Supporting Adaptive E-Learning: An Approach Based on Open-Source Learning Management Systems

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Abstract: *The paper presents a working prototype of an adaptive learning management system (LMS) and a generalized schema for achieving process awareness in an LMS (or other type of system). Further, it proposes a reference implementation to the generalized schema based on the open-source computer learning environment Moodle and achieves adaptability by utilizing the Workflow Management System Activiti.*

Key words: *Business Process Management, Workflow Management Engine, Activiti, e-Learning Systems, Moodle, Adaptive Learning*

INTRODUCTION

Learning Management Systems (LMS) are the most popular and convenient way to deliver e-learning materials to students. Such systems use a repository of learning objects, organized according to some pre-collected metadata and designed to enhance students' learning experience and provide a way to deliver (visualize, reuse) those learning objects, preferably over the Internet. An important extension of LMSs is the ability to meet individual course participant's needs and to gather information about the students' progress in the learning process.

In the context of LMS such adaptability is defined to be the potential to select specific materials for each student depending of his/her knowledge level and performance during the course. Students should follow different learning paths in order to achieve highest results.

To extend e-learning systems with this kind of functionality, technologies and means from Business Process Management (BPM) and its supporting technology – Workflow Management Systems (WMS) are often employed.

For example, [8, 9] analyse the need to create ways and means for more flexible representation in designing of learning courses and the ways in which the learning processes are delivered. An extension to the e-learning environment Flex-eL is proposed as a possible solution. The extension consists in integrating the FlowMake tool for modeling and management of workflows into the above-mentioned e-learning system.

In [10] the authors focus on a process modeling mechanism, which they apply to represent learning courses. The introduced graphical language [13] for workflow representation conforms to the standard defined by the Workflow Management Coalition [2], but implements only the basic set of its patterns, namely: Sequence, XOR-Split, XOR-Join, AND-Split and AND-Join.

A complete solution – from the modeling to the real-time execution of learning work-flows, is presented in [1]. As means of virtual execution of business processes some corporate instruments (including Microsoft BizTalk) are used. The modeling of the processes is done in a graphical environment. The produced models are represented in the XLANG language (used in BizTalk).

The authors of [11, 12] have developed an interesting strategy for collaborative process-based learning. They use Moodle and JBPM [19] as LMS and WMS respectively to achieve adaptability. However, this adaptability is limited to section level (Moodle term for a group of learning objects/activities) and does not support sequencing

of resources/activities.

In the reviewed adaptive e-learning systems, usually a set of rules, which describe the learning process, is coded into some internal representation and fed to a workflow engine, forcing the people involved in the process to perform suggested step by step activities. If a branch appears in the learning path the user chooses a way and the workflow acts accordingly.

The paper presents a working prototype of an adaptive learning management system. The paper naturally builds on the ideas presented in [4, 6] by presenting a generalized schema for achieving process awareness in an LMS (or other type of system). Further, it proposes a reference implementation to the generalized schema based on the open-source computer learning environment Moodle [22], which achieves adaptability by utilizing the Workflow Management System Activiti [16].

POSSIBLE APPROACHES

According to [4] there are several approaches for utilization of workflow technology for management of virtual learning and teaching processes:

Approach 1. Creation of a specialized e-learning (e-assessment) system equipped with integrated tools for modeling and management of workflows ('from scratch');

Approach 2. Creation of an LMS by using already established tools for modeling of business processes, i.e. on the basis of a popular WMS (new LMS over an existing WMS);

Approach 3. Extending the functionality of a popular LMS with means of modeling and management of e-learning processes (specialized new WMS over an existing LMS);

Approach 4. Integration of a popular LMS and a WMS (integration of existing LMS and WMS).
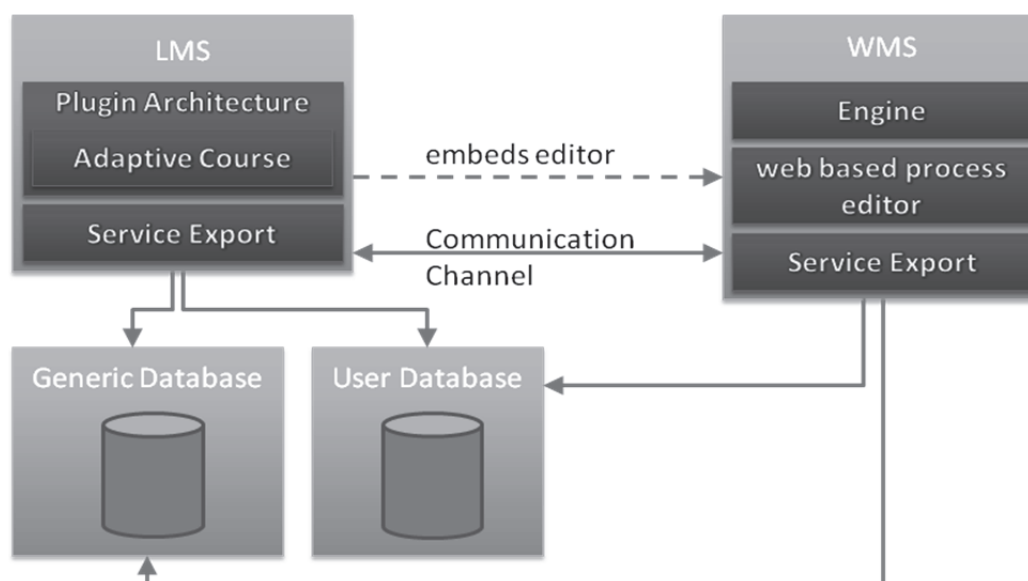

Figure 1 Approach 4 – generic implementation schema

Further, [4] describes the realization of the approaches two and three as infeasible due to copyright restrictions and compatibility problems. [4] also rejects approach one first because it requires a lot of manpower to implement and second and more importantly because of the "yet another system" problem. The "yet another system" hindrance is a result of the abundance of already existing tools both LMS and WMS. Scholars worldwide already use "their" favorite LMS and have spent a lot of time to get to know it and eventually master it. The natural way to apply approach one would be in an environment without an (actively used) LMS.

Therefore, this writing focuses on approach four and proposes a generic schema (Figure 1) for its implementation.

In general the schema presented on Figure 1 contains four main components: Learning Management System, Workflow Management System, a generic database and a user database. One could combine the last two components (a generic database and user database) into a single database component for the sake of simplicity. However, usually the user and the general purpose database are separate entities in a complex multi-system environment.

The LMS includes an adaptive course format which is used to create e-courses. The course creation is facilitated by the embedded process editor, which is provided by the WMS. LMS and WMS communicate through a two way channel which facilitates system state synchronization.

Further, the generic schema depicted on Figure 1 imposes the following feature constraints on the WMS and LMS candidates:

- Only web based LMS are considered
- Only WMS which feature a web based process editor are considered, (The main idea here is to embed the process editor in the natural flow of the chosen LMS, thus allowing for the users to create the process from within an already known user interface)
- Both LMS and WMS should be able to use a common user database (If possible the LMS and WMS must feature tools for the consumption of user databases like LDAP Servers, etc.)
- Both LMS and WMS should feature interoperable data export services (If possible the chosen LMS and WMS should include a "ready to use" server and/or client for SOAP, REST, etc)
- The LMS must be extensible through a plugin architecture (An additional course type "Adaptable course" must be created, which utilizes the WMS)
- The WMS process editor should allow for the definition of domain specific process elements (The idea here is to be able to model the learning activities featured by the LMS with the process definition language provided by the WMS.)

It is essential that the WMS provides possibilities to model and manage not only the business process, but also the components of the workflow itself (activities, sub-processes, resources, constraints, etc.). In other words, one can first model the elements of the business environment (in this case e-learning), which are used for definition, execution and management of the respective processes, and then this system with 'wide range of applicability' starts to act like a specialized (for the needs of the e-learning environment) WMS.

PROTOTYPE IMPLEMENTATION

There are several similar experiments, as stated in the introduction, which satisfy partially the general schema on Figure 1. However, this section presents a functional prototype, which fulfills all of the requirements from the previous section. Further it is solely based on open source technology.

The experiment outlined here is based on the popular open source e-learning platform *Moodle 2.4.3* [22] and a light-weight workflow and Business Process Management (BPM) Platform – Activiti 5.12 [16]. The resulting prototype of a WMS for e-learning, offers tools for modelling and management of concrete e-courses. The modeling is facilitated by complex (in general nonlinear and adaptable) flow structures based on learning activities (as defined by the *Moodle* environment). The *Activiti engine* manages the e-learning process for a set of students taking part in a given e-course.

Moodle is very popular among educators around the world as a tool for creating online courses for their students. The main advantages of _Moodle_ are listed below:

- It can run on any web-server which supports the PHP programming language and also supports variety of databases;
- _Moodle_ requires minimal set up and can be installed and ready for use in less than a minute;
- It provides an easy to use interface in many different languages;
- It supports wide variety of course formats as well as content (pdf, html, video, etc.) and assessment types;
- _Moodle_ is an open source software with many extensions;
- It scales easy, which allows it to serve large as well as small deployments;
- It supports the SCORM standard, etc.

The selection of the _Moodle_ environment for the experiments is based on the above-mentioned features.
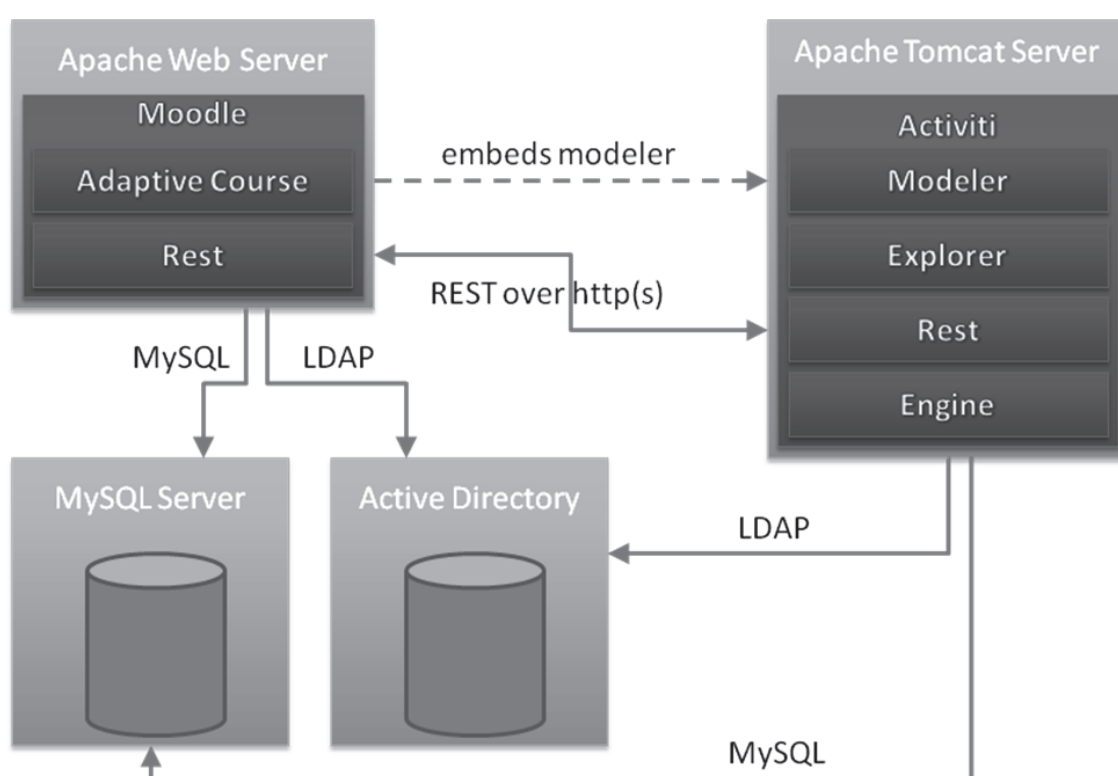

Figure 2 Approach 4 – concrete implementation shema

Activiti BPM Platform is a general purpose workflow and Business Process Management (BPM) Platform targeted at business people, developers and system admins. Further, it is open-source, implements the general purpose process language BPMN 2.0 [18] and runs in any Java application (on a server, on a cluster or in the cloud), integrates with Spring Framework [27] and it is extremely lightweight.

Sadly Activiti has currently no plugin framework. However there are plans to develop one in the near feature.

One part of Activiti's vision motivates the authors of this paper to use it as a main part of the prototype: "A BPM System should not require an organization to drop all tools that they are comfortable with and replace everything with a single system. Instead, organizations must use the best tool for each job and the BPM System must be able to deal with that diversity". Promotion of diversity is what one should seek in a multi-system environment.

The general purpose database is MySQL [28]. It can be replaced with any other mutually supported by Activiti and Moodle.

The user database is Active Directory [15] and is accessed through the LDAP [21] protocol, which is supported by both Moodle and Activiti. As mentioned earlier, it is not necessary to use a separate user database. In our scenario (at the University of Plovdiv "Paissii Hilendarski") the user data for teachers and students is stored in an Active Directory forest.

Figure 2 presents a concrete implementation of the general schema specified in the previous section. It also provides an insight on the way Activiti and Moodle modules integrate. In this scenario both systems (LMS, WMS) provide a convenient and extensible REST [23] interface, through which the state synchronization (information exchange) happens naturally. Further, the Adaptive Course extension to Moodle embeds Activiti's web process editor, allowing for process editing directly from Moodle (Figure 3).

In order to enable the adaptability features of the prototype several changes/fixes to Activiti and one extension to Moodle were made.

A new course format ("Adaptable format") was introduced into the Moodle environment. It embeds a web process editor and facilitates the addition of learning materials and creation of the course structure in the form of a workflow. The rest service needed for the acquisition of uploaded course materials is a part of the standard Moodle REST API and no further modification were made to it. In fact no modifications to Moodle's database structure or code were made. It was possible to extract every bit of information needed for the modeling and execution of Moodle resources and activities with the help of a REST service. For example, all process variables needed for the Quiz's execution are retrieved with Activiti's TaskListeners throught Moodle's REST API. In the case where Quiz results are not submitted automatically, the student can complete the Quiz task manually, as usual.

In order for Activiti Modeler to support Moodle activities/resources its stencilset was extended with a new "Moodle" category. Each element in the Moodle category extends a BPMN construct and adds custom functionality to it. One can now directly drag a Moodle File, Url, Chat, Quiz, etc. into the process modeler. Further, functionality was added to retrieve the image representation of undeployed processes. Several REST services were developed allowing for specific process information retrieval. A small bug related to taks listeners and initialization variables was fixed and reported back to Activiti developers [17].

The process of e-course creation in the *Moodle* environment is left unchanged. One can easily create an adaptive course by utilizing the standard *Moodle* tools. A description of the e-course creation process follows:

Step 1. Create a new adaptive Moodle e-course. When creating a new Moodle course select "Adaptive Format" from the **Format:** combobox. Fill in the rest of the course information as needed.

Step 2. Add materials and create structure. The course creator uploads course materials (Figure 3) to the designated materials container on the top of the course page and uses the Activiti Modeler to create the course structure. The first time the course creator enters a newly created adaptable course she/he is presented with an empty container for resource creation and an example model of a process.

Basically while in this step, the user repeats the actions listed below (Figure 3):
1. Add a Moodle resource/activity to the learning materials container (Figure 3 (1)).
2. Add it to the process model by using the process editor (Activiti Modeler) directly from within Moodle (Figure 3 (2)).

After the modeling of the course is complete (e.g. the elements of the course had been assigned the desired relations) the process is saved and deployed to the engine. The process is then instantiated per student upon first visit to the course page.

The student experience in the Moodle environment is untouched. The student receives the current state of her/his individual course progress in the form of an image and her/his current tasks in the form of list. She/he could also access past assignments/materials from a history list.
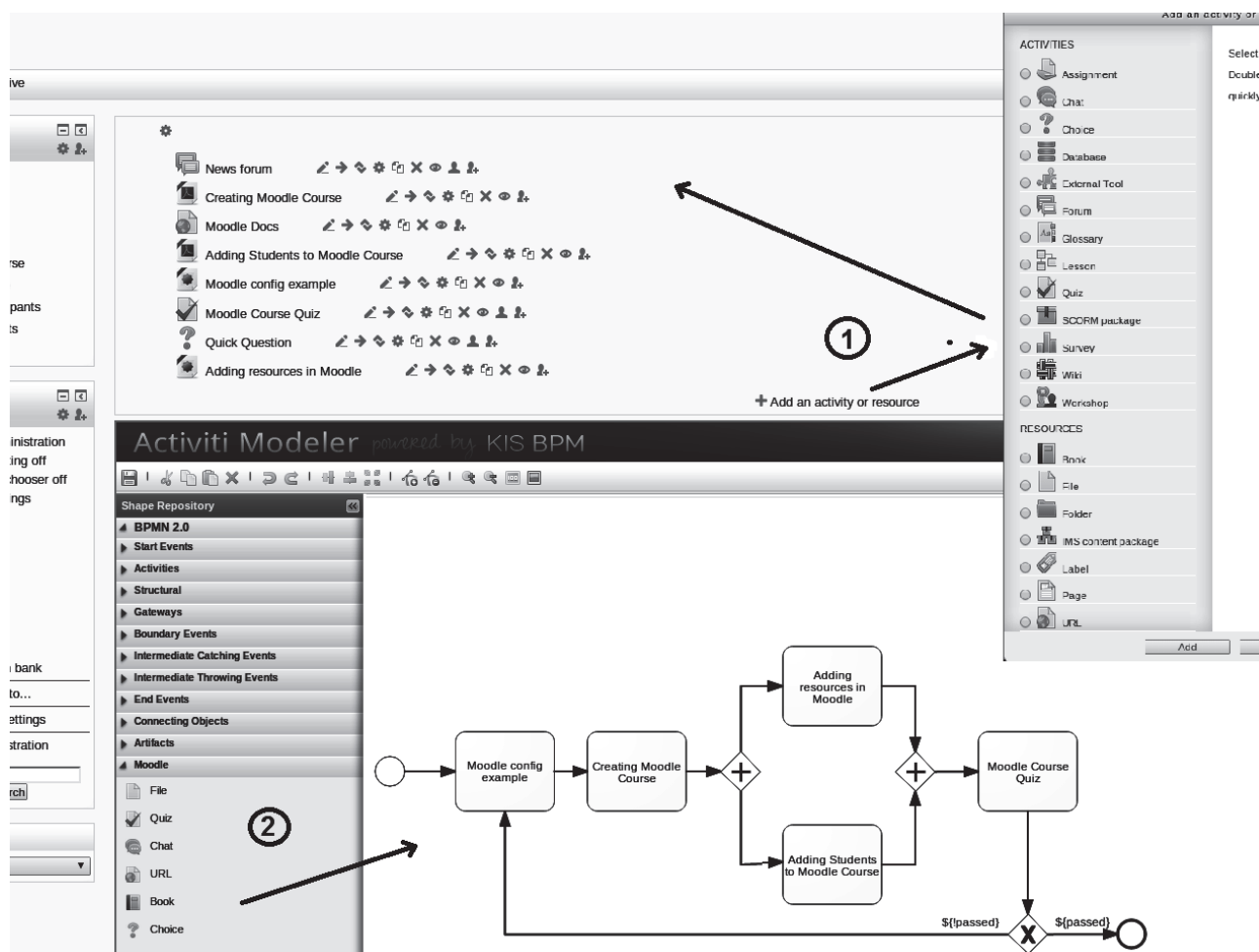

Figure 3 Adaptive course creation.

The teacher has an overview of the individual learner's progress in the form of an image for each student and a list of pending tasks (e.g. Quiz Assessment). The teacher and the course creator could be the same person or different people.

The prototype is available for online experiments on the following address: http://mactiviti.pastelstudios.com.

CONCLUSIONS AND FUTURE WORK

This paper presents a software prototype based on an LMS and WMS: Moodle and Activiti. The prototype extends the current Moodle system to support process-based e-courses by only adding an additional course type. In contrast to [11, 12], where adaptation occurs on Moodle's section level, the proposed implementation sequences Moodle resources and activities.

A big advantage of the proposed implementation is that no changes to Moodle that are outside of its plugin framework were made. This is possible mainly because of the generality of the BPMN language, the fact that Activiti promotes diversity and the extensible REST interfaces of both Moodle and Activiti.

It is to be expected that the improvement and integration of such systems could considerably enhance the quality of the offered education, by giving the user the

opportunity to create adaptive (consistent with the achievements and success of each learner) virtual courses.

The prototype proves that a general purpose language could be used to model e-learning processes. With its ready to use constructs BMPN 2.0 (activities, tasks, gates, events, subprocesses, etc.) is suitable for the creation of templates for different pedagogical scenarios. The templates could then be populated with learning materials prior or during their execution. One could model not only the education process related to an e-course but also an entire education program (eg. distance learning).

In a similar fashion one could model and execute an educational process, which includes not only learning activities (which are in general simple processes too) but calls to processes/activities outside of the LMS (eg. administrative processes). In other words, one could apply this integration approach, not only to LMS like Moodle but to other existing university-related (or unrelated) systems as well.

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