Adaptive e-learning system based on accumulative digital activities in revised Bloom's taxonomy

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Adaptive E-learning System Based on Accumulative Digital Activities in Revised Bloom's Taxonomy

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Abstract: *Adaptive e-learning systems enhance efficiency in education by providing personalized e-course content (learning objects and activities), while taking into consideration learners' needs and achievements. An adaptive approach, based on accumulative digital activities ordered by the cognitive levels and the components of the knowledge dimension of the Revised Bloom's Taxonomy, is presented in this study. Using this approach makes possible dynamic selection of different assignments for these activities, according to learners' results of working on these assignments. This type of selection assures that individual curriculum content will be determined by the level of knowledge of each learner and the educational objectives. In order to be implemented the adaptive approach was created workflow that describes logical and meaningful connections between assignments of the digital activities. The implementation is made in Moodle e-learning system, using Bonita software to provide workflow modelling.*

Key words: *adaptive e-learning systems, e-courses, learning activities, digital activities, Bloom's taxonomy.*

INTRODUCTION

Adaptive e-learning systems provide flexible learning in order to enhance efficiency during the educational process by satisfying learners' needs [3, 11]. These systems have to achieve two basic objectives: reuse of the learning objects and personalized learning taking into account the context of the collaborative learning activities. There are four main categories of adaptation in the different e-learning environments [10]:

- *Adaptive interaction* – supports users interaction with the system by suitable interface;
- *Adaptive course delivery* – fits course content to the users' characteristics and requirements;
- *Content discovery and assembly* – application of adaptive techniques in discovering the most appropriate content (learning objects) from given repositories;
- *Adaptive collaboration support* – capture adaptive support when there is communication between several learners towards common objectives.

The design of an adaptive e-learning system includes the construction of three basic models [11]: ***learner's model,*** containing learners' preferences and the results obtained in the different activities, taken during the e-course; ***content model***, consisting of learning objects (materials and learning activities) stored in a repository, and ***instructional model***, comprised of adaptable learning strategies that assure different ways of selecting learning objects from the content model, according to the concrete learner's model. The most difficult and time-consuming task in creating adaptive e-learning systems is to choose the most appropriate framework for finding the connection between the learner's model and the educational objectives.

An adaptive approach based on the ***accumulative digital learning activities***, according to the ***Revised Bloom's Taxonomy*** (RBT) [1, 2], is presented in this study. The approach is implemented in the Moodle e-learning system.

ACCUMULATIVE DIGITAL ACTIVITIES IN THE REVISED BLOOM'S TAXONOMY

E-learning systems support a great variety of digital activities, such as chat, forum, wiki, databases, quizzes, workshops, etc. [12, 15] that are used during the e-course, not only to help learners to learn the necessary course's content, but also to evaluate their level of knowledge. Each activity consists of three important elements [6]: *context* – theme, level of difficulty, results and the environment, where the activity is done; *pedagogical approach* – models and strategies; and *assignment* – concrete tasks including techniques, tools and roles of the participants. Analyzing specific characteristic features of every digital activity is a necessary prerequisite for creating adequate e-courses according to the learners needs. The main problem in designing an adaptive e-learning system is to find an appropriate framework to determine the order of presentation of digital activities during the educational process in compliance with the learner's model. In order to improve efficiency in education, the adaptive model must fulfill two functions. On one hand, it must assure the connection between the users' goals and the objectives in the education process. On the other hand, it should make learning objects and activities reusable. Most of the adaptive models developed and implemented in e-learning platforms use only static approaches based on determining the learner's model specification without taking into consideration educational objectives. In order to overcome this gap, we have developed a flexible approach based on two main aspects - accumulative digital activities and the hierarchical model of the learning objectives in the cognitive levels, and the components of the knowledge dimension of the RBT (fig. 1).

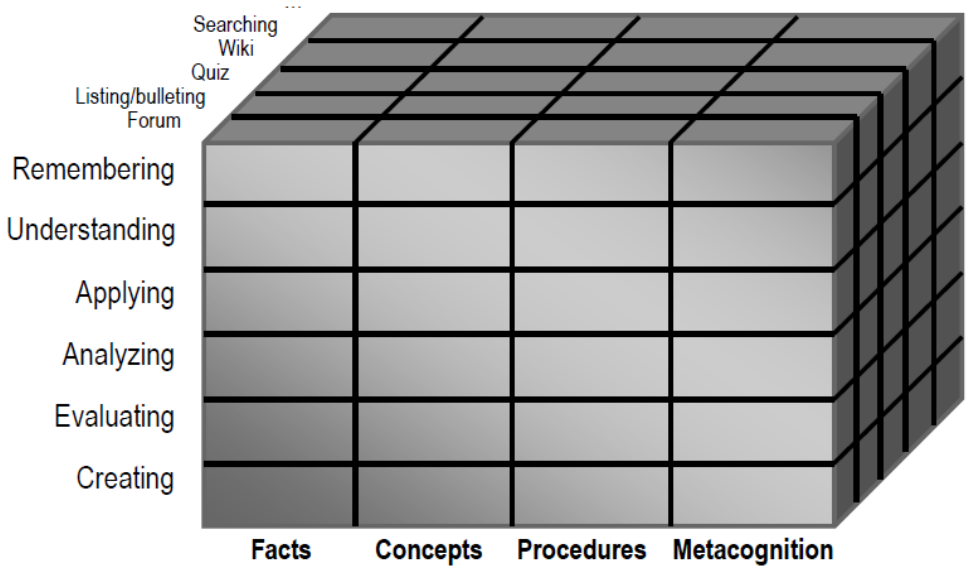

Figure. 1 Adaptive Model, based on Digital Activities in RBT

Applying an analogous approach to one concrete digital activity – a quiz - led to successful implementation [9]. A computer adaptive test (CAT) system, based on accumulative question type and RBT was developed as an extension of Moodle e-learning system. Test items were ordered according to the cognitive levels, and the components of the knowledge dimension. Their logical and meaningful connections were presented in a workflow. An adaptive algorithm for test creation traversing the nodes of the workflow was developed and item selection was done based on the learners' level of knowledge. The correct answers to previous such items were used for designing new test items. This method has been used for dynamic calibration of the question bank and individualized approach to every learner.

Learning digital activities depending on their level of difficulty can be ordered in different cognitive levels of Bloom's taxonomy [5]. In [8] is presented an adaptive approach that uses this order for implementing different strategies for traversing digital activities at the concrete knowledge level according to learners' achievements.

Learning Activities	Moodle Digital Activities	Learning Activities	Moodle Digital Activities
Listing/ Bulleting	Assignments	**Interviewing**	Forum, Chat, Workshop
Searching	Search forums	**Report, Diagram**	Assignments
Labelling	Label, Assignments	**Survey**	Survey
Definition	Glossary, Assignments	**Posting**	Workshop, Forum
Quiz	Quiz, Choice	**Moderating**	Workshop, Forum, Blog
Journaling	Blog, Assignments	**Annotating**	Blog, Workshop, Forum
Commenting	Workshop, Forum, Blog, Comments	**Uploading, Sharing**	Forum, Workshop, Assignments
Outlining	Assignments	**Summary**	Assignments, Forum, Workshop
Publishing, Blogging	Blog, Forum	**Creating Database**	Database
Editing	Assignments, Wiki	**Creating Wiki**	Wiki

Table 1. Digital Activities in Moodle

A number of different assignments for each digital activity listed in the first column of table 1 (learning activities) were developed in order to implement such an approach. Every assignment has its concrete place in the hierarchical model of the educational objectives in the RBT. These assignments are used as templates and can be developed further according to the subject of the e-course. Some of the tasks suitable for digital activities 'listing (bulleting)' and 'forum' are shown in table 2.

By using this framework, two important goals are achieved:

- Template assignments are used for collecting information (data) that is used for the next assignments;
- Exact placing of the task in the RBT helps provide the connection between educational objectives, on one hand, and learners' goals and level of knowledge on the other. The difficulty level of the next digital activity is determined dynamically during the e-course. This is how the individual curriculum based on learner's results is created in the education process.

The presented framework is used to select the most appropriate assignment for the concrete digital activity, according to dynamically determined learner's level of knowledge. A workflow that presents logical and meaningful connections between the assignments was created to implement the adaptive model shown on fig 1. It provides different possibilities for traversing the assignments depending on the educational strategy chosen, keeping in mind the educational objectives and personal results of the learners.

One possible way of traversing is to start with an assignment at the first level – 'remembering' of 'facts'. If the learner achieves good results at this, the next assignment is chosen from the next cell of Table 2 - 'Understanding' 'Facts'. If the result is not satisfactory, then the system presents another assignment from the same cell (on the same cognitive level). The outcome of the education process depends on dynamic traversing of the workflow with the assignments in table 2 and a decision about the path in the workflow has to be made at every step of the process.

Assignments for Digital Activities 'listing/bulleting' and 'forum'				
	Facts	**Concepts**	**Procedures**	**Metacognition**
Remembering	1.1.F. List/give facts that you have learned 1.2.F. List/give persons, events connected with the subject	1.1.C. List/give basic concepts, described in the learning object forum 1.2.C. Describe (give definition) every basic concept	1.1.P. List/give basic problems connected with the subject 1.2.P List/give possible solutions of each basic problem	1.1.M. List/give what else are persons in the learning object famous with forum 1.2.M What is the learning object about (basic subject)
Understanding	2.1.F List/give categories (groups) in which learned facts are ordered 2.2.F List/give facts in each category (group)	2.1.C List/give states, of each concept forum 2.2.C. Which is the basic concept connected with the subject and why?	2.1.P List/give categories in which the procedures are ordered forum 2.2.P Describe the basic problem, presented in the learning object, give its solution	2.1.M. List/give field/domain to which you can refer the basic concepts forum 2.2.M. Present in your own words the basic concepts in the learning objects
Applying	3.1.F List/give situations where learned facts can be used in practice forum 3.2.F Formulate thesis which proof is connected with the learned facts	3.1.C. List/give for what can be used concepts, described in the learning object forum 3.2.C. How the state of the concept can influence its application	3.1.P List/give situations in which learned procedures can be used in practice forum 3.2.P Give problems that can arise if learned procedures are applied	3.1.M. List/give situations in which you'll have to use learned things forum 3.2.M. What conclusions can you make of the learning object
Analyzing	4.1.F List/give facts chronologically ordered 4.2.F List/give what happens after fact F1	4.1.C. List/give composite concepts forum 4.2.C. Describe the structure of the compound concepts	4.1.P List/give separate steps of each procedure forum 4.2.P Describe how a concept passes from one state to another	4.1.M. List/give other connections between the concepts in the learning object forum 4.2.M.C. Compare concepts of the subject with concepts of other areas
Evaluating	5.1.F List/give the most important facts, ordered by their significance 5.2.F Give consequences of given fact/statement	5.1.C List/give concepts, ordered by their significance forum 5.2.C. Choose one concept of the learning object and present it. Give reasons for your choice	forum 5.1.P Evaluate the procedures of different points of view	5.1.M.P List/give mistakes in the learned procedures forum 5.2.M. Analyse titles (sections, figures, pictures etc.) of the learning object. Which of them are not suitable and why.
Creating		6.1.C List/give concepts that, have to be clarified/highlighted	forum 6.1.P List/give procedures that need to be changed and why, give your variants	6.1.M.P List/give another possible ways for solving given problem

Table 2. Assignments for digital activities 'listing/bulleting' and 'forum', according to RBT (sample)

EXPERIMENTS

According to rankings of several e-learning platforms based on eight groups of criteria stressing on adaptation capabilities, [7] Moodle has proven to be an easy-to-extend system, which will help the above-described personalized approach implementation.

A non-linear traversing of the workflow has been achieved by using a generic method for the integration of Workflow Management System (WMS) elements into Learning Management System (LMS), presented by [13]. In this particular case Bonita Open Solution [13] is used as the modeling tool and as the workflow execution engine. One of the improvements over the WMS system, presented by [13], is that Bonita Open Solution uses Business Process Model and Notation (BPMN) 2.0 as a standard workflow notation, which improves compatibility with other workflow engines [14].

Bonita Open Solution consists of three main components: Bonita Studio, Bonita Execution Engine and Bonita User Experience. Bonita Studio is more than a graphical process editor, which supports BPMN notation. It supports seamless integration with other information systems with the help of ready-to-use connectors and simplifies the interaction between users and processes by utilizing web interfaces. Bonita Studio integrates a visual editor for the web interface, which accompanies a given process. Bonita Execution Engine is the backbone, which executes and manages processes. It is created by means of its easy integration with other systems with the use of programming interface. Bonita User Experience is a user portal, which allows the end user to interact with a given workflow.

The development of the prototype is based on Moodle version 2.2.2 and Bonita Open Solution version 5.6.2. A module was created to enable the communication between the two systems. The module consists mainly of two parts:

- Invasive – it requires changes to the LMS, which are required for the WMS to deliver the right content to the users,
- Non-invasive – it does not require changes to the LMS. It utilizes Moodle's capabilities for exporting data through web services [16].

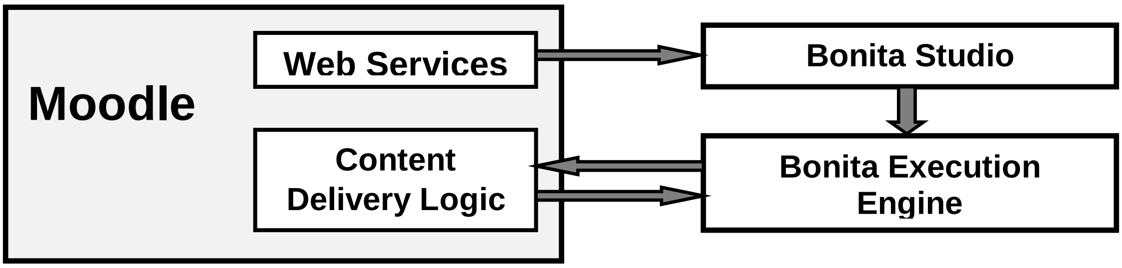

Figure 2. Moodle-Bonita integration schema

The extensions and changes to Moodle and Bonita Open Solution needed for the realization of the above architecture (fig. 2) are listed below.

- A web service, which allows users to access information about activities included in the e-course. The web service is realized by standard means, provided by Moodle for development of external services.
- A Bonita Connector, which can access activity information, provided by Moodle through the above-mentioned web service. The connector provides data needed for the successful modeling of workflows.
- A modification of the way Moodle serves activity content, which enables the rendering of Human Tasks [13].
- A PHP client, which provides access to the Bonita workflow execution engine. The access is accomplished via REST (REpresentational State Transfer) technology.

As Moodle is a PHP application, a special Bonita REST PHP client was developed.

The standard tools provided by Moodle are used to create e-courses. The modeling of workflows consisting of e-activities connected to the process of learning is done with Bonita Studio, which can access Moodle data through the Bonita web service connector mentioned above. The connector is realized in Java and provides a universal mechanism for exporting data from Moodle and importing it in a WMS, which supports SOAP (Simple Object Access Protocol).

After successful connector setup, the data for a given e-course is accessible from the graphical process editor and the modeling of learning activities can commence. Fig. 3 presents a part of the workflow, which forms the connections between activities listed in table 2.

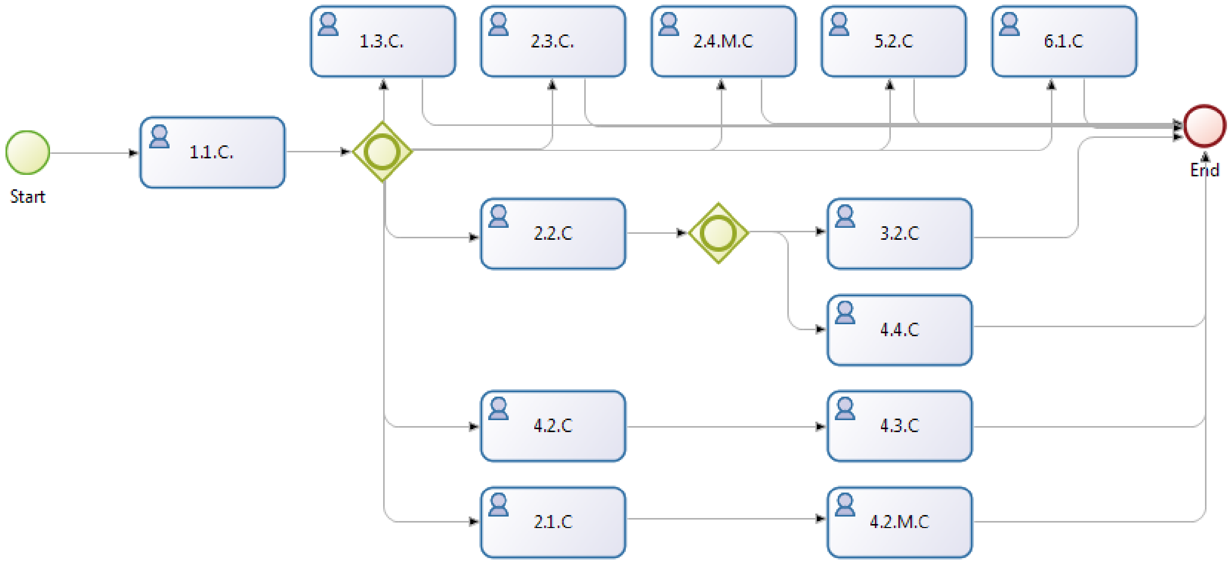

Figure. 3. Workflow of digital activities created with BPMN 2.0 notation and Bonita.

The created workflow is then loaded into the Bonita execution engine. Now the modeling phase is complete, and the accumulation of answers can begin. Bonita Execution engine takes care of the workflow execution. Accumulative assignments for digital activities are realized as Human Tasks (presented on fig. 3). By default Bonita User Experience provides its own rendering of the human task. In this case, however, the rendering is done by Moodle with the help of the modified content delivery module (fig. 2). The PHP REST module mentioned earlier is used by Moodle to manage the delivered content by accessing information about the current status of the student directly from the WMS engine.

CONCLUSIONS AND FUTURE WORK

An adaptive approach, based on accumulative digital activities and the Revised Bloom's Taxonomy, was developed to achieve dynamic order of the digital activities during the e-course according to learners' personal results. Thus it is guaranteed that the individualized course curriculum takes educational objectives into consideration. This approach was implemented in Moodle e-learning platform by using Bonita Open Solution as the modelling tool and the workflow execution engine. This implementation provides means to dynamically determine the order of the proposed digital activities and assures the flexible content of the e-course.

Several basic tasks have to be solved in the future:

- Implementation of different strategies for traversing the workflow of the assignments of digital activities;
- Creating and using different evaluation procedures to automate the evaluation process;
- Experimenting with different algorithms for traversing the workflow;
- Using accumulated data in the next steps of the learning process;
- Carrying out experiments in the real e-learning process and analyzing the results.

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