their solutions. A systematic review of the literature - findings from the HeXL project. *Health Information & Libraries Journal*, 22:20–32.

Chong, S.-M. (1998). Models of asynchronous computer conferencing for collaborative learning in large college classes. *Electronic collaborators: Learner-centered technologies for literacy apprenticeship and discourse. . In C. J. Bonk & K. S. King (Eds.)*, pages 157–182. New Jersey: L. Erlbaum Associates, Inc.

Chowdhury, G. and Chowdhury, S. (2008). SIMS: A student-centred information management system to support learning and living in HEIs. May 6, 2012 from http://www.ics.heacademy.ac.uk/projects/development-fund/final_reports/12ov_GobindaChowdhuryAdditionalReport.pdf.

Chuang, H.-M. and Shen, C.-C. (2008). A study on the applications of learning paths concepts to the teaching in elementary school. *Intelligent Systems Design and Applications, International Conference on*, 2:543–548.

Clark, D. (2003). Blended learning. *Brighton: EPIC Group PLC.* Retrieved January 3, 2010 from http://www.oktopusz.hu/domain9/files/modules/module15/261489EC2324A25.pdf.

Colace, F. and Santo, M. D. (2007). Adaptive hypermedia system in education: A user model and tracking strategy proposal. *2007 37Th Annual Frontiers in Education Conference Global Engineering Knowledge Without Borders Opportunities Without Passports*, pages T2D–18–T2D–23.

Colace, F., Santo, M. D., and Vento, M. (2005). Personalized learning path based on metadata standards. *International Journal on E-Learning*, 4(3):317–335.

Coombs, T. W. and Rybacki, K. (1999). Public relations education: Where is pedagogy? *Public Relations Review*, 25(1):55 – 63. Education.

Corcoran, G. (2009). Blended learning lead institute. *in Proceedings of the Australian Vocational Education and Training Research Association*, page 25. Crows Nest, New South Wales: AVETRA.

Costagliola, G., Ferrucci, F., and Fuccella, V. (2006). Scorm run-time environment as a service. In *Proceedings of the 6th international conference on Web engineering*, ICWE '06, pages 103–110, New York, NY, USA. ACM.

Crawford, V. M., Schlager, M. S., Penuel, W. R., and Toyama, Y. (2008). *Supporting the Art of Teaching in a Data-Rich, High-Performance Learning Environment*, pages 1–46. Teachers College Press.

Dalziel, J. (2008). Using LAMS version 2 for a game-based Learning Design. *Journal of Interactive Media in Education*, 2008(2). http://www-jime.open.ac.uk/article/2008-24/369.

Dalziel, J. R. (2006). Lessons from LAMS for IMS Learning Design. In *Sixth International Conference on Advanced Learning Technologies*, pages 1101 –1102.

Dashwood, A., Lawrence, J., Burton, L., and Brown, A. (2009). Student perspectives on scholarship: A contemporary issue in higher education. *International Journal of Arts and Sciences*, 3(5):64–79. ISSN 1557-718X.

Davies, J. and Graff, M. (2005). Performance in e-learning: Online participation and student grades. *British Journal of Educational Technology*, 36(4):657–663.

Davis, H. (2010). The justification for a new learning environment at Southampton. Event Dates: 1st December 2010. http://eprints.soton.ac.uk/271740/.

Davis, H. and White, S. (2011). The personalisation of a learning environment: Student-led connections online and offline. Invited Talk Event Dates: 25-26 May 2011.

Dawson, S. (2010). 'Seeing' the learning community: An exploration of the development of a resource for monitoring online student networking. *British Journal of Educational Technology*, in press(in press):736–752.

De Boer, W. and Collis, B. (2002). A changing pedagogy in e-learning: From acquisition to contribution. *Journal of Computing in Higher Education*, 13:87–101. 10.1007/BF02940967.

de Freitas, S., Oliver, M., Mee, A., and Mayes, T. (2008). The practitioner perspective on the modeling of pedagogy and practice. *J. Comp. Assisted Learning*, 24(1):26–38.

Dellit, J. (2002). Using ICT for quality in teaching - learning evaluation process. *Using ICT for Teaching, Learning and Management*, pages 56–66.

Denev, D. (2007). LMS vs. LCMS vs. CMS vs. VLE or e-learning vs. e+learning. Retrieved January 6, 2011 from http://moodle.org/mod/forum/discuss.php?d=65417.

Dillenbourg, P. (2000). Virtual learning environments. *Learning in the new millennium: building new education strategies for schools, Workshop on Virtual Learning Environments, University of Geneva.*

Dimitrova, M., Mimirinis, M., and Murphy, A. (2004). Evaluating the flexibility of a pedagogical framework for e-learning. In *Proceedings of the IEEE International Conference on Advanced Learning Technologies*, ICALT '04, pages 291–295, Washington, DC, USA. IEEE Computer Society.

Dimitrova, M., Sadler, C., Hatzipanagos, S., and Murphy, A. (2003). Addressing learner diversity by promoting flexibility in e-learning environments. In *Database and Expert Systems Applications, 2003. Proceedings. 14th International Workshop on*, pages 287 – 291.

Dong, A. and Li, H. (2005). Multimedia access platform for virtual learning environment. In *Electro Information Technology, 2005 IEEE International Conference on*, pages 6 pp. –6.

Draper, S. (2004). From active learning to interactive teaching: Individual activity and interpersonal interaction. *In Proc. of Teaching and Learning Symposium: Teaching Innovations*. The Hong Kong University of Science and Technology.

Earle, A. (2002). Designing for pedagogical flexibility: Experiences from the candle project. *Journal of Interactive Media in Education*, 2002(1).

Eduworks (2009). SCORM concepts. Retrieved September 10, 2012 from http://www.eduworks.com/LOTT/Tutorial/scormconcepts.html.

Edvardsen, L. F. H. and Sølvberg, I. T. (2007). Metadata challenges in introducing the global IEEE Learning Object Metadata (LOM) standard in a local environment. *The Webist 2007 conference in Barcelona, Spain.*

Elias, T. (2011). Learning analytics: Definitions, processes, and potential. creative commons. *Learning and Knowledge Analytical.* Retrieved February 3, 2012 from http://learninganalytics.net/LearningAnalyticsDefinitionsProcessesPotential.pdf.

Eraut, M. (2007). Learning from other people in the workplace. *Oxford Review of Education*, 33(4):403–422.

Ertmer, P. A. and Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 6(4):50–72.

Esteves, M. (2008). Towards the pedagogical excellence of higher education. *Sísifo : Educational Sciences Journal*, 07:99–106.

Euler, T., Jackson, P., and Tod, C. (2001). Changing the perspective: Exploring a commercially oriented approach to teaching marketing decision making with oinline flexible delivery and studenty centred learning. *In Proceedings for the Australian and New Zealand Marketing Academy Conference.*

Fielding, R. T. (2000). *Architectural styles and the design of network-based software architectures.* PhD thesis. University of California, Irvine.

Friesen, N. (2003). Three objections to learning objects and e-learning standards. Retrieved January 3, 2010, from http://learningspaces.org/n/papers/objections.html.

Friesen, N. (2004). Learning objects and standards: pedagogical neutrality and engagement. In *Advanced Learning Technologies, 2004. Proceedings. IEEE International Conference on*, pages 1070 – 1071.

Garrett, R. (2005). *E-learning in tertiary education : where do we stand? / Centre for Educational Research and Innovation*, volume 4. OECD, Paris :.

Garrison, R. D. and Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *The Internet and Higher Education*, 7(2):95 – 105.

Gherardi, S. (2001). From organizational learning to practice-based knowing. *Human Relations*, 54(1):131–139.

Gold, S. (2001). A constructivist approach to online training for online teachers. *Journal of Asynchronous Learning Networks*, 5:35–57.

Graf, S., Ives, C., Rahman, N., and Ferri, A. (2011). AAT: A tool for accessing and analysing students' behaviour data in learning systems. In *Proceedings of the 1st International Conference on Learning Analytics and Knowledge*, LAK '11, pages 174–179, New York, NY, USA. ACM.

Graf, S. and List, B. (2005). An evaluation of open source e-learning platforms stressing adaptation issues. In *Advanced Learning Technologies, 2005. ICALT 2005. Fifth IEEE International Conference on*, pages 163 – 165.

Graham, P., Bokma, A., and Bowerman, C. (2005). Using adaptive navigation on a mobile device for students. *IADIS International Conference Mobile Learning*, pages 63–70. 972-8939-02-7.

Griffiths, D. and Blat, J. (2005). The role of teachers in editing and authoring units of learning using ims learning design. *Educational Cybernetics: Journal Articles*, page 3.

GWT, G. W. T. (2010). Retrieved January 11, 2011 from Google code `http://code.google.com/p/google-web-toolkit-doc-1-5/wiki/DevGuidePlumbingDiagram`.

Hagel, J. (2006). SOA versus Web 2.0? *Edge Perspectives with John Hagel*. Retrieved January 12, 2011 from `http://edgeperspectives.typepad.com/edge_perspectives/2006/04/soa_versus_web_.html`.

Hamat, A. and Embi, M. A. (2010). Constructivism in the design of online learning tools - EJES. *European Journal of Educational Studies*, 2(3). ISSN 1946-6331.

Harman, K. and Koohang, A. (2005). Discussion board: A learning object. *Interdisciplinary Journal of Knowledge and Learning Objects*, 1:67–77.

Hedaya, M. A. and Collins, P. (1999). Pharmacokinetic teaching utilizing the world wide web: a flashlight (TM) assessment. *American Journal of Pharmaceutical Education*, 63(4):415 – 421.

Hedge, N. and Hayward, L. (2004). Redefining roles: university e-learning contributing to lifelong learning in a networked world? *ELearning*, 1(1):128.

Heller, J., Mayer, B., Hockemeyer, C., and Albert, D. (2005). Competence-based knowledge structures for personalised learning. In *1st International ELeGI Conference on Advanced Technology for Enhanced Learning, Vico Equense - Naples, Italy. 15 - 16 March 2005 1st International ELeGI Conference on Advanced Technology for Enhanced Learning*, page 8, Vico Equense (Naples) Italy.

Heller, J., Steiner, C., Hockemeyer, C., and Albert, D. (2006). Competence-based knowledge structures for personalised learning. *International Journal on E-Learning*, 5(1):75–88.

Hendriks, P. (1999). Why share knowledge? The influence of ICT on the motivation for knowledge sharing. *Knowledge and Process Management*, 6(2):91–100.

Huang, W., Webster, D., Wood, D., and Ishaya, T. (2006). An intelligent semantic e-learning framework using context-aware semantic web technologies. *British Journal of Educational Technology*, 37(3):351–373.

Hubball, H. and Burt, H. (2007). Learning outcomes and program-level evaluation in a four-year undergraduate pharmacy curriculum. *American Journal of Pharmaceutical Education*, 71(5):90.

Hung, D. (2001). Design principles for web-based learning; implications for vygotskian thought. *Educational Technology*, 41(3):31–41.

Hung, D. and Nichani, M. (2001). Constructivism and e-learning: balancing between the individual and social levels of cognition. *Educational Technology*, 41(2):40–44.

Hung, J.-l. (2008). Revealing online learning behaviors and activity patterns and making predictions with data mining techniques in online teaching. *Learning*, 4(4):426–437.

Hurle, O. (2006). The SOA tools platform project. *STP PMC Lead*. Retrieved January 12, 2011 from http://www.osoa.org/display/Main/The+SOA+Tools+Platform+Project.

IMS (2003). "IMS Learning Design Information Model. Version 1.0 Final Specification" Retrieved December 28, 2010 from http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html.

IMS (2006). "IMS Meta-data Best Practice Guide for IEEE 1484.12.1-2002 Standard for Learning Object Metadata " Retrieved January 3, 2010 from http://www.imsglobal.org/metadata/mdv1p3/imsmd_bestv1p3.html.

Ivanova, M. and Popova, A. (2009). An exploration of formal and informal learning flows in LMS 2.0: Case study Edu 2.0. In *Proceedings of the 2009 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology - Volume 03*, pages 227–230.

Jarvela, S. (2006). Personalised learning? New insights into fostering learning capacity. *In Personalising Education*. (Schooling for Tomorrow series) Paris.

Jekjantuk, N. and Hasan, M. M. (2007). E-learning content management: An ontology-based approach. In *Proceedings of the third conference on IASTED International Conference:*

Advances in Computer Science and Technology, ACST'07, pages 78–83, Anaheim, CA, USA. ACTA Press.

Johnson, M., Griffiths, D., and Wang, M. (2011). Positioning theory, roles and the design and implementation of learning technology. *Journal of Universal Computer Science*, 17(9):1329–1346.

JURUBESCU, T. (2008). Learning content management systems. *Informatica Economica Journal*, 7(4):91–94.

Kahiigi, E. K., Ekenberg, L., Hansson, H., Tusubira, F., and Danielson, M. (2008). Exploring the e-learning state of art. *The Electronic Journal of e-Learning*, 6(2):77–88.

Kaur, H. and Kaur, K. (2005). Collaborative online learning: Issues in online facilitation. *In: ICDE International Conference*. New Delhi, India.

Kelly, B., Phipps, L., and Swift, E. (2004). Developing a holistic approach for e-learning accessibility. *Canadian Journal of Learning and Technology*, 30(3). Please note that this article is copyrighted by AMTEC. We are grateful to AMTEC and the Canadian Journal of Learning and Technology for permission to provide access to this article.

Kelly, T. and Nanjiani, N. (2004). *The business case for e-learning*. Network business series. Cisco Press.

Kesici, S., Sahin, I., and Akturk, A. O. (2009). Analysis of cognitive learning strategies and computer attitudes, according to college students' gender and locus of control. *Comput. Hum. Behav.*, 25(2):529–534.

Kirriemuir, J. (2008). Measuring the impact of second life for educational purposes - responses and second life meeting transcript. *Eduserv Foundation*. Retrieved January

3, 2010 from http://www.virtualworldwatch.net/wordpress/wp-content/uploads/2009/10/impactreport.pdf.

König, F. and Paramythis, A. (2010). Towards improved support for adaptive collaboration scripting in ims ld. In Wolpers, M., Kirschner, P., Scheffel, M., Lindstaedt, S., and Dimitrova, V., editors, *Sustaining TEL: From Innovation to Learning and Practice*, volume 6383 of *Lecture Notes in Computer Science*, pages 197–212. Springer Berlin / Heidelberg.

Ko, R. K. L., Lee, S. S. G., and Lee, E. W. (2009). Business process management (BPM) standards: a survey. *Business Process Management Journal*, 15(5):744–791.

Kohlbacher, M. (2009). The effects of process orientation on customer satisfaction, product quality and time-based performance. *29th International Conference of the Strategic Management Society*.

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. *Upper Saddle River, Englewood Cliffs, NJ7 Prentice Hall*.

Koohang, A. and Harman, K. (2005). Open source: A metaphor for e-learning. *Informing Science Journal*, 8:75–86.

Korb, J. and Strodl, S. (2010). Digital preservation for enterprise content: A gap-analysis between ECM and OAIS. *Environment*, (6.10.2010):221 – 229.

Lam, W. (2004). Teaching tip: Encouraging online participation. *Journal of Information Systems Education*, 15(4):343–348.

LDP (2003-2004). Leadership development program 2003-2004. *LPD e-Portfolio Report. Regents of the University of California*, page 3. Retrieved January 8, 2011 from http://bearlink.berkeley.edu/ePortfolio/page3.html.

Lee, F. (2011). Learning object standards in education: Translating economy into epistemic atomism. *Science as Culture*, 20(4):513–533.

Levinsen, K. and Orngreen, R. (2003). Locating students' competencies - a prerequisite for collaboration". In *2nd European Conference on e-Learning (ECEL 2003)*.

Levinsen, K. T. (2006). Collaborative on-line teaching: The inevitable path to deep learning and knowledge sharing? *Electronic Journal of elearning*, 4(1):41–48.

Lim, D. H. (2002). Perceived differences between classroom and distance education: Seeking instructional strategies for learning applications. *International Journal of Educational Technology*, 3(1):20–32.

Lin, H.-F. (2007). Knowledge sharing and firm innovation capability: an empirical study. *International Journal of Manpower*, 28(3/4):315–332.

Liu, J., Derzsi, Z., Raus, M., and Kipp, A. (2008a). *eGovernment Project Evaluation: An Integrated Framework*, volume 5184/2008, pages 85–97. Springer.

Liu, Y., Hu, E., and Chen, X. (2008b). Architecture of information system combining SOA and BPM. In *Information Management, Innovation Management and Industrial Engineering, 2008. ICIII '08. International Conference on*, volume 1, pages 42 –45.

LTSC (2002). Draft standard for learning object metadata. Retrieved January 6, 2011 from http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf.

LTSC (2008). "IEEE learning technology standards committee" Retrieved December 28, 2010 from http://ieeeltsc.org/.

Malkin, W. (2009). Integration of financial models into workflow software to enable activity based costing. (20090089130). (Edmonton, CA).

Mansukhani, M. (2005). Service oriented architecture white paper. *Business*.

Markett, C., Sánchez, A. I., Weber, S., and Tangney, B. (2006). Using short message service to encourage interactivity in the classroom. *Comput. Educ.*, 46:280–293.

Martin, E., Basu, S., and Xie, T. (2007). WebSob: A tool for robustness testing of web services. In *Companion to the proceedings of the 29th International Conference on Software Engineering*, ICSE COMPANION '07, pages 65–66, Washington, DC, USA. IEEE Computer Society.

Martínez-Ortiz, I., Moreno-Ger, P., Sierra, J. L., and Fernández-Manjón, B. (2006). Using DocBook and XML technologies to create adaptive learning content in technical domains. *IJCSA*, 3(2):91–108.

Mason, J. (1994). Enquiry in mathematics and in mathematics education, in paul ernest (ed.). *Constructing Mathematical Knowledge: Epistemology and Mathematics Education*, pages 190–200. The Falmer Press.

Matuga, J. M. (2001). Electronic pedagogical practice: The art and science of teaching and learning on-line. *Educational Technology & Society*, 4(3):77–84.

Mayfield, J. (1997). Two-level models of hypertext. In Nicholas, C. and Mayfield, J., editors, *Intelligent Hypertext*, volume 1326 of *Lecture Notes in Computer Science*, pages 90–108. Springer Berlin / Heidelberg. 10.1007/BFb0023961.

Mbatha, B. and Naidoo, L. (2010). Bridging the transactional gap in Open Distance Learning (ODL): The case of the university of south africa (Unisa). *Journal of Humanities and Social Sciences*, 2:64 – 69.

McAndrew, P., Weller, M., and Barret-Baxendale, M. (2006). Learning design and service oriented architectures:a mutual dependency? *Journal of Learning Design*, 1(3):51–60.

Mcgregor, D. (2004). Interactive pedagogy and subsequent effects on learning in science classrooms. *Westminster Studies in Education*, 27(2):237+.

Meccawy, M., Blanchfield, P., Ashman, H., Brailsford, T., and Moore, A. (2008). WHURLE 2.0: Adaptive learning meets web 2.0. *Times of Convergence Technologies Across Learning Contexts*, 5192:274–279.

Milligan, C., Beauvoir, P., and Sharples, P. (2005). The reload learning design tools. *Journal of Interactive Media in Education*, 2005(1).

Mircea, M. (2012). SOA adoption in higher education: A practical guide to service- oriented virtual learning environment. *Procedia - Social and Behavioral Sciences*, 31(0):218 – 223. World Conference on Learning, Teaching & Administration - 2011.

Mison, D., Wakizaka, S., Osawa, T., and Kobayashi, T. (2010). JBPM users guide. http://docs.redhat.com/docs/en-US/JBoss_Enterprise_SOA_Platform/4.2/html-single/JBPM_Users_Guide/index.html.

Moallem, M. (2003). An interactive online course: A collaborative design model. *Educational Technology Research and Development*, 51:85–103. 10.1007/BF02504545.

Mohamed, I. and Noordin, M. (2011). Business metadata with the STA data modelling technique. In *Electrical Engineering and Informatics (ICEEI), 2011 International Conference on*, pages 1–4.

Moodle, G. (2011). Moodle development: Developer documentation. Retrieved March 25, 2011 from http://docs.moodle.org/en/Development.

Moodle.org (2011). Pedagogy. Retrieved December 8, 2011 from http://docs.moodle.org/20/en/Pedagogy.

Moore, M. G. (1989). Editorial: Three types of interaction. *American Journal of Distance Education*, 3(2):1–7.

Morales, L., Castillo, L. A., FernÃąndez-Olivares, J., and GonzÃąlez-Ferrer, A. (2008). Automatic generation of user adapted learning designs: An ai-planning proposal. In Nejdl, W., Kay, J., Pu, P., and Herder, E., editors, *Adaptive Hypermedia and Adaptive Web-Based Systems, 5th International Conference, AH 2008, Hannover, Germany, July 29 - August 1, 2008. Proceedings*, volume 5149 of *Lecture Notes in Computer Science*, pages 324–328. Springer.

Morrison, J. L. and Khan, B. H. (2003). The global e-learning framework: An interview with Badrul Khan. Retrieved February 21, 2011 from http://technologysource.org/article/global_elearning_framework/.

Mulwa, C., Lawless, S., Sharp, M., Arnedillo-Sanchez, I., and Wade, V. (2010). Adaptive educational hypermedia systems in technology enhanced learning: A literature review. In *Proceedings of the 2010 ACM conference on Information technology education*, SIGITE '10, pages 73–84, New York, NY, USA. ACM.

Nanayakkara, C. and Whiddett, R. J. (2005). A model of user acceptance of e-learning technologies: A case study of a polytechnic in new zealand. In *ISTA*, pages 180–190.

Nardini, E. and Omicini, A. (2008). Agent-based collaboration systems: A case study. In *Knowledge Construction in E-learning Context: CSCL, ODL, ICT and SNA in Education*, CEUR Workshop Proceedings. Sun SITE Central Europe, RWTH Aachen University.

Natis, V. Y. (2003). Service-oriented architecture scenario. Retrieved December 9, 2011 from http://www.gartner.com/DisplayDocument?doc_cd=114358.

Neuhauser, C. (2002). Learning style and effectiveness of online and face-to-face instruction. *American Journal of Distance Education*, 16(2):99–113.

Neven, F., Duval, E., Ternier, S., Cardinaels, K., and Vandepitte, P. (2003). An open and flexible indexation- and query tool for ariadne. In Lassner, D. and McNaught, C., editors, *World Conference on Educational Multimedia, Hypermedia, and Telecommunications*.

Nguyen, L. and Do, P. (2008). Learner model in adaptive learning. *Engineering and Technology*, 35(November):396–402.

Nichols, M. (2008). E-learning in context. *E-Primer Series*, 1.

Nwana, H. S. (1996). Software agents: An overview. *Knowledge Engineering Review*, 11(2):205–244.

O'Brien, L., Merson, P., and Bass, L. (2007). Quality attributes for service-oriented architectures. In *Proceedings of the International Workshop on Systems Development in SOA Environments*, SDSOA '07, pages 3–, Washington, DC, USA. IEEE Computer Society.

O'Leary, R. (2002). Virtual learning environments. *LTSN Generic Centre and ALT*. Retrieved January 6, 2011 from http://www.alt.ac.uk/docs/eln002.pdf.

Oreilly, T. (2007). What is web 2.0: Design patterns and business models for the next generation of software. *Communications and Strategies*, (65):17+.

Papert, S. and Harel, I. (1991). Situating Constructionism. In Papert, S. and Harel, I., editors, *Constructionism*, chapter 1. Ablex Publishing Corporation, Norwood, NJ.

Paramythis, A. and Loidl-Reisinger, S. (2004). Adaptive learning environments and elearning standards. *Electronic Journal of ELearning, EJEL*, 2:181–194.

Perrie, Y. (2003). Virtual learning environments. *The Pharmaceutical Journal*, 270:794–795.

Peter, Y. and Vantroys, T. (2005). Platform support for pedagogical scenarios. *Educational Technology & Society*, 8(3):122–137.

Pinner, R. (2010). VLE or LMS? Retrieved October 22, 2012 from http://www.engnet-education.com/2010/10/vle-or-lms/.

Polsani, P. R. (2003). Use and abuse of reusable learning objects. *Journal of Digital Information*, 3(4).

Ramage, T. R. (2002). The "No Significant Difference" Phenomenon: A Literature Review. 5(1):1–7.

Rate, N. (2008). Assessment for learning & eportfolios what are the formative benefits of eportfolios? New Zealand Ministry of Education. Retrieved January 14, 2011 from http://www.scribd.com/doc/9336533/ePortfolios-and-Assessment-for-Learning.

Redmond, P. and Lock, J. (2009). *Designing Flexible Learning: Learning With Each Iteration*, volume 2009, pages 3116–3124.

Reichert, R. and Hartmann, W. (2004). On the learning in e-learning. In Cantoni, L. and McLoughlin, C., editors, *ED-MEDIA 2004 : World Conference on Educational Multimedia, Hypermedia & Telecommunications*, pages 1590–1595, Lugano, Switzerland. AACE.

Roqueta, M. (2008). Learning management systems: A focus on the learner. *Distance Learning*, 5(4):59–66.

Rosenberg, M. J. (2002). *E-Learning: Strategies for Delivering Knowledge in the Digital Age*. McGraw-Hill, Inc., New York, NY, USA.

Rothery, A., Cilia, J., Stenalt, M. H., and Dupuis, M. (2008). EUNIS e-learning snapshots 2008. In *EUNIS2008, Aarhus University, Denmark.* Retrieved January 3, 2010 from http://eunis.dk/papers/p60.pdf.

Roussou, M. (2004). Learning by doing and learning through play: An exploration of interactivity in virtual environments for children. *Comput. Entertain.*, 2(1):10.

Ruskov, M. (2009). Using interactive technologies for social learning (a case study). In *CSECS*.

Santos, S. G., Pardo, A., and Kloos, C. D. (2008). Authoring courses with rich adaptive sequencing for IMS Learning Design. *Journal of Universal Computer Science*, 14(17):2819–2839.

Schneider, D. K., Synteta, P., Frete, C., Girardin, F., and Morand, S. (2003). Conception and implementation of rich pedagogical scenarios through collaborative portal sites: Clear focus and fuzzy edges. In *International Conference on Open and Online Learning*.

Schroth, C. (2007). Web 2.0 versus SOA: Converging concepts enabling seamless cross-organizational collaboration. In *E-Commerce Technology and the 4th IEEE International Conference on Enterprise Computing, E-Commerce, and E-Services*, pages 47 –54.

Scott, J. E. (2007). Mobility, business process management, software sourcing, and maturity model trends: Propositions for the is organization of the future. *Information Systems Management*, 24(2):139–145.

Seale, J. and Cooper, M. (2010). E-learning and accessibility: An exploration of the potential role of generic pedagogical tools. *Computers & Education*, 54(4):1107–1116.

Selwyn, N. (2007). The use of computer technology in university teaching and learning: A critical perspective. *Journal of Computer Assisted Learning*, 23(2):83–94.

Shuell, T. J. (1986). Cognitive conceptions of learning. *Review of Educational Research*, 56(4):pp. 411–436.

Shute, V. and Towle, B. (2003). Adaptive e-learning. *Educational Psychologist*, 38:105 – 114.

Siemens, G. (2004). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning*, page 7.

Sigala, M. (2007). Integrating web 2.0 in e-learning environments: A socio-technical approach. *International Journal of Knowledge and Learning*, 3(6):628–648.

Singhal, N. (2011). Knowledge management and testing methods in e-learning systems. *International Journal of Computer Information Systems*, 2(1):6–11.

Slosser, S. (2002). ADL and the sharable content object reference model (SCORM). Retrieved January 12, 2011 from http://www.snw.ac.th/courseware/www.nectec.or.th/courseware/pdf-documents/adl-scorm.pdf.

Sosteric, M. and Hesemeier, S. (2002). When is a learning object not an object: A first step towards a theory of learning objects. *International Review of Research in Open and Distance Learning*, 3(2).

Steiner, C. M. and Albert, D. (2007). Personalising learning through prerequisite structures derived from concept maps. In *Advances in Web Based Learning - ICWL 2007*, pages 43–54. Lecture Notes in Computer Science 4823.

Stiggins, R. J. (2001). The unfulfilled promise of classroom assessment. *Educational Measurement Issues and Practice*, 20(3):5–15.

Stohr, E. A. and Zhao, J. L. (2001). Workflow automation: Overview and research issues. *Information Systems Frontiers*, 3:281–296. 10.1023/A:1011457324641.

Stoyanov, S. and Kirchner, P. (2004). Expert concept mapping method for defining the characteristics of adaptive e-learning: Alfanet project case. *Educational technology research and development*, 52(2):41–54.

Surjono, H. (2009). The development of an adaptive e-learning system based on the e-learning style diversity of visual-auditory- kinesthetic. *The International Seminar On ICT For Education*. Yogyakarta State University, Indonesia.

Takhirov, N. and Sølvberg, I. T. (2009). Adaptive personalized elearning on top of existing LCMS. In *Proceedings of the 9th ACM/IEEE-CS joint conference on Digital libraries*, JCDL '09, pages 445–446, New York, NY, USA. ACM.

Tardif, M. (2005). Communication technology and pedagogical power. *Essays in Education*, 14.

Tavangarian, D., Leypold, M. E., NÃűlting, K., RÃűser, M., and Voigt, D. (2003). Is e-learning the solution for individual learning ? *Learning*, 2(2):273–280.

Taylor, J., de Roeck, A., Anderson, A., Sharples, M., Boyle, T., Hall, W., Rodden, T., and Scott, D. (2004). A grand challenge for computing: Learning for life,. *Current Grant Challenges*. Retrieved May 6, 2012 from http://cloudworks.ac.uk/cloud/view/3049.

Ternier, S., Massart, D., Campi, A., Guinea, S., Ceri, S., and Duval, E. (2008). Interoperability for searching learning object repositories: The prolearn query language. *D-Lib Magazine*, 14(1).

Téllez, A. G. (2010). E-learning authoring with DocBook and SMIL. In *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on*, pages 246–248.

Tosh, D. and Werdmuller, B. (2004). ePortfolios and weblogs: One vision for ePortfolio development. Retrieved from http://www.morrisville.org/classrooms_curriculum/hive_portal/documents/ePortfolio_Weblog.pdf.

Tsandilas, T. (2003). Adaptive hypermedia and hypertext navigation. Research Review for Depth Oral Examination, Department of Computer Science University of Toronto. Retrieved May 11, 2012 from http://www.lri.fr/~fanis/docs/Depth.pdf.

Tsolis, D., Stamou, S., Christia, P., Kampana, S., Rapakoulia, T., Skouta, M., and Tsakalidis, A. (2010). An adaptive and personalized open source e-learning platform. *Procedia Social and Behavioral Sciences*, 9:38–43.

Tynjala, P. and paive Hakkinen (2005). E-learning at work: Theoretical underpinnings and pedagogical challenges. *Journal of Workplace Learning*, 17(5/6):318–336.

Unhelkar, B., Ghanbary, A., and Younessi, H. (2010). Fundamentals of collaborative business. *Collaborative Business Process Engineering and Global Organizations: Frameworks for Service Integration*, pages 1–36. IGI Global, doi:10.4018/978-1-60566-689-1.ch001, accessed June 02, 2012.

Usluel, Y. K. and Mazman, S. G. (2009). Adoption of web 2.0 tools in distance education. *Procedia - Social and Behavioral Sciences*, 1(1):818–823.

Van Joolingen, W., De Jong, T., and Manlove, S. (2007). CIEL: setting the stage for integrated inquiry learning. In *Annual Meeting of the American Educational Research Association, AERA annual meeting, April 9-13, 2007, Chicago, United-States*, page 7 pages, Chicago, États-Unis.

Vatrapu, R., Teplovs, C., Fujita, N., and Bull, S. (2011). Towards visual analytics for teachers' dynamic diagnostic pedagogical decision-making. *Proceedings of the IEEE*, pages 93–98.

Vera, A. and Kuntz, L. (2007). Process-based organization design and hospital efficiency. Health care management review. *Health Care Management Review*, 32(1):55–65. ACM Press.

Verpoorten, D., Glahn, C., Kravcik, M., Ternier, S., and Specht, M. (2009). Personalisation of learning in virtual learning environments. *Environments*, 5794/2009:52–66.

Vrasidas, C. (2004). Issues of pedagogy and design in e-learning systems. In *Proceedings of the 2004 ACM symposium on Applied computing*, SAC '04, pages 911–915, New York, NY, USA. ACM.

Wagner, N., Hassanein, K., and Head, M. (2006). E-learning in higher education: A stakeholders' analysis. In *Information Technology Interfaces, 2006. 28th International Conference on*, pages 307–312.

Walsh, N. and Muellner, L. (1999). Docbook: The definitive guide. Publisher: O'Reilly Media, C.A, USA.

Wang, W., Ding, H., Dong, J., and Ren, C. (2006). A comparison of business process modeling methods. In *Service Operations and Logistics, and Informatics, 2006. SOLI '06. IEEE International Conference on*, pages 1136 –1141.

Watkins, C. (2002). Learning about learning : Resources for supporting effective learning. Routledge, Florence, KY, USA, 2 edition, 2000.

Weller, M. (2006). VLE 2.0 and future directions in learning environments. *The First International LAMS Conference.*

Weller, M. (2007). *Virtual Learning Environments: Using, Choosing and Developing your VLE.* Routledge, Oxford, UK.

Wiley, D. A. (2002). *Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy.*, pages 3–23. The Agency for Instructional Technology, Bloomington, IN.

Wolf, A. (1995). *Competence-Based Assessment.* Buckingham: Open University Press.

Woodill, G. (2004). Where is the learning in e-learning? *Educational Psychology Interactive, Valdosta, GA*.

Yi-Cheng, C., Chun-Yu, C., Yi-Chen, L., and Ron-Chen, Y. (2007). Predicting college student' use of e-learning systems: An attempt to extend technology acceptance model. *Pacific Asia Conference on Information Systems (PACIS)*.

Zhang, D., Zhao, J. L., Zhou, L., and Nunamaker, Jr., J. F. (2004). Can e-learning replace classroom learning? *Commun. ACM*, 47(5):75–79.

Zhang, H., Almeroth, K., Knight, A., Bulger, M., and Mayer, R. (2007). Moodog: Tracking students' online learning activities. In Montgomerie, C. and Seale, J., editors, *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007*, pages 4415–4422, Vancouver, Canada. AACE.