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

Hristina Kostadinova, George Totkov, Hristo Indzhov

Abstract: Adaptive e-learning systems enhance efficiency in education by providing personalized e-course content (e.g., learning materials and activities) that changes with respect to learners’ needs and achievements. An adaptive approach is presented in this paper, which is based upon accumulative digital activities and which is ordered according to pre-established demarcations of cognitive skills with components of the dimension of knowledge within Revised Bloom’s Taxonomy. Utilizing the adaptive approach allows for a dynamic selection of different assignments for these activities in accordance with learners’ resultant scores that are established after working on previous assignments. This type of selection ensures that individualized curricular content is determined by the level of knowledge of each learner and educational objectives. In order to be implemented the adaptive approach creates workflow that describes logical and meaningful connections between assignments of the digital activities. The implementation of the approach is made within the Moodle e-learning system by means of Bonita software in order 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 via satisfying learners’ needs [3, 11]. These systems have to achieve two basic objectives: (1) reuse of the learning materials; and (2) personalized learning, which both take 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 (i.e., learning materials) 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]: the **learner’s model** contains learners’ preferences and the results obtained in the different activities during the e-course. The **content model** consists of learning objectives, learning materials and learning activities that are stored in a repository. Lastly, the **instructional model** is 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 regard to 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 is presented in this study, which is based on the **accumulative digital learning activities** in accordance with **Revised Bloom’s Taxonomy** (RBT) [1, 2]. The approach is implemented within the Moodle e-learning system.
ACCUMULATIVE DIGITAL ACTIVITIES IN THE REVISED BLOOM’S TAXONOMY

E-learning systems support a wide variety of digital activities, such as chat, forums, WIKIs, databases, quizzes, workshops, etc. [12, 15], which are used during the e-course, not only to facilitate learning the required course content, but also to evaluate students’ specific levels of knowledge. Each activity consists of three important elements [6]: (1) the context – involving themes, levels of difficulty, results and the environment within which the activity is accomplished; (2) the pedagogical approach – involving models and strategies; and (3) the assignment – involving concrete tasks including techniques, tools and roles of the participants. Analyzing specific characteristics of each digital activity is a necessary prerequisite for creating suitable e-courses in accordance with the learners’ needs. The main problem in designing an adaptive e-learning system is finding an appropriate framework to determine the order of the 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, the model must facilitate the connection between the users’ goals and the objectives in the education process. On the other hand, the model should make learning materials and activities reusable. Most of the adaptive models developed and implemented in e-learning platforms use only static approaches based on predetermining the learning model specification without consideration for educational objectives. In order to overcome this gap, we have developed a flexible approach based on two major aspects – (I) accumulative digital activities; and (II) the hierarchical model of the learning objectives, which demarcates distinct cognitive levels as well as the components of the dimension of knowledge of RBT (See fig. 1).

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

Applying an analogous approach to one concrete digital activity, i.e., an electronic quiz - via an online e-course, led to successful implementation [9]. A computer adaptive test (CAT) system was developed as an extension of the Moodle e-learning system and is based on accumulative type questioning in addition to RBT. Test items were ordered according to pre-established levels of cognition and the components of the dimension of knowledge. Their logical and meaningful connections were presented in a workflow. An adaptive algorithm for the creation of tests, traversing the nodes of the workflow was developed and each item’s selection was performed on the basis of each learner’s level of knowledge. The correct answers to previous questions were utilized in order to design new tests. This method has been utilized for dynamic calibration of question banks and
individualized approaches for diverse learners, e.g., visual or auditory learners.

Learning digital activities, depending on their levels of difficulty, can be ordered in different cognitive levels of Bloom’s taxonomy [5]. Reference [8] presents an adaptive approach that utilizes this hierarchy in order to implement different strategies for traversing digital activities at the concrete level of knowledge in accordance with learners’ achievements.

<table>
<thead>
<tr>
<th>Learning Activities</th>
<th>Moodle Digital Activities</th>
<th>Learning Activities</th>
<th>Moodle Digital Activities</th>
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<td>Interviewing</td>
<td>Forum, Chat, Workshop</td>
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<td>Outlining</td>
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<td>Wiki</td>
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**Table 1. Digital Activities in Moodle**

A number of different assignments for each digital activity listed in the first column of table 1 (i.e., 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 further developed 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 that is used for the assignments that follow previous ones;
- Precise placing of the task in the RBT helps provide the connection between educational objectives, on one hand, and learners’ goals and levels of knowledge on the other. The level of difficulty of the next digital activity is determined dynamically during the e-course. This is how the individual curriculum, which is based on learners’ results, is created in the education process.

The abovementioned framework is utilized in order to select the most appropriate assignment for the digital activity at hand in accordance with learners’ levels of knowledge, which are dynamically determined. A workflow that presents logical and meaningful connections between the assignments was created to implement the adaptive model shown in fig 1. The workflow provides different possibilities for traversing the assignments, depending on the educational strategy chosen and with respect to the educational objectives and personal testing results of each learner.

One possible way of traversing digital activities in the e-course is to start with an assignment at the first level of cognitive difficulty – ‘remembrance of facts’. If the learner achieves good results on this, then the next assignment is chosen from the next cell of Table 2 – i.e., ‘Understanding Facts’. If the latter result is unsatisfactory, then the system presents another assignment from the same cell (i.e., on the same cognitive level). The outcome of the educational process is dependent upon a dynamic traversing of the workflow with the assignments in table 2 and a decision about the pathway in the workflow is made at every step of the process.
| **Assignments for Digital Activities ‘listing/bulleting’ and ‘forum’** |
|-------------------------|-------------------------|-------------------------|-------------------------|
| **Facts**               | **Concepts**            | **Procedures**          | **Metacognition**       |
| 1.1.F. List/give facts that you have learned | 1.1.C. List/give basic concepts described in the learning object | 1.1.P. List/give basic problems connected with the subject | 1.1.M. List/give what else are persons in the learning object famous with |
| 1.2.F. List/give persons, events connected with the subject | 1.2.C. Describe (give definition) every basic concept | 1.2.P List/give possible solutions of each basic problem | |
| **Understanding**       | **Remembering**         | **Applying**            | **Remembering**         |
| 2.1.F. List/give categories (groups) in which learned facts are ordered | 2.1.C. List/give states, of each concept | 2.1.P List/give categories in which the procedures are ordered | 2.1.M. List/give field/domain to which you can refer the basic concepts |
| 2.2.F. List/give facts in each category (group) | 2.2.C. Which is the basic concept connected with the subject and why? | 2.2.P Describe the basic problem, presented in the learning object, give its solution | 2.2.M. Present in your own words the basic concepts in the learning objects |
| **Applying**            | **Remembering**         | **Analyzing**           | **Remembering**         |
| 3.1.F. List/give situations where learned facts can be used in practice | 3.1.C. List/give for what can be used concepts, described in the learning object | 3.1.P List/give situations in which learned procedures can be used in practice | 3.1.M. List/give situations in which you’ll have to use learned things |
| 3.2.F. Formulate thesis which proof is connected with the learned facts | 3.2.C. How the state of the concept can influence its application | 3.2.P Give problems that can arise if learned procedures are applied | 3.2.M. What conclusions can you make of the learning object |
| **Analyzing**           | **Remembering**         | **Evaluating**          | **Remembering**         |
| 4.1.F. List/give facts chronologically ordered | 4.1.C. List/give composite concepts | 4.1.P List/give separate steps of each procedure | 4.1.M. List/give other connections between the concepts in the learning object |
| 4.2.F. List/give what happens after fact F1 | 4.2.C. Describe the structure of the compound concepts | 4.2.P Describe how a concept passes from one state to another | 4.2.M.C. Compare concepts of the subject with concepts of other areas |
| **Evaluating**          | **Remembering**         | **Creating**            | **Remembering**         |
| 5.1.F. List/give the most important facts, ordered by their significance | 5.1.C List/give concepts, ordered by their significance | 5.1.P Evaluate the procedures of different points of view | 5.1.M.P List/give mistakes in the learned procedures |
| 5.2.F. Give consequences of given fact/statement | 5.2.C. Choose one concept of the learning object and present it. Give reasons for your choice | 5.2.M. Analyse titles (sections, figures, pictures etc.) of the learning object. Which of them are not suitable and why. | |
| 6.1.F. List/give concepts that have to be clarified/highlighted | 6.1.C List/give concepts that need to be changed and why, give your variants | 6.1.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 the rankings of various e-learning platforms, which are based upon eight sets of criteria stressing adaptation capabilities, [7] Moodle has proven to be an easy-to-extend system which facilitates the aforementioned, personalized approach and its implementation during the learning process.

A non-linear traversing of the workflow is well achieved by using a generic method for the integration of Workflow Management System (WMS) elements into Learning Management System (LMS), which is 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 the 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. 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 – requires changes to the LMS, which are required for the WMS in order to deliver appropriate content to users,
- Non-invasive – does not require changes to the LMS. The module utilizes Moodle’s capabilities for exporting data through web services [16].

The extensions and changes to Moodle and Bonita Open Solution required 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.

To enable the communication between Moodle (a PHP application) and Bonita a
special connector (a PHP REST client) is 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 accomplished with Bonita Studio, which can access Moodle data through the Bonita web service connector mentioned above.

After the 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.

![Workflow Diagram](image-url)

**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. At this point 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 (fig. 3). By default Bonita User Experience provides its own rendering of the human task. However, in the latter case the rendering is performed by Moodle with the aid 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 in order to achieve dynamic order of digital activities during the e-course and in accordance with learners’ personal performances within the system. Thus, it is guaranteed that the individualized course curriculum thoroughly incorporates educational objectives. This approach was implemented in the Moodle e-learning platform by using Bonita Open Solution as the modelling tool and the workflow execution engine. This implementation provides means in order to dynamically determine the order of the proposed digital activities and ensure the flexible content of the e-course.

Several basic tasks must 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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REFERENCES
[2] Bloom, B. Taxonomy of Educational Objectives. Published by Allyn and Bacon, Boston, MA Copyright (c) 1984 by Pearson Education (1956).
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