E-Learning and Intelligent Planning: Improving Content Personalization

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***Title*—E-Learning and Intelligent Planning: Improving Content Personalization.**

***Abstract*— Combining learning objects is a challenging topic because of its direct application to curriculum generation, tailored to the students' profiles and preferences. Intelligent planning allows us to adapt learning routes (i.e. sequences of learning objects), thus highly improving the personalization of contents, the pedagogical requirements and specific necessities of each student.**

This paper presents a general and effective approach to extract metadata information from the e-learning contents, a form of reusable learning objects, to generate a planning domain in a simple, automated way. Such a domain is used by an intelligent planner that provides an integrated recommendation system, which adapts, stores and reuses the best learning routes according to the students' profiles and course objectives. If any inconsistency happens during the route execution, e.g. the student fails to pass an assessment test which prevents him/her from continuing the natural course of the route, the system adapts and/or repairs the course to meet the new objectives.

***Index Terms*—Educational technology, Electronic learning, Computer aided instruction, Courseware, Content Personalization**

I. Introduction

The current European University system has suffered a drastic transformation during the last few years. Information and Communication Technologies (ICTs) have been directly applied to learning and e-learning, and are now present in many Universities around the world. Most of these Universities provide virtual campus services by using e-learning platforms and Learning Management Systems (LMSs), which are designed to support the teaching/learning process at different aspects: content visualization and navigation (compound of reusable learning objects), students' and teachers' points of view, among others.

LMSs are widely used to promote and as a support in learning, either face-to-face learning, distance-learning or blended-learning. They also provide interactive tools to store and offer (almost) unlimited and ubiquitous access to any kind of content. This content is usually implemented by using XML standards such as SCORM, IMS or IEEE-LOM [1]-[3], with the objective of facilitating and increasing their interoperation. But LMSs should not be merely static contents repositories that hardly allow the interoperability among their elements. The LMSs must not offer the same contents in the same way for all the students, because their personal knowledge preferences and objectives are hardly the same [4] –this statement contradicts the model based on individual necessities, such as the model approved in the European Higher Education Area (*http://ec.europa.eu/education*). Therefore, it is imperative to build intelligent tools for recommending, planning and sequencing the best fitted contents to each student [5], [6]. This poses some important challenges when creating the courses:

1. The description of the contents is not enough. We also need to specify which contents are pedagogically better for each learning style (profile adaptation).
2. The description of how the contents are interrelated is needed, as contents cannot be seen as isolated elements.
3. We need to decide what contents the students should use and how.
4. And finally, we need to propose how to monitor and adapt the learning objects of each learning route against unexpected contingencies (e.g. a failed evaluation task or an activity that exceeds its due time), among others [5], [7].

From an educational point of view, there are new challenges too: i) a new vision of the educational paradigm is required, where the teacher has no longer the main role and establishes the pace of the learning process; ii) we must extend the content generation process with the support of experienced designers and pedagogues, to make this process more focused on the student's profile adaptation, because not all the students are equal and learn equally; and iii) it is necessary to rethink the didactic method, according to the students' diversity and their individual needs and profiles.

At a glance, intelligent planning can notably improve the learning routes personalization in a virtually transparent way to the user. This represents the main contribution of this paper, on a bigger system named *myPTutor* (*http://servergrps.dsic.upv.es/myptutor*). The underlying idea is to build a strongly-connected and structured leaning route

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capable of satisfying each student's profile. Thus, even if the course structure is predefined, the selection and ordering of the contents can change according to the student's profile. For example, a learning object of the "diagram" kind is recommended for a "visual" student's profile, but not for a "verbal" student, and just the opposite holds for a "textual" content [8]. Hence, the same route is not necessarily valid for two different students.

Once the learning route is defined, it has to be executed and monitored. It is not enough to offer a navigation graphical interface and statistical graphics, despite being very attractive, but it is very important to control and react against any contingency. Intelligent planning is very useful during this process too, adapting the route to the new situation, making it valid again and minimizing changes to avoid further problems to students and teachers, that is, maintaining a kind of *inertia*.

Through this paper we review the more recent works which are the founding of our proposal, as well as justify the use of intelligent planning for personalizing contents. After that, we describe the general structure of *myPTutor* and its application on a specific LMS (*Moodle*). Next, the results of a qualitative and quantitative evaluation are shown. Finally, we give some ideas about the lessons learned and the main limitations we have found, as well as the conclusions of the work.

II. Related Work and Motivation

A. Related Work

Several techniques have been used in recent literature to personalize contents and generate learning routes in an e-learning context. Some authors have applied adjacency matrices, integer programming constraint satisfaction models, neural networks and soft computing methods [4], [9]-[11]. Essentially, these techniques simulate the decision-making process of the teacher. Consequently, the learning object's flow is predefined and too much teacher-oriented.

On the other hand, most of the previous techniques do not consider standards during the personalization process: i) extraction of information and data mining, ii) learning route generation, iii) deployment and execution of the learning route, and iv) monitoring the right execution of every route.

Several authors have proposed methods to facilitate representation and course information extraction by the teacher, through IEEE-LOM standard basis. Some examples of using standards can be found in ontology-based methods [12] and in workflows [13], [14], which do not only allow us to represent relationships among learning objects, but also among the different roles (teacher/student/students group) that participate in each of the course activities.

From a point of view based on current standards, there are approaches like [15] that allow us the adaptation of the route by using IMS-MD and displaying this route within the IMS-CP standard. However, this standard is very static, and if changes in the sequence of contents are required during the execution time, either a complete replanning of the route [16] or a continuous planning process [15] is needed. Continuous planning is very useful indeed if we accept the premise that the student does not need to access/know the complete learning route from the very beginning of the course.

From a monitoring (of the execution of routes) point of view, we have not found recent works about automated adaptation techniques together with standards usage. Generally, this process is so very complex and time-consuming that is only used in embedded systems or Intelligent Tutoring Systems. These systems check what the next learning object to execute is, once the results of the predecessor object are analyzed [17]. Note, however, that this is not appropriate when the student wants to know the complete learning route a priori, i.e. from the beginning of the course as the model of many universities or continuous education academies dictate.

B. Motivation. What is Intelligent Planning and why Use it in E-learning?

Most of our daily activities imply some kind of intelligent planning to determine a sequence of tasks that, when executed, allow us to achieve a set of objectives. And that is exactly what planning is about: given a domain of possible tasks, select a subset of them (e.g. a plan where tasks are ordered according to their causal/effect relationships) that, after their execution, allow us to reach an objective state starting from an initial state [18]. Hence, intelligent planning offers an interesting number of possibilities when applied to the e-learning field and learning routes creation.

The main advantage of using planning techniques is that it helps bridge the gap between the e-learning necessities and the student content adaptation. Specifically, planning goes beyond the intricacies of e-learning by supporting a better content personalization, handling temporal constraints, resources and even multi-objective optimization functions.

Metaphorically speaking, a learning route generation is fairly similar to a planning process. As we can see in Table I, the main elements of e-learning are: i) the background and student's preferences, ii) the learning outcomes to achieve, iii) the learning objects adapted to the student's profile, iv) the ordering relationships, and v) the specific learning route for each student. Through a knowledge extraction process and mapping definition, which will be detailed later, these elements can match, respectively, with the next planning elements: i) the initial state, ii) the problem objectives, iii) the actions, iv) the causal links, and v) the solution plan. The multi-objective optimization that planning offers is also very interesting, because students and teachers often prefer a quality learning route in terms of time, resources usage and/or cost, and not *yet another route*.

Several authors have used planning for generating learning routes based on students' preferences [15], [19]-[21], but these have some limitations: i) they do not use the learning standards extensively, ii) the routes are not displayed and integrated in a common LMS, and iii) they are limited to a specific ontology, course, and/or planning paradigm. In contrast, by using our approach it is possible to use any standard planning to find the best learning route, with the idea of offering the right content to the right student. Additionally, we also support the e-learning standard metadata based on IEEE and IMS standards [1], [3], which are automatically extracted and compiled as a planning standard model in PDDL (*Planning Domain Definition Language*, [18]). Furthermore, teachers can easily define both compulsory and optional objectives as well.

TABLE I
E-LEARNING *VS.* INTELLIGENT PLANNING

E-learning	Planning
Background and student's preferences	Problem initial state
Learning objectives	Problem outcomes (*top level goals*)
Learning objects adapted to the student's profile, with pre-requisites and effects	Actions with preconditions and effects.
Order relationships	Cause-effect relationships given by causal links
Personalized learning route	Solution plan

Mapping between e-learning and planning basic elements.

III. THE *MYPTUTOR* APPROACH. USED TECHNIQUES

Our approach, namely *myPTutor* (see Fig. 1) consists of a complete system that ranges from a knowledge engineering stage (e-learning representation and metadata information extraction) to planning, monitoring and repair/adaptation, when necessary.

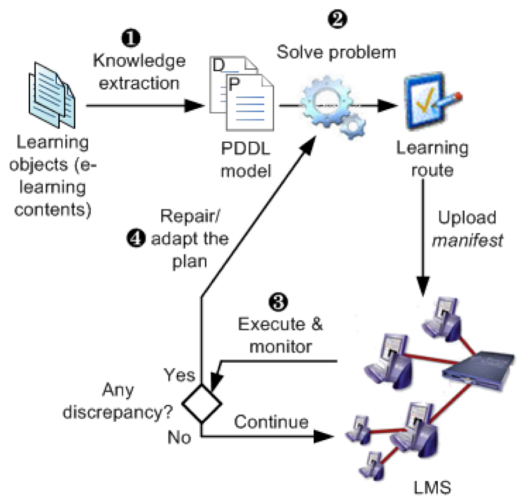

Fig. 1. General schema of *myPTutor*, which consists of four steps.

E-learning standards usually label contents by using metadata, typically inspired by the IEEE LOM model. The **first step** consists, therefore, in parsing this information by means of automated techniques of knowledge engineering to extract their essential features. After the compilation and automated generation of the planning model, the **second step** requires the use of an intelligent planner to find a plan or learning route. The **third step** comprises the execution of the learning route within a LMS that supports monitoring (given by the additional information on cause-effect relationships implicitly stored in the plan). After executing an assessment object (test, questionnaire, etc.) we check whether the real state matches the expected state. If a discrepancy is found, that is if an inconsistency occurs during the route execution, we use a plan-validation technique to check if the route is still executable [22]. If it is not, the **fourth step** involves repairing or adapting the plan to make it executable again. Next we explain these four steps in more detail.

A. *Metadata in E-learning. Knowledge Extraction and Generation of the PDDL Planning Model*

Learning objects are labelled by metadata that helps define their structural and dynamic properties. Although there are many elements (i.e. general descriptors, identifiers and keywords, annotations, taxonomies, copyright restrictions, etc.) only a few of them are really essential for generating a planning model (see Fig. 2), which in PDDL consists in defining two plain text files, one for the planning domain and another for the planning problem.

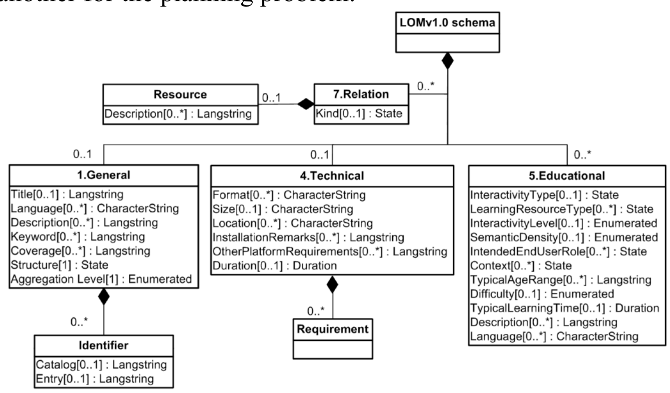

Fig. 2. Essential elements of the LOM schema to be used for extracting a planning model. Simplified version of the original one depicted in *http://en.wikipedia.org/wiki/Learning_object_metadata*. This image is under the terms of the GNU Free Documentation License.

A thorough description of the mapping between the XML labels used in LOM and the PDDL domain+problem files is out of the scope of this paper (the interested reader can find more information in [23]). At a glance, the e-learning knowledge extraction process and generation of the PDDL model is done by means of a polynomial-time efficient compilation, which for each learning object extracts: i) the name (*Identifier*+*Title* in Fig. 2); ii) the average duration, as a measure of its complexity (*TypicalLearningTime* in Fig. 2); iii) their prerequisites, based on the dependency relationships and profile adaptation, and required resources (*Relations* and *OtherPlatformRequirements*, respectively, in Fig. 2); and iv) their effects, in the form of the learning results attained by that learning object (as a measure of *Coverage* in Fig. 2).

We also extract information about the student from his/her e-portfolio, based on IMS-LIP [3], which allows us to increase the profile adaptation. This way, we obtain the students' learning styles, their preferences and learning goals including, optionally, their interests in a shorter or cheaper learning route, which also gives the planning system an idea of the metric to be optimized. Finally, *myPTutor* allows the teacher to include information on the particular student's profile

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which is not part of that standard but it is deemed important for improving content personalization, such as general foreign language knowledge or any very topic-oriented particular experience.

B. Solving the Planning Problem

myPTutor generates a standard PDDL model which allows us to use a high range of planners, despite the internal algorithms they implement. A complete list of the most important PDDL compliant planners, and their main capabilities, that have participated in the international planning competitions is given in *http://ipc.icaps-conference.org*.

The planner's task is to choose the best contents, as learning objects, to make each student attain his/her learning goals by using the most appropriate learning objects, that is, those that best fit his/her profile. Therefore, the planner returns a fully tailored learning route per student that identifies which learning objects, when and with which resources are to be used.

C. Monitoring and Finding Discrepancies

Once the planner generates the learning route, it needs to be uploaded, in a particular manifest format, to a LMS that supports monitoring, as depicted in Fig. 1. The LMS is not only useful for visualization and navigation matters, but also for monitoring and checking the students' progress while executing their respective learning route. It also detects significant discrepancies between the current (real) state and the expected one. Loosely speaking, after executing an assessment object (test, questionnaire, assignment to be marked, etc.) we need to check whether the student has achieved the state expected from the learning route or a contingency has happened. Note that in *myPTutor* the monitoring stage is performed only after an assessment object. We do not perform a continuous monitoring because of its high complexity. The reason for this is that in an e-learning scenario, where students log in and out frequently and work at their own pace, a continuous monitoring process based on different connection times can be very time-consuming and become inappropriate.

Discrepancies appear due to different reasons:

1. Changes in the background or student's profile, which make the learning objects planned in the learning route not to be adequate any more.
2. Due times that are exceeded, e.g. failing to finish an activity or test on time.
3. Unavailability of a resource required by a learning object, i.e. if a necessary computer breaks down.
4. The student's not passing an assessment learning object, e.g. failing an exam, which prevents the student from continuing the natural flow defined by the learning route.

If a discrepancy prevents the student from achieving his/her learning goals, a replanning stage becomes necessary to adapt the learning route to the current scenario.

D. Replanning and/or Adapting the Learning Route

In case of discrepancies we use a plan-validation technique that, starting from the new current state, simulates the execution of the remaining part of the plan and checks whether it is still executable. If the plan cannot be executed, the teacher can repair it either manually or opt for an automated adaptation. Such adaptation can be done by using different techniques. Our system applies a Case-Based Planning (CBP) technique [5], [22]. This technique reuses plans, previously learned and stored in a plan library, to obtain new solutions more efficiently. Two reasons make this very appealing in an e-learning setting. First, we can learn from past plans and adapt them to the scenario given by the current students. After all, similar students make similar errors and the way to solve them is usually similar as well. Second, adapting an existing plan to a new scenario (reusing the original plan as much as possible) is proved to be as expensive as generating a new plan from scratch; however, it tends to be more efficient on average. This has an additional nice property: students and teachers take advantage of a kind of *inertia* in the learning routes, as they are not constantly changing after any discrepancy. This also promotes a better and easier continuity in the learning process.

Once the plan is adapted to the new scenario, it is validated by the teacher previously to its execution. If the teacher agrees with the size and sequence of learning objects given in the plan, it is stored in the plan library as a new case-base, thus it becomes available in the future by the case-based planner. Afterwards, the cycle shown in Fig. 1 is resumed.

E. Full Integration within a LMS. Moodle as a Test Case

The four steps presented above can be implemented in an intelligent system that allows us to: i) recover information about the students and learning objects in an easy way, and ii) manage the execution of the learning route generated by the planner.

Our approach is flexible enough to be compatible with any LMS. As a proof of concept we have tested *myPTutor* within *Moodle* (*Module Object-Oriented Dynamic Learning Environment, http://moodle.org*), a free source, e-learning web application implemented in PHP that educators can use to create effective on-line learning sites. *Moodle* implements modules for collaborative communities and simplifies the content management by importing SCORM packages and other activities that can be easily integrated altogether.

We have implemented our approach on top of *Moodle*. Although we do not describe all the technical details here, we have needed to implement a new module to support the mixed-initiative interaction between users (students and teachers) and planning services. The most significant changes to allow this interaction are:

- In the database (data tier): editing the schemata and creating new relational tables to support the relationships among

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preconditions and the learning objects, and the learning goals of each student.

- In the business code (logic tier): implementing a communication API between *Moodle* and the planning module (implemented as a web service). Some code for supporting monitoring of the SCORM contents has been also implemented.
- In the Graphical User Interface (GUI, presentation tier): designing new forms for both teachers and students, as shown in Fig. 3 and Fig. 4, respectively.

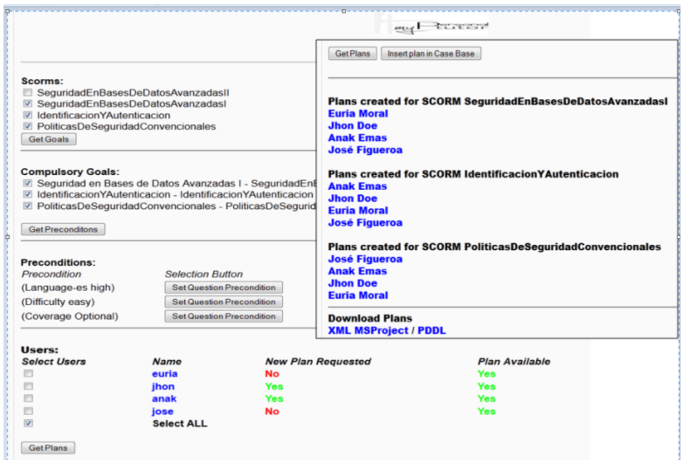

Fig. 3. GUI for the teacher: definition of curricular options for personalization and generation of plans.

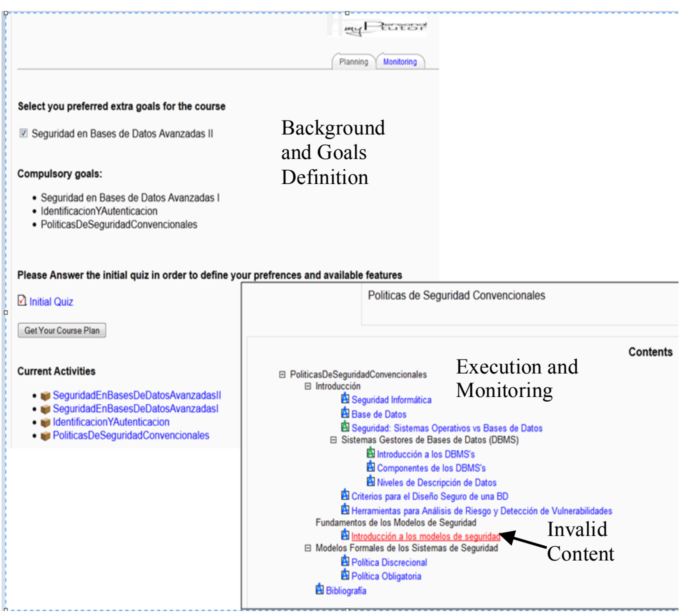

Fig. 4. GUI for the student: plan personalization and visualization.

The overall behaviour is straightforward. The teacher defines the contents (learning objects stored in a SCORM package) of the course, indicates which learning goals are compulsory/optional in that course, and the initial preconditions (background) that a student needs to be able to enrol on the course (Fig. 3). On the other hand, the student inputs his/her background and chooses in which additional goals (s)he is interested, which increases the possibilities for content personalization (Fig. 4). If during the execution of the learning route a discrepancy is found, the content that is still valid is shown as usual but the content that has become invalid is marked until its future adaptation is finished (as depicted in Fig. 4). Finally, it is important to note that all the code and API for adaptation, execution and monitoring has been implemented for *Moodle*, but it could be reused in other similar LMSs.

IV. Evaluation

A thorough and detailed evaluation of our approach is difficult because it requires the collaboration of many teachers, students and the availability of courses of different topics. From a formal standpoint, we can carry out both a qualitative and quantitative evaluation. Although these evaluations are still ongoing work, we present some results here, which are extended in [5] and [24].

From a qualitative point of view, we have given several questionnaires to small groups with at least five teachers, who are experts in Object Oriented Programming and/or Artificial Intelligence courses. We have also given these questionnaires to students in the field of Computer Science that are enrolled on these courses. The objective is to assess the quality of the learning routes and their profile adaptation. Some of the questions included in the questionnaires are:

- *Is the number of learning objects appropriate for the course?*
- *Is the duration of the learning route adequate?*
- *Does the content of the learning route adapt to the students' profile (in terms of their learning styles and background)?*

Thanks to these questionnaires we are able to evaluate different aspects: i) the consistency of the planned contents with respect to the course objectives, ii) the adaptation of these contents to the student's profile, iii) the size of the course, i.e. learning route, in terms of the number of learning objects and their duration, iv) the viability of this approach according to the teacher's and student's opinion, etc. All in all, teachers agree with the profile adaptation. In general, they like that kind of adaptation, although in some cases they cannot answer why; they know this because of their experience, but it turns out difficult to explain. Teachers also believe that a priori knowledge on planning is not compulsory, but it is recommendable. On the other hand, the students find the personalized learning routes very valuable in comparison to the classic learning routes that are identical for all the students. Evidence shows, consequently, that content personalization is highly appreciated and both students and teachers believe this approach is useful and very recommendable.

From a quantitative point of view, we have run several experiments to evaluate: i) the scalability of our approach, and ii) how good the repair/CBP-adaption techniques are. More particularly, we have created hundreds of synthetic problems with up to 100 students that simulate discrepancies during the execution of the learning routes. The results, further detailed in [24], show that repairing/adapting the learning route is at least as fast as solving the problem again (i.e. replanning) from scratch, and the quality of the solution is always better. Informally speaking, the new learning route is as similar to the original one as possible. This is better than returning a new learning route that differs completely from the original one. In fact, teachers and students do not like routes that differ a lot because of the lack of *inertia* this implies.

V. Lessons Learned and Limitations Detected

Google returns millions of hits when searching for the "learning object" expression which, together with the on-line available repositories (e.g. *http://www.merlot.org, http://www.ariadne-eu.org* or *http://www.ocwconsortium.org*), allows us to count on terabytes of information as reusable digital resources. However, trying to use these learning objects as isolated objects is not very useful; they become really useful when combined with other objects to assemble bigger structures and more complex objects and/or courses. This is one of the main limitations we have found in our work: there is a significant number of repositories that do not provide high quality learning objects (on many occasions the metadata is empty), nor valid information about their relationships and dependencies. A lack of metadata labelling (or a wrong labelling) may reduce the definition time of the learning object, but it does make its combination with other objects much more complex, which also reduces the possibilities for being used in bigger courses.

On the other hand, current standards for metadata labelling of learning objects do not always provide all the required information to take full advantage of intelligent planning techniques [5], [24], such as the use of complex resources and the definition of temporal constraints they could have attached. Clearly, metadata as currently defined offer information from the pedagogic point of view, but it does not have enough information on temporal constraints and resources that can be useful in grouping activities that may require synchronization. This is essential to support collaborative activities, resource sharing and handling of complex constraints, no matter the LMS we want to use. Despite this, current metadata is sufficient to allow a reasonably flexible and powerful content personalization process.

Finally, it is important to highlight that, initially, the approach presented in this paper is more demanding than the traditional approach of teaching in terms of teachers' effort and time. Our approach requires an important change in the paradigm for generation of digital contents, and a bigger effort in designing and developing learning contents. Likewise, in some cases, teachers are reluctant to these changes. However, while more and more learning objects are defined this extra burden is significantly reduced. It is also important to note that this approach does not reduce the control of the teacher on the contents definition nor the students' evolution. Quite on the contrary, this approach encourages and facilitates the evolution and tracking of the students by means of a recommendation/planning system that takes into consideration the individual necessities of both the teachers and students.

VI. Conclusions

Current trends in distance education focus on displaying digital contents on LMSs and on packaging such contents as learning objects labelled according to SCORM standards. The aim of these standards is probably to sell, exchange among platforms and/or universities, or simply access the contents remotely; and all of these by using LMS-based environments. Following this thread, in this paper we have presented a general system implemented on top of *Moodle* that facilitates the use of "generic" GUIs to configure, integrate and administrate the adaptation system based on intelligent planning.

The planning tools do not only allow us to personalize the learning routes, but also to execute, monitor their progress and adapt them when unexpected contingencies are found. The use of planning techniques in an approach like the one presented here shows highly appealing for students, but less popular among teachers, who are reluctant to abandon their traditional role of *human planners*. In any case, both students and teachers have the shared opinion that applying planning techniques is very useful to offer the best contents to the right person at the right moment. Thus, the integration of intelligent planning systems with LMSs through approaches similar to ours, with the objective of personalizing learning routes, is a challenging topic in the fields of ICT research and development.

Acknowledgments

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