A BUSINESS PROCESS MANAGEMENT BASED VIRTUAL LEARNING ENVIRONMENT: CUSTOMISED LEARNING PATHS

Ayodeji Adesina, Derek Molloy
CIPA, RINCE, School of Electronic Engineering, Dublin City University, Glasnevin, Dublin 9, Republic of Ireland
Ayodeji.Adesina2@mail.dcu.ie, Derek.Molloy@dcu.ie

Keywords: Customised Learning Paths, Competence-Based Assessment, Virtual Learning Environment, Business Process Management, Learning Workflow.

Abstract: Virtual Learning Environments (VLEs) such as Moodle help facilitate the management of educational courses for students, in particular by helping lecturers with course administration and students manage their own learning. However, even today problems still remain; in particular, e-learning environments provide a “one size fits all” approach to the learning process, where each student must follow the same learning path through course materials, regardless of their prior knowledge, learning requirements or of possible learning disabilities. Many commercial VLEs allow course writers to build courses as groups of lessons, but it is currently not possible to customise the learning path of individual learners through the course material. This paper presents the development of an e-learning system based on Business Process Management (BPM) concepts, principles and technologies, which are used by the enterprise business community for managing workflow. The developed system allows for the creation of customised learning paths through course materials in a blended pedagogical approach within a custom VLE. Course designers can use visual BPM tools to design workflows using intuitive flow diagrams. The same diagrams can be used to visually track the progress of a cohort of learners through the course contents, viewing the learning paths followed, and allowing for a quantitative analysis of student(s) performance, which could lead to real-time design changes and additions to the course content. The paper concludes by discussing the benefits and limitations of our BPM implementation, and future extensions to investigate open documentation standards.

1 INTRODUCTION

E-learning has in no doubt had a profound effect on the way training and education is delivered. The significant growth in the requirement for e-learning and the significant investment in e-learning technologies over the last few years will continue to impact significantly on the development and delivery of training and development programs, both in the industrial and academic environments. In academia, e-learning is becoming vital for distance education, and often seen as complementary to the classroom environment, where it can help to strengthen the traditional pedagogy. Internet materials, such as YouTube videos, open-source hardware/software and Creative Commons materials have allowed for the design of course content, raising the quality of the traditional formative process. However, the volume of materials that can be obtained from the Internet is so immense that students can easily be confused, especially given the variability of quality. Teachers can also be disconcerted by the quantity of content and are often unable to suggest the correct content for their students (Colace et al., 2005). It has been determined that different learners browsing and studying the same e-learning materials will generally show different learning behaviours according to their personal characteristics (Chuang, H., and Shen, C., 2008). This is because of the heterogeneous nature of learners’ knowledge and their current
learning needs. Consequently, learners tend to meander through different paths through learning content. Although students can learn to some degree independently in an e-learning environment, they have to determine “what to learn” and “where to go” at each learning node/decision, often consuming mental and physical efforts during learning that causes cognitive overload and results in student anxiety (Lin and Wu, 2007). Within the academic environment, a Virtual Learning Environment (VLE) (e.g. Blackboard, Moodle etc) is a software system that allows for the implementation of e-Learning. However, one of the limitations of existing VLEs is that they provide a “one size fits all” approach to the learning process through the course materials, as each student must follow the same learning path regardless of their prior knowledge, learning requirements or any learning disability. There is a need to extend current VLE functionality beyond this limitation, where learners’ runtime behaviour in a learning process should determine the path to progression through course materials. The system should be able to allow for manual (human interaction and intervention) or dynamic (automatic) adaptation and customisation of the learning path (through a path manager) through course material.

This paper presents the design and implementation of an e-learning system that allows:
- a course writer to draw and configure using a graphical interface the paths possible through course materials;
- a course writer (and student) can see the progress of learner on this graphical user interface;
- the course writer can see the statistical progress of a learner versus other learners, or the statistical progress of the entire cohort.

2 CURRENT VLE SOLUTIONS AND LIMITATIONS

VLEs are pervasive, with 86% of respondents from United Kingdom Higher Education institutions in 2003 reporting the presence of a VLE in their institution (Weller, 2006). The principal components of a VLE include: curriculum mapping; student tracking; online support for teachers and students; electronic communication; and, internet links to outside curriculum resources (Adesina and Molloy, 2010). Over the last decade, a number of VLEs have been developed and adopted by universities and even second level schools. VLEs provide a relatively flexible learning environment and improve learning experience through the provision of collaboration, communication and assessment tools (Dong and Li, 2005). However, the extent of flexibility to providing a customised learning path in a learning process is still difficult to achieve as they are not ingrained into an instance of a learning process in current VLEs. Weller (2006) states that a lack of innovation is perhaps why many researchers and educational technologists often hold them in disdain, with a number of charges often levelled at the more popular VLEs, particularly the commercial ones:

- they are content focused;
- they have no strong pedagogy;
- they are based around a teacher-classroom model;
- they combine a number of average capability tools, but not the best ones;
- they do not feature a particular tool;
- they operate on a lowest common denominator approach;
- they do not meet the needs of different subject areas;
- it is difficult to exchange content between them, despite claims of interoperability.

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

We believe that a VLE that addresses the “one size fit all” problem is important, where:

- It seamlessly integrates heterogeneous technologies and multiple pedagogical approaches;
- Flexible formal and informal learning flow are allowed to drive new education approaches;
- Learners learning pathway can be tailored to their profile and dynamically adapted to their run-time behaviour.

This paper is focused on the particular issue of the design and implementation of a software framework for VLE systems that is capable of customised and/or personalised learning paths management.
3 CUSTOMISED LEARNING PATH

Within the literature it is widely recognised that an important component of success in distance education is related with the ability to customise the learning process for the specific needs of a given learner (Colace et al., 2005). However, such an implementation is still far from realisation. There is also much interest in investigating new approaches and tools for adapting the formative process for specific individual needs (Colace et al., 2005). In this general context, personalised learning is a potential approach to meeting future educational needs and may provide new alternatives that foster learning capacity among individual learners (Bentley and Miller, 2004). Jarvela (2006) states that personalisation of learning has become imperative, where personalisation of learning does not purely mean individualised learning, nor is it the opposite of social learning, but as an approach in educational policy and practice whereby every student matters - equalising learning opportunities in terms of learning skills and motivation to learn. Jarvela (2006) further investigated the power of personalised learning systems along seven critical dimensions as:

- Development of key skills that are often domain-specific;
- Levelling the educational playing field through guidance for improvement of students’ learning skills and motivation;
- Encouragement of learning through “motivational scaffolding”;
- Collaboration in knowledge-building;
- Development of new models of assessment;
- Use of technology as a personal cognitive and social tool;
- Teachers’ new role in better integration of education within the learning society.

Heller et al. (2006) give a definition that "personalised/customised learning aims at tailoring the teaching to individual need, interest and aptitude so as to ensure that every learner achieves and reaches the highest standards possible.” While learners’ cognitive skills (the mental capabilities needed to successfully learn academic subjects) and academic skills (appraise of academic competencies such as the ability to critique, to produce scholarly work, to synthesise, and to apply newly acquired principles and concepts (Simon and Forgette-Giroux, 2001)) may be determining parameters of success rate, especially after examination, the quest to reduce the level of knowledge deficit amongst students should also focus on dynamic 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 outcome can be achieved by learners following personalised learning paths, supplemented with contingent teaching, where the lecturer does not have a fixed linear "script" but rather a diagnostic branching tree where audience responses to early questions determine what is performed next (Draper, S.W, 2004). An e-learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these activities on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge of its users and the subject matter, to dynamically facilitate the learning process (Paramythis, 2004).

The implementation of learning processes in this paper is based on the assumption that some learners have a broader requirement of needs/supports than others. The approach links learning objects (LOs) and competency on individual topics as the basis for adaptive assessment of the learner’s skills, and for the selection of personalised learning paths. The learning structure together with a student’s current competency state (mastery level) is used to generate this personalised learning path. Profiling a student’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 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:

- Emphasis on outcomes; specifically, multiple outcomes, each distinctive and separately considered;
- The belief that these outcomes can and should be specified to the point where they are clear and "transparent". Assessors, asseesees, and “third parties” should be able to understand
what is being assessed and what should be achieved.

For creating personalised learning paths and efficiently uncovering the knowledge or competence level of a learner, prerequisite structures on LOs and assessment problems, or on skills underlying those entities, are extremely useful (Steiner and Albert, 2008). Prerequisite structures can be utilised for realising adaptive navigation support in Web-based learning (Brusilovsky, 2004), for instance by link hiding or by annotating learning content that suits a learner’s current knowledge/competence. An educational system that responds to individual needs by creating a personal learning path enables individual students to experience excellence in his or her learning (Heller et al., 2005). Heller et al. further stated that among the various benefits of a personalised learning environment is the fact that the time taken to learn is reduced, and that the learner’s retention is improved. The mutual implications and relationships between assessment problems, LOs, and competencies allows for the generation of personalised learning paths, and for an efficient adaptive assessment of knowledge and competencies.

Figure 1 illustrates an overview of a learning path through course material within a typical VLE, where competence-based assessment is incorporated. The learning path in the VLE is linear and not customised. The linearity engages students in the path categorised by YanGu (2005) as follows: (1) Sequential: Learners follow the instructed ways of learning. Sometimes they jump out the recommended paths, but turn back to them soon after; (2) Challenging: Learners will browse pages related to course summaries and unit tests first. When they fail such tests, they go back to find related detail course materials and iteratively perform the tests until passed; (3) Free: Learners browse the pages randomly without specific rules or sequences, often due to their interest toward different course subjects; and (4) Iterative: Learners have hybrid learning paths of those mentioned above, often browsing the same course webpage iteratively.

Figure 2 illustrates an overview of the proposed VLE, 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. A learner logs into the VLE to view course materials. The requisition component checks for outstanding prerequisite or special needs that might impede the 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 path manager to additional external resources, giving learners the ability to gain additional knowledge. The course-writer can login to the same system to see a dashboard, which allows for the visualisation and monitoring of an individual or aggregate learners’ progress through the course materials (Adesina and Molloy, 2010).

4 BUSINESS PROCESS MANAGEMENT BASED VIRTUAL LEARNING ENVIRONMENT

4.1 BUSINESS PROCESS MANAGEMENT (BPM)

BPM refers to: aligning processes with the organisation’s strategic goals; designing and implementing process architectures; establishing process measurement systems that are aligned with organisational goals; and, educating and organising managers to manage processes effectively (Bosilj-Vuksic et al., 2005). It ensures continued improvement of business performance by managing the processes and their components: organisational structure, policies, business rules, regulations, human resources, and ICT. The term is occasionally used to refer to various automation efforts such as workflow systems.
BPM enables automation of business processes by separating process logic from the applications that run them; managing relationships among process participants; integrating internal and external process resources; and, monitoring process performance (Bosilj-Vuksic et al., 2005). Figure 3 illustrates the life-cycle of a BPM system right from the inception of a business concept. A business concept is: modelled in a business modeller; implemented and deployed in a business run-time engine; monitored in a business monitoring activity system (e.g. dashboard); and, analysis/optimisation is performed based on feedback for continuous improvements.

4.2 BPM-based VLE

The technologies used in the design of any VLE can potentially determine the extent to which a VLE can serve to implement an educational pedagogy. For the orchestration of flexible and adaptive learning processes, BPM technologies would be essential to its implementation as they are the best practice for modern workflow management systems. Workflow to this point has always been about software, computer or machine interactions, but BPM also facilitates the introduction of human interaction into the workflow model. A typical commercial example would be in product sales, where orders can be placed through a sales counter, over the phone or through the Internet – BPM allows for formal workflow integration so that a single process can be
used to manage the order. This is one of the greatest advantages of BPM, as human interaction and intervention is expected in the implementation of a "hands-on" adaptive learning process. This paper employs and explores the particular BPM technologies that enable the automation and monitoring of the footprint of an adaptive learning process, enabling human (interactive pedagogy) to be part of a customised learning path within a learning process workflow.

4.3 DESIGN OF CUSTOMISED LEARNING PATHS

BPM technologies are employed to design and implement customised learning paths in a learning process through course materials as shown in Figure 2; this is achieved by orchestrating interactions between learning services (learning objects and competence-based assessment) and human-task services (learner and course writer) within the proposed BPM-based VLE. The paper focuses on the use of the following BPM technologies, which have been applied in our implementation:

**Business Process Modelling Notation (BPMN)**

BPMN is a core enabler of BPM. It is a standardised graphical notation for drawing/modelling business processes in a workflow system. BPMN has been developed to enable a business user to develop readily understandable graphical representations of their business processes.

BPMN elements are made up of simple diagrams that use a small set of graphical elements. Figure 4 shows the core sets of BPMN elements, these elements falls into four basic categories: 1) Flow objects: These include event (i.e. start, end and intermediate events) activity (i.e. task) and gateway (i.e. a diamond shape and will determine different decisions). 2) Connection objects: This allows flow objects to be connected together. 3) Swimlanes: These serve as a mechanism to organise activities and responsibilities on a process diagram. 4) Artifacts: These allow developers to bring some more information into the model/diagram. In this way the model/diagram becomes more readable.

**Eclipse Service Oriented Architecture Tool Platform – Intermediate Model (STP-IM)**

BPMN is a visual description and is therefore not executable. STP-IM is the bridge between the workflow designed using BPMN and the service creation world. The transformation process is completely transparent to the course writer but is an important part of our technical implementation.

**Java Process Definition Language (JPDL)**

JPDL (executable computer language) is a JBoss process orchestration language that is executable in a workflow engine. It is an intuitive process language that expresses business processes both in graphical and XML form (in terms of tasks, wait states for asynchronous communication, timers, automated actions etc.). To bind these tasks together, JPDL has an extensible control flow mechanism. Based on the configured BPMN model designed by the course writer, the resultant output of the Eclipse STP-IM is a JPDL version of the customised learning paths. The generated JPDL is an XML file that is ready to be deployed into JBoss JBPM runtime engine (workflow engine) where it can be accessed by any BPM client.
5 IMPLEMENTATION AND RESULTS

Figure 5 shows a screen grab of our BPM-based VLE implementation (all web-based). The figure shows the learning interface for students and a monitoring interface that allows the lecturer to view learners’ progress.

To orchestrate a customised learning path for a learner, the system uses information collected during introductory tests to ascertain that a learner meets any prerequisites. Also, during the learning process, as the learner begins to navigate through each topic, the system is able to infer learner’s knowledge using the results from the learner’s competence-based assessment (mastery level) on a specific topic; this inference is a basis for building the individual learning path for each learner. The implementation of a customised learning path 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 learning path 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. Each of these categories is a model and process that are typically established in adaptive e-learning systems.

![Figure 5: Student and lecturer BPM-based VLE web interface. This interface provides a simple 'one click' conversion of the designed workflow BPM models into a custom VLE environment, so that course writers/lecturers do not need to understand the complexities surrounding BPM.](image-url)
5.1 Customised learning path model in BPMN

Using the basic BPMN elements mentioned previously, an example customised learning path is modelled in BPMN as shown in Figure 6. The swimlanes in the overall diagram represent the activities and responsibilities between learner and lecturer. Learning through each topic in the course material is modelled as task lists that need to be fulfilled by a learner. Competence-based assessment in this example is modelled as a simple question to test a learner’s competency on particular topics. However, implementations of more complex assessments are possible. Learners are provided with the option to seek alternative sources when difficulties arise. In this example workflow, consistent failure to answer questions correctly is modelled as a task for the lecturer to intervene as necessary. Lecturer intervention can be a face-to-face meeting with the learner when possible.

Figure 6: BPMN diagram of a customised learning process
5.2 Implementation and deployment

While the design and modelling of a learning process is accomplished using BPMN elements, the implementation is based on JPDL XML descriptive language. The JPDL version of our modelled customised learning path is deployed in JBoss JBPM runtime engine; where it can be access/invoked by all the e-learning actors that were defined in the BPMN swim lanes (learners and lecturer(course writer)).

5.3 Monitoring Instance of a Learning Path on a Dashboard Console

Capturing and monitoring the lifecycle of a learning process when invoked by a client (learner) in a transparent manner requires a BPM dashboard/ Business Activity Monitoring (BAM). BAM or business dashboard is the marriage between business integration and business intelligence. BAM provides real-time alerts based on business metrics when business processes are in need of intervention. In our current implementation, the major benefit of this added functionality is for the detection of lack of progression (of the individual or cohort). The lecturer/course manager can act in real-time using the monitored data, rather than detecting problems at semester-end/major assessments.

Figure 7: Learning path of an advancing learner captured, monitored and need no support (Path followed in red).
The chain of the deployed learning process can be viewed by the course writer (lecturer) within a BPM dashboard as shown in Figure 6 (if no learning process is invoked). In the case depicted in Figure 7, a learner completed topic one and correctly answered the question that follows. The course writer, who is able to monitor the progress, does not need to intervene and the system auto-routes the learner to the next topic. However, Figure 8 captures a learner who failed to correctly answer question one after completing the first topic. In this example, the system auto-routes the learner to other learning resources (i.e. customised web material, supplementary notes and recommended books). The learning is able to select the resource of interest that can further assist his/her learning process on the particular topic. The learner in Figure 8 chose to access a customised web resources and return to answer question one again. For this example, the learner still failed to provide the correct answer and consequently remains deadlocked at the first topic. As a result, the workflow designed by the course writer indicates that the system should send an intervention notice to the course writer. The course writer can give the support needed to help the learner overcome areas of difficulties before progression to next topic can be permitted. Progression permission is part of the workflow designed and only the course writer can grant progression to next based on the intervention outcome.

Figure 8: Learning path of a struggling learner captured, monitored and given support by lecturer (Path followed in red).
6 CONCLUSION

In this paper we have presented a software framework and prototype system that uses BPM technology to allow course writers to define and model customised learning workflows, which can contain multiple learning paths. Using a BPMN graphical interface, a course writer is able to draw an intuitive flow diagram that captures the pathway required. The flow diagram can also be used to configure the possible pathways through the course contents. The customised paths in the BPMN diagram are transformed into executable process language (JPDL) implementations with the aid of eclipse STP-IM. The JPDL version of our customised path is deployed into a JBPM workflow engine. We have also presented the use of a BPM dashboard (BAM) to monitor an instance of a learning process in a real-time manner. Our BPM-Based VLE implementation helps course writers define a workflow that: 1) helps learners progress through the course materials, 2) personalise the learning material for specific needs, 3) identifies the need for human intervention in response to monitored data.

REFERENCES


