Automatic Learning Path Design: development and implementation

AGOSTINO MARENGO, ALESSANDRO PAGANO, GIULIO MONOPOLI
Department of Economics and Mathematical Methods
University of Bari
Largo Abbazia Santa Scolastica, 53
ITALY

Abstract: - This paper will describe the development and implementation of an Adaptive System Prototype with the aim to manage an automated and customized learning experience.

After the first in-depth study on the usefulness and effectiveness of personalized learning approach, the research team intended to fill the gap between the theory of personalized learning environments and its practice trough the development of an adaptive learning plugin implemented on mostly used, Open Source, Learning Management Systems.

The developed technology, follow the goal to identify any end user of the LMS, create a customized user profile with their starting skills and learning preferences in order to automatically tailor a personalized learning path. The main purpose is to maximize student's performance.

This paper describes the main steps for the implementation of the prototype of this Adaptive Learning System named **iO3** (intelligent Open Cube), as it will be an *intelligent, Open Source, Open Learning, Open Plugin* system.

Key-Words: - Adaptive learning, Automatic Learning Path design, e-learning, Personalized Learning Environments.

1 Introduction

Considering the state of the art of most common e-learning environments [15], many researchers believe that adaptive learning is a critical requirement to enhance the teaching quality and the user performance throughout the learning process. The adaptive learning feature improves the starting skills of a user, providing specific content related to his learning style.

The road to follow in order to build an effective learning and teaching performance cannot overlook the aspect of personalized learning environments.

Generating a *customized learning path* for any learner provides a challenging work for researchers involved, both, in informatics and education fields. Learning Path is a collection of different learning items that are combined to achieve a specific learning goal. Furthermore, the development of an customized (*adaptive*) learning path means that learner's starting skills should be evaluated for providing a tailored learning path suitable for each student.

Different learners may have different characteristics, prior knowledge, starting skills, motivation or needs. This variety of "distinguishing marks" commonly requires the management of different information to different learners in a different format [16]. Taking this in count, our research group believes that it is fundamental to develop adaptive educational systems which consider the several individualities of each student when presenting information, learning objects and/or practice opportunities, in order to make the learning process as effective, efficient, and motivating as possible. [1] This is not a way to rethink education, but a way to reinforce opportunities of professional and educational growth [17].

The purpose of this research study is to identify a process to deliver the right contents according to the student's learning style and to develop/implement it in a software module.

The goal of this research is to develop **iO3** (intelligent Open Cube) system, an adaptive technology, based on an Open Source LMS that automatically build suitable learning path for each user/student considering his own assessed profile. **iO3** will be:

- **Intelligent (i)** as it will project an <u>innovative Intelligent Agent</u> to support e-learning and develop such an approach, evaluating the impact on the speed and success of learning given specific learning outcomes;
- **Open Source (O[1])** as it will only use <u>Open Source software verifying its quality standards</u>. Open Source technology will be used and analyzed considering the efficiency and efficacy of services and the

design of tools to ease interactive and collaborative processes;

- **Open Learning (O²)** as it will <u>deliver constructive knowledge functional proficiency and to all people who want to approach it</u>. This academic environment will become a landmark for university students, high school students, adult or senior learners, professionals and whoever wants to access to the high level knowledge without necessarily pay for it.
- **Open Plugin (O³)** as it will define a plugin prototype and deliver it on the Open Source Community using GNU Licence;

On the methodological point of view, the main questions that this research project aims to answer are:

- Which learning objects should be picked to build a learning path suitable for each user?
- How could adaptive learning be implemented in Open Source LMS (Learning Management System)?

To answer these questions the research team investigates the adaptive technology and, in this paper, describes the implementation of an adaptive "strategy" in the mostly used Open Source Learning Management System (LMS): Moodle.

The first step in building an adaptive learning tool is to identify the student's profile with his own learning style and starting skills in order to determine the appropriate learning content that corresponds to the individual students learning style and learning needs. [2]

In the development approach proposed, user profile is assessed and evolved using Case Based Reasoning. The Adaptive Learning Path is generated using the learner's behaviour patterns, which are modelled as the learner's characteristics like learning styles, goals and performance.

This paper shows the development of a plug-in for Open Source LMS that helps to select the suitable learning object each student.

In this personalized learning environment, the student's performance will be enhanced and the expected result is to reach higher motivation to finish the course, avoid situation in which the student has to study un-useful or unsuitable contents. [3]

2 Methodology

The steps needed to achieve the research objectives of the whole research project in which this paper is placed, are to be identified in the technological innovation process.

First of all, the research team performed a deep study of the state of the art.

At the end of this phase, the research team proceeded to the code development of the software and all the technical works needed to meet the functional requirements.

After development, a phase of tests and experiments conducted in vitro and in vivo will be launched. This step will ensure the compliance with the objectives of the project and measure the degree of goals achievement, through statistical surveys and satisfaction questionnaires on teachers and the learners.

During this phase it will be possible to take action to make changes and functional maintenance/bug-fix. Finally, the collection and organization of results phase will take place in order to proceed to the scientific dissemination.

3 Problem Solution

The merely delivering of Learning Objects inside a learning path is not enough. Repositories of Learning Objects are built with specific user interfaces and architectures that make them easy to use and permits various levels of interactivity including search, submissions, comments/reviews, and creating personal collections. The prospect of these personal high-educational paths may be the way to empower people, in particular during the Life Long Learning of an employee (developing acquired work positions or developing skills in case of mobility). Furthermore any academic network could benefit of this repository, sharing best practices in the different fields of research.

Moodle is the mostly used open source LMS. It can be used to deliver online learning in a huge variety of scenarios.

These scenarios are mainly virtual schools, K12 [4], higher education, corporate universities, charter schools, and commercial training, to name but a few. Moodle is used primarily as an asynchronous learning tool, where learners study at different times. However, it also includes synchronous tools. Moodle is used both as the primary delivery vehicle for courses as well as a supplemental tool for face-to-face learning. To put it simply, Moodle is a teacher's toolkit to help improve learning, is designed in a community with teachers interacting directly with programmers. Moodle's intuitive and simple interface is the result of this collaboration.

Moodle originally stood for Modular Object-Oriented Dynamic Learning Environment. From a

programmer's perspective, the "M" in Moodle is a very important concept. Modularity is designed throughout Moodle. This lets a developer make significant modifications to Moodle without having to modify its code. This is a very important capability in terms of reducing the amount of time taken to make modifications when new versions of Moodle are released [5].

Moodle lacks of student classification, so the research team focus the work providing a student modelling process to add a brand new feature: tailored learning paths.

Once information about the learners is available from the student model, the adaptive procedure can be provided.

Different aspects have to be considered when aiming at providing students with adapted courses. One dimension refers to what can be adapted in a system.

Different methods exist for providing students with adapted courses. These methods determine which features of the system are different for different learners.

Existing adaptation features can be classified regarding their aim into two groups, namely for adaptive navigation support and adaptive presentation.

Adaptive navigation support is based on links and includes features such as direct guidance, map adaptation, as well as adaptive sorting, hiding, annotating and generating of links.

Adaptive presentation includes adaptation features based on content such as adaptive multimedia presentation, adaptive text presentation, and adaptation of modality.

An example of existing tool for adaptive navigation support in Moodle is the Activity locking.

The basic concept locks a student out of a specific activity until the student meets a score, a time or a view criterion matrix for one or more specific activities or re-sources in a course. In Moodle LMS, there are options to hide the locked activity, or hide a complete section of activities and resources. Other options include showing a progress icon next to completed activities. Some specialized conditional activities locks are based on an overall course criterion matrix (http://docs.moodle.org/dev/Adding_activity_lock).

With this tool, the teacher is the only one who can change or hide/unhide activities and resources depending on his assessment of the individual differences of his students. So, teachers or instructors, who are creating a course, should prepare some alternative version of the course for better or weaker students.

The proposed, and much more effective approach, is an adaptive sequencing of learning courses/activities for each particular learner based on a student model updated after each interaction with the learner

4 Adaptive Software Analysis

To better understand the concepts expressed in the rest of the paper it is necessary to clarify some terms:

➢ **course**: a set of one or more 'learning objectives'
course = (lb1, lb2,….., lbn) n > 0

➢ **learning object (lo)**: a set of one or more 'assets'
lo = (as1, as2,……, asn) n > 0

➢ **tag**: a string representing the content of the Moodle's resource/activity

➢ **asset (as)**: a Moodle's resource or activity (Assignment, Chat, Choice, Database, External Tool, Forum, Glossary, Lesson, Quiz, SCORM package, Survey, Wiki, Workshop, Book, File, Folder, Page, URL) with one or more tag.

asset = (M, tag1,…, tagn) n > 0

M = {Moodle's resource | Moodle's activity}

➢ **vis(as)**: the visibility of a generic asset as. It can only be 'VISIBLE' or 'NOT VISIBLE'

vis(as) = {VISIBLE | NOT VISIBLE}

➢ **pre-test**: a specific quiz submitted to the user at the beginning of the course to evaluate his preparedness.

pre-test = (q1, q2,….., qn) n ≥ m
m = number of total assets in the course

➢ **quiz:** a set of 'tagQuestions'

quiz = (q1, q2,….., qn) n > 0

➢ **tagQuestion (q)**: a set composed by the text of the question, one or more correct answer, one or more wrong answer, one or more reference to an asset and a rate.

question = (t, CA, WA, AS, r)

-t = text of the question

-CA = {ca1, ca2,…., can}   n > 0 a set of correct answers
-WA = {wa1, wa2,…., wan}   n > 0 a set of wrong answers
-AS = {as1, as2,….,ask}   k > 0 a set of linked assets
-r = the rate of the question (0-100%)

➢ **answ(q)**: the final user's answer to a generic tagQuestion q. It can only be 'CORRECT' or 'INCORRECT'

answ(q) = {CORRECT | INCORRECT}

Following the guidelines expressed by Ian Sommerville, Pete Sawyer [6] and Gerarld Kotonya [7] the research team identified the following functional requirements:
Teacher will be able to:

FR1, FR2, FR3 – Create, Modify, and Delete a tag.
FR4, FR5 – Create and delete an asset.
FR6, FR7 – Create and delete a tagQuestion.
FR8 - The plugin must hide or display the assets of the course based on the profile obtained for the user.

5 Use Case Diagram

These use case diagrams (Fig. 1,2,3) were made accordingly to M. Fowler [8], I. Jacobson [9], D. Booch [10] and S. Cook [11].
      The use cases approach helps the research team to deeply profile the teacher/editor role inside the described scenario.
      As shown in the Functional requirements list, below the teacher's use case is described for tags, assets and tagQuestions.
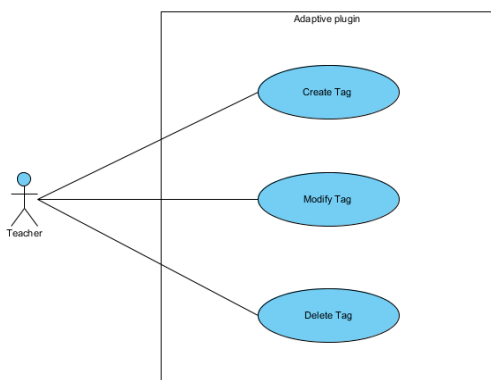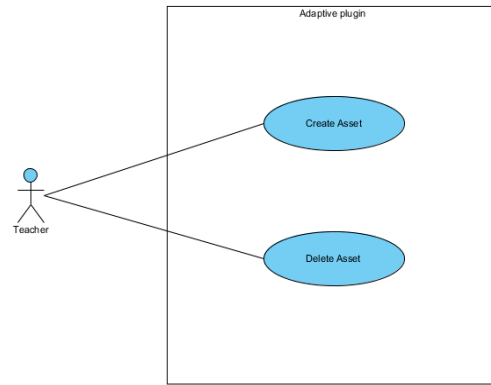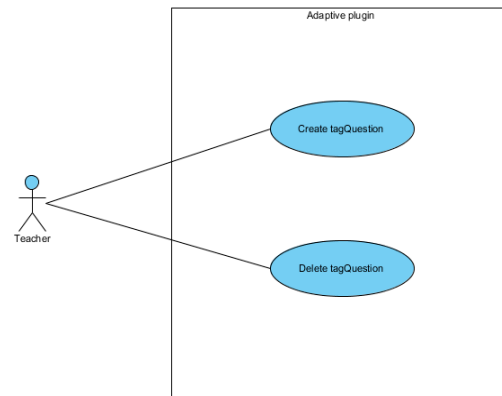

Fig. 1 Manage tags

Fig. 2 Assets

Fig. 3 tagQuestions

6 Plugin Development

The plugin is composed by two segments: the first segment allows teachers to manage assets and tagQuestions, the second segment is a Moodle's availability condition plugin.
The "concept flow" for this adaptive plugin that design suitable learning paths for each user, works as follow:

•   When registered to a new course, the user is forced to answer to a pre-test;
•   The plugin makes available only some assets in a customizes learning path, based on the answers given by the user during the pre-test;
•   To complete the learning path, the user must assimilate the available assets;
•   After the user assimilated all the available assets in the learning path, the plugin submits a new test;
•   If the user passes this last test, he completes the path, otherwise the plugin shows him other assets in a new learning path.

The teacher needs to create the assets and the tagQuestions, useful to build every customized learning path, linking to each other Moodle's

resources or activities-tags and questions-Moodle's resources or activities using the tools provided by the plugin.

To achieve these goals the team created some "ad hoc" HTML pages to allow the teacher create links. Furthermore, the research team analysed the database scheme proposed above, founded trough the analysis of the state of the art [12], and decided to project and implement a new one in order to better satisfy the new identified requirements.

The image shown below (Fig. 4) highlights the implementation of the plugin at database level.
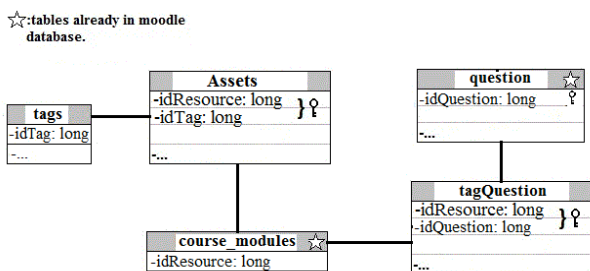
Fig.4 Added database tables

As the reader can see, the starred tables are already in Moodle existing database, the new ones are:

- Assets: This table saves links between tags and a Moodle's resource or activities. The primary key is composed by idResource and idTag. This allows to link one or more tag to a single resource.

- tags: This table saves new tags and their respective name and description.

- tagQuestion: This table saves links between questions and a Moodle's resource or activities. The primary key is composed by idResource and idQuestion. This allows to link one or more question to a single resource and vice versa.

7 Algorithm

The core of this adaptive plugin is the "Control Algorithm". The logic behind should be described briefly with some sentences.
Suppose that Q is a pre-Test, then:

$\forall q_i \in Q$, $0<i<n$ where $Q = \{q_1,\ldots, q_n\} \wedge$
$q_i = \{T, CA, WA, A, r\}$ where

T = text of the tagQuestion
CA = $\{ca_1,\ldots, ca_h\}$ h>0 is a set of correct answers
WA = $\{wa_1,\ldots, wa_l\}$ l>0 is a set of wrong answers

A = $\{as_1,\ldots, as_m\}$ is a set of linked assets
r = the rate of the question

if answ(q_i) = 'INCORRECT' then $\rightarrow \forall as_j \in$ A, $0<j<m$ vis(ass_j) = VISIBLE

8 Plugin Code Implementation

The code implementation of this prototype needed the generation of two different plugins: a "local" plugin and an "availability condition" plugin. Both of them have been realized following the guidelines expressed by Developer's Moodle Community in the documentation's website. [13] [14]

The "adaptive" plugin deals with:
- the production, editing and removal of tags;
- the production and removal of logical links between tags and Moodle's Resources;
- the production and removal of links between individual questions and their related Moodle's Resources.

In the end, looking at he file package, Moodle's files (required in the specifications) add up the software package plus some "supporting files" that the plugin needs for its purpose. In detail:

- 'access.php' into the 'db' folder is the file in which the capabilities (or permissions) used by the plugin are declared;

- 'install.php' and 'install.xml' (automatically created by using Moodle's XMLDeditor) are used to create new necessary tables in Moodle's database;

- 'local_adaptive.php' under 'en' (and 'it') folder, contain the strings used in the plugin's interface;

- 'version.php' is delegated to the plugin version control and to the state of development (BETA);

- 'settings.php' creates the settings page for the local plugin and adds a shortcut to the adaptive plugin homepage under 'local plugins' in Site administration;

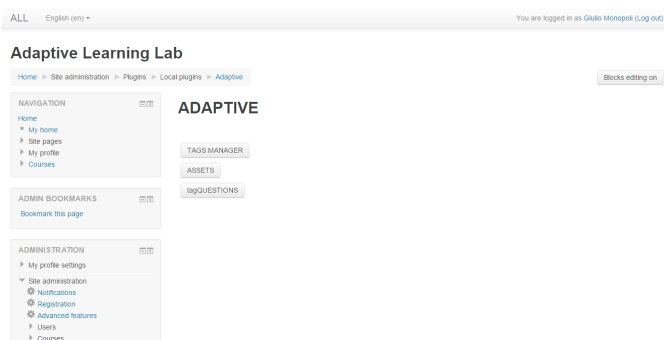- 'index.php' contains the code for creating the home page of the plugin:

Fig. 5 Adaptive buttons

As the reader can see in Fig. 5, the page contains buttons for "Tags Manager", "Assets" and "tagQuestions" which refer respectively to the files 'Tags_Manager.php', 'Assets.php' and 'Tag_Questions.php' described below:

- 'Tags Manager.php' bring the user to a page for create, edit and delete of one or more tags (see tags meaning in future development section);
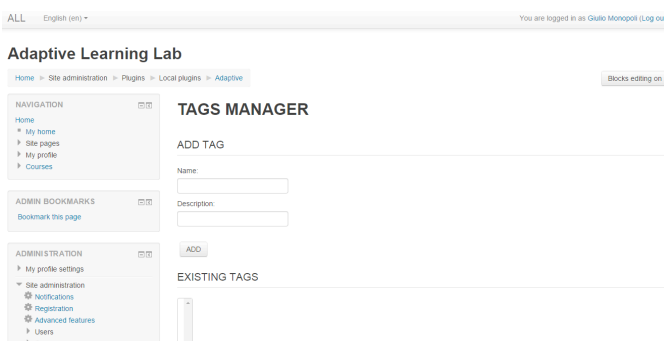

Fig. 6 Tags manager

- 'Assets.php ' give the possibility to the user to assign or delete one or more tags to a Moodle's Resource
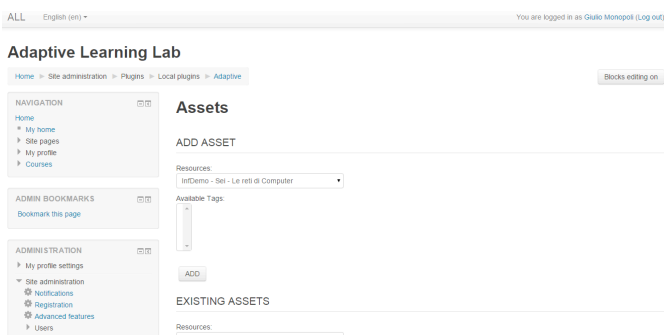

Fig. 7 Assets manager

- 'Tag_Question.php' allows user to connect an application to one or more related Moodle's or to remove an existing link:
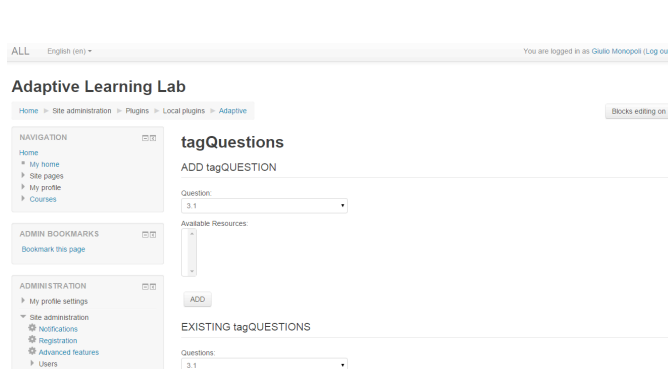

Fig. 8 tagQuestions manager

- 'popola***. php' , in conjunction with the file 'functionsFile.js' are used to dynamically populate select in differents pages by taking the data from the database:
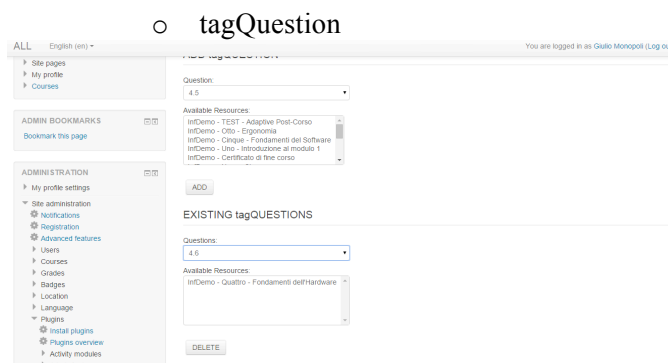
  o tagQuestion

Fig. 9 managing tagQuestions

- 'accessDB.php', centralize the access to the database for all files (except for the different file 'popola***.php' files that interface directly with the database)

The "ad" plugin manages the availability or non-availability of Moodle's Resources. It actually implements the core algorithm described.

This part of the whole plugin was created using all the necessary files according to the official Moodle's specifications, in particular:

- 'version.php' manages the version and dependencies of the current plugin; Indeed the 'ad' plugin can not be installed if the 'adaptive' plugin is not already installed in the system;

- 'condition.php' is the file that handles the logic of the plugin, it is here that the proposed algorithm has been implemented;

- 'frontend.php' lets the user choose when to make available the option to add the 'Adaptive' condition to a Moodle's Resource
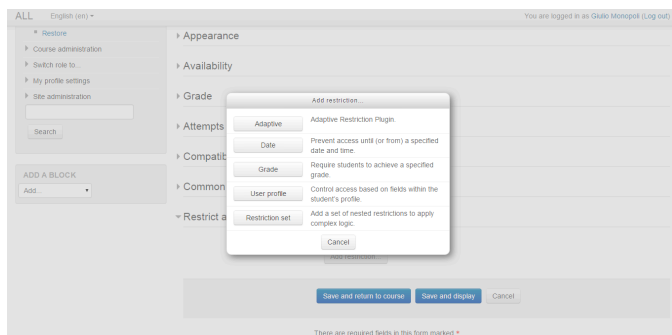

Fig. 10 Adding restrictions

- Inside the 'availability_ad.php' file there are the strings used in the rest of the plugin

- 'form.js' under yui > src > form> js handles the plugin's form appearance when 'Adaptive' is selected as a condition of access
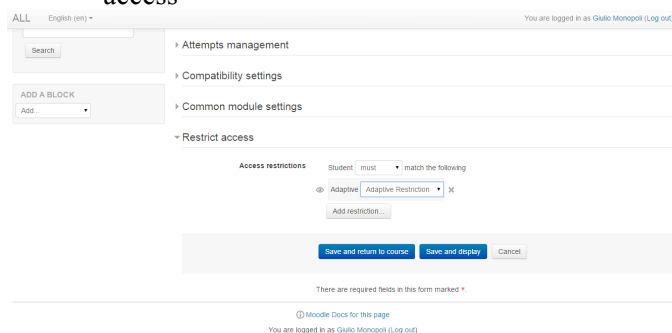

Fig. 11 Adding Adaptive restrictions

- Files under yui > builds are auto-generated by ' Yui Shifter ' , a needed (mandatory) program for creating a plugin of this type described in the official Moodle's documentation

9 TESTS

At the moment of writing this paper, several tests have been conducted "in vitro". In these tests the team tried to annotate in the plugin a variable, for each active user, to indicate the level of learning in order to fill the weaknesses identified during the initial pre-test.

The plugin is well integrated inside the Moodle architecture and it respect the functional requirements identified during the analysis stage.

No lacks have been discovered in performances of the software related to the web server or the user experience.

To perform the "in vitro" test the research team created a sample class of 50 (fake) students and 10 teachers of different subjects. Each user, in relation of his role and permissions, tries to perform some planned actions.

Further tests are being analysed in different scenarios: academic blended course, corporate training course, pure online learning.

10 Conclusion and Future work

The goals planned for this frame of the research timeline are successfully achieved.

The "Adaptive plugin" picks the suitable learning objects building a tailored learning path suitable for each student.

In vitro tests demonstrate that the software is working and is consistent with the identified functional requirements.

The future steps after this stage, concern the "in vivo tests" to prove the efficiency and the effectiveness of this approach in real cases.

Other future steps, related to software development consist in an early upgrade of the developed plugin in order to extend its functionalities. According to this, the team will develop the Tag "feature", this tag is not actually used but represents a future development's item whose purpose is to better adapt the course content.

The research team also plans to improve the user experience thanks to the design of HTML5 interfaces that helps to become more intuitive and accessible on multiple devices.

References
[1] A. Marengo, A. Pagano, A. Barbone – "Active turorship in adaptive e-learning process using data-mining tools" – Proceedings of 6th International Conference of Education, Research and Innovation (ICERI) – 18th-20th November 2013, Seville, Spain – pp. 1733-1739
[2] Chih-Ping Chu, Yi-Chun Chang "A Prediction Mechanism of Adaptive Learning Content in the Scalable E-Learning Environment"; Advanced Information Networking and

Applications Workshops, 2007, AINAW '07. 21st International Conference on (Volume:2) pp.1029 - IEEE Publishing - 1034 Niagara Falls, Ont. 2007

[3] B. Dharani, T.V. Geetha, "Adaptive learning path generation using colored Petri nets based on behavioral aspects" Recent Trends in Information Technology (ICRTIT), 2013 International Conference on - IEEE Publishing 2013

[4] Borich Gary D. "Effective teaching methods" – Lavoisier ed., 2009.

[5] Moore, J., Churchward, M., "Moodle 1.9 – Extension Development", Packt Publishing, 2010

[6] Ian Sommerville & Pete Sawyer: Requirement Engineering, a Good Practice Guide; John Wiley& Sons, April 2003

[7] Gerarld Kotonya and Ian Sommerville: Requirement, Processes and Techniques; John Wiley& Sons, May 2004

[8] M. Fowler, "UML Distilled", 3th edition, Pearson Addison Wesley, 2004

[9] I. Jacobson, "Object-Oriented Development In an Industrial Environment", OOPSLA'87 Conference Proceedings, special issue of SIGPLAN Notices, Vol. 22, No. 12, December 1987, pp. 183-191

[10] G. Booch, "Object-Oriented Analysis and Design – With Applications", Second Edition, Benjamin/Cummings, Menlo Park, California, 1994

[11] S. Cook, J. Daniels, "Designing Object Systems - Object Oriented Modelling With Syntropy ", Prentice Hall, Englewood Cliffs, New Jersey, 1994

[12] A. Marengo, A. Pagano, A. Barbone – "Data mining methods to assess student behavior in adaptive e-learning processes" – Proceedings of The Fourth International Conference on e-learning "Best practices in management, design and development of e-courses: standards of excellence and creativity" – IEEE 2013

[13] https://docs.moodle.org/dev/Local_plugins

[14] https://docs.moodle.org/dev/Availability_conditions#Introduction

[15] S. Campanella, G. Dimauro, A. Ferrante, D. Impedovo, S. Impedovo , M. G. Lucchese, R. Modugno, G. Pirlo, L. Sarcinella, E. Stasolla, C. A. Trullo - "E-learning platforms in the Italian Universities: the technological solutions at the University of Bari" - WSEAS TRANSACTIONS on ADVANCES in ENGINEERING EDUCATION

[16] EVA MILKOVÁ - Multimedia Applications and their Benefit for Teaching and Learning at Universities - WSEAS TRANSACTIONS on INFORMATION SCIENCE & APPLICATIONS

[17] ELENA VERDÚ, LUISA M. REGUERAS, MARÍA JESÚS VERDÚ, JUAN PABLO DE CASTRO AND MARÍA ÁNGELES PÉREZ - An analysis of the Research on Adaptive Learning: The Next Generation of e-Learning - WSEAS TRANSACTIONS on INFORMATION SCIENCE & APPLICATIONS