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Towards an Adaptive System for the Evaluation of Network Services

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***Abstract*—This paper presents a new educational system to automatically adapt the evaluation activities to the students' needs in the context of Higher Engineering Education. As an example, a subject focused on the configuration of network services has been chosen to implement our proposal. Therefore, the system will be able to guide each student through the learning process based on his/her particular knowledge-level. In addition to this, specific techniques are needed to dynamically evolve the system depending on the students' progress. In our case, this is analyzed by using data mining techniques. Finally, we show survey results, which illustrate the ease of use and usefulness of the system.**

Keywords—Assessment and Evaluation Strategies; Educational Adaptive Systems (EAS); Distance Education; Learning Analytics; Data Mining;

I. Introduction

New issues related to the teaching/learning process in the field of higher education, especially on-line or distance evaluation, are currently a hot topic of research, and it is of a great interest due to the growing use of the Internet [1]. In particular, the evaluation procedure is a key element within the learning process. Basically, it allows faculty to check whether educative objectives are accomplished, not only by students, but also by all the participants involved in an educative program [2]. As a consequence, lecturers must make pedagogical decisions to adapt the curricula to students' needs or level of knowledge, enforcing or extending it if necessary, and following the framework of the European Higher Education Area (EHEA) [3]. The importance of evaluation is even more important at distance Universities, as our case is, since students are more independent and self-demanding, they have no strict schedules. By means of evaluation, faculty is able to select the most suitable evaluation criteria and dynamically adapt the content resources to students [4].

As a consequence, some specific techniques are needed for defining the students' knowledge-level and analyzing their interactions with the educational platform to be used during the process of customization. One of the most recent research areas for these types of learning experiences is *Learning Analytics (LA)* [5], [6]. Its main goal is to discover and organize the existing information in order to extract useful knowledge during the teaching/learning process. An interesting general approach that uses LA for monitoring the learning activities occurring in a student personal work-space can be found in [7]. Within the area of LA, our work focuses on the field of evaluation by using data mining techniques. In this case, the process of LA will be focused on the information gathered from the educational system. In order to perform the evaluation process more efficiently, it is desirable to develop customized systems that ease the automatic selection and adaptation of the assessment resources to students' needs. Each of them has to be created with different levels of difficulty.

Therefore, this work presents an educational system for the automatic adaptation of the evaluation resources to the students' needs in the context of Higher Engineering Education. As an example, a subject focused on the configuration of network services has been chosen to implement our proposal. The system includes three types of roles: *administrator*, *lecturer*, and *student*. Administrator basically manages the activation or deactivation of users. Lecturer specifies the knowledge base by choosing the most relevant pedagogical resources and assesses the students' activities. From the student's perspective, the proposed system will automatically adapt evaluation contents to each student's knowledge-level and have perfect knowledge of the students' progress, since all the information is registered in the tracking tools. That is, the system will contain quantitative and qualitative information about the students' level of knowledge and skills. In particular, some data mining techniques from the Weka libraries [8] were adapted and calibrated to our purpose of adapting the evaluation criteria. Finally, a satisfaction survey was completed by a group of students belonging to a post-degree subject in Computer Science, as a proof of concept. The system was found easy to use and useful.

The rest of this paper is organized as follows. In Section II, the motivation of this work is described. Section III presents our proposed adaptive system for the evaluation of network services. The evaluation results of the system are detailed in Section IV. Finally, Section V highlights our final remarks and suggests guidelines for future work.

II. Motivation of our Work

Over the last years, adaptive hypermedia has been widely used for the development of customized Web-based courses in the field of Education [9]. Therefore, the students' learning process was guided, adapting both pedagogical resources and learning ways to specific user's features. Since lecturers (or automatic systems) adapt course materials to students' skills and usage data dynamically [10], they were able to acquire more knowledge in less time. ELM-ART [11] and TANGOW [12] are some examples of traditional educational adaptive systems. The students' interaction in these types of architectures is different from face-to-face students [13]. On-line students have to be able to adapt their communication way to the user interfaces of the adaptive systems. Additionally, it is essential to ensure that the proposed activities within the system are correctly adapted to the students' needs [14], so that they feel comfortable interacting with the educational environment.

On the other hand, it is also convenient to adapt collaborative issues taking into account the students' behaviors. The most relevant research works related to adaptation in Computer Support for Collaborative Learning (CSCL) systems are COALE [15], WebDL [16], and COL-TANGOW [12]. COALE is a collaborative environment where different exercises are recommended to students. However, students are free to choose the next exercise to be performed. The main goal in WebDL is to facilitate user access to services. It focuses on adaptive support for navigation. COL-TANGOW is also a system that supports the dynamic generation of adaptive Web-based courses. These courses are generated at run time by selecting, at every step and for each student, the most suitable activities to be proposed.

Nowadays, the evolution of the Web 2.0 allow us to develop more sophisticated techniques to analyze more efficiently the students' learning process, so improving the learning contents and structure of a course. One of the most recent research areas is *Learning Analytics (LA)* [5] in order to discover and organize the information contained in the educational platform. Figure 1 depicts all the phases which follow this process, as described in [6]:

1) *Data Capture*. The existing information must be captured in order to perform an intelligent data selection. Computer theories can be used, such as algorithms for clustering, collaborative filtering, Bayesian networks, etc.
2) *Data Processing*. At this stage, computational techniques for analytic processing are usually employed, such as associative rules, decision trees, neuronal networks, or machine learning.
3) *Knowledge Application*. From the processed data, new knowledge must be acquired and applied in order to improve the educational process. In addition, the new knowledge must be used as a starting point at the first phase of this process.

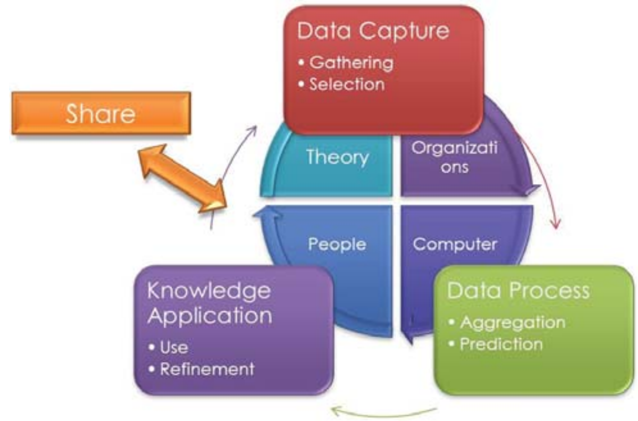

Fig. 1. The Process of Learning Analytics.

4) *Sharing*. The new knowledge extracted from the captured data and applied to the students' necessities may be shared to other contexts. As before, the new data can be used as a starting point at the first phase.

Within the area of LA, our work focuses on using data mining techniques in the field of evaluation. Data mining techniques [17] have led to a gradual replacement from data verification to knowledge discovery. These techniques can be divided in two groups: *supervised* and *unsupervised*. The supervised (or predictive) techniques are based on predicting the value of an attribute from a set of data, by using other known attributes. They are composed of two phases: training and testing. On the other hand, when predictive techniques are not enough to infer new information, unsupervised (or knowledge discovery) techniques could be employed in order to discover patterns or trends in the current data.

The most recent proposal related to assessment and customization can be found in [18]. The system proposed, named *askMe!*, supports and compensates deficits in students' individual learning by considering the students' strengths and preferences. In this work, the system core and the adaptation model employ rules in order to guide them in the evaluation process. Its main drawback is that it does not consider both the students' knowledge level and progress in order to adapt the evaluation resources to students. Additionally, this system has not been tested yet by a set of students. In contrast to this, our proposed system automatically includes both criteria and, also, it has been tested by a set of students in terms of ease of use and usefulness.

III. The Proposed Adaptive Evaluation System

The principal objective of this paper is to present a new service-oriented educational system for the automatic adaptation of evaluation activities to each student's knowledge level and progress. The Adaptive System, *AdaS* (*in Spanish*, named Sistema Adapta), will be able to guide students during their evaluation procedures. This fact can become useful since it is more difficult to dynamically keep track of the students' progress at a distance University, as our case is. In particular, we detail the architecture and user interfaces of our proposal and, then, the requirements and user models of this approach with a particular example.

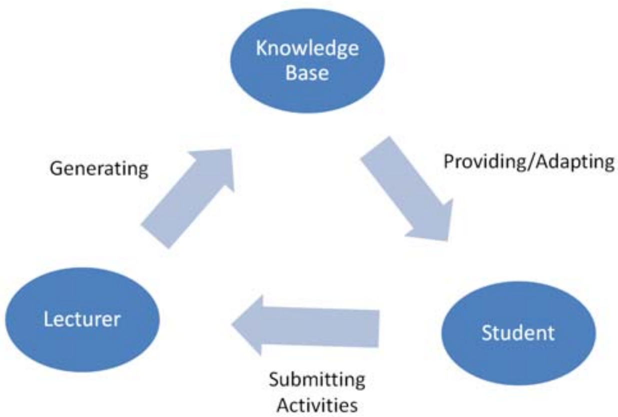

Fig. 2. Main Components of an Educational Adaptive System (EAS).

A. Adaptation and Levels of Proficiency

As shown in Figure 2, an educational adaptive system (EAS) must be composed of three main components: *knowledge base*, *lecturer*, and *student*. The knowledge base contains all pedagogical resources necessary to make possible the process of adapting the course to students. In our case, we define the evaluation resources to be included in *AdaS*. Note that, in order to adapt these resources for several levels of knowledge, each activity has been created with different grades of difficulty, so that one version or another is offered to students depending on their knowledge and particular progress in the course. Students can also rate the usefulness of each performed activity in order to improve the quality of the system.

Our system implements several user models for the customization of the evaluation criteria. To achieve this, some data mining techniques from the Weka libraries [8] were adapted and calibrated for our purposes. We use two combined ways to perform this adaptation, which are complementary:

1) The initial information for the students' customization is provided by themselves based on an initial survey. Each student is classified as *low*, *low-medium*, *medium*, *medium-high*, *high*, and *expert* according to his/her level of knowledge for each required skill and competence of the learning syllabus. Clustering techniques are used in order to establish the students' classification depending on their level of proficiency. We have employed the Expectation Maximization (EM)) [19] algorithm to make this classification possible. This statistic algorithm calculates the probabilities of each element to belong to a particular group of elements.
2) The information is automatically obtained from the previously performed interaction with the evaluation activities. Associative rules are employed to modify the student's knowledge level and, in this case, his/her skills (in terms of experience gained in the system). To make this possible, the OneR [20] algorithm have been chosen, as a first approximation of other works based on the use of rules to make user adaptation [18].

A new knowledge base is built and tested as follows. First, lecturers have to determine the pedagogical contents to be included in the knowledge base depending on the students' skills and competences to be gained for a particular context. After that, they must design the evaluation activities for each set of competences. For each activity, lecturer includes several statements with different levels of difficulty. So, a particular statement will be shown to the student taking into account how he/she was initially classified.

In our case, when students are activated in the system, they must answer a survey of initial knowledge, which contains several questions for each competence of the subject. As a result, students are established a personalized level of knowledge for each pedagogical competence. Each question will be weighted by lecturers depending on its quantitative importance to acquire the competence (or skill) in the context of the EHEA.

As a consequence, the system will offer a range of evaluation exercises based on students' particular knowledge. Note that, a student can be classified with a different level of proficiency, depending on the competence or skill to be gained. After that, they can download and perform the proposed activities for their submission. After the submission of some activity, students are required to indicate their grade of preference with regard to it. Therefore, the system will be able to adapt the evaluation exercises to students depending on their level of knowledge, progress, as well as the quantitative learning outcomes of students (from the evaluation activities rated in the system by lecturers).

Finally, lecturers will grade each activity and check the students' preferences as for the pedagogical evaluation resources offered to them. From these information, they can test and tune the system in order to improve the knowledge base.

B. Architecture of the System

Figure 3 depicts the architecture of our Web-based system. Users can access the system and perform their role-specific tasks using a web browser. The web gateway to the clients is provided by the Apache Tomcat [21], an open source application container. Additionally, the Tomcat server together with STS (Spring Source Tool Suite) [22], an open source framework for building Java-based applications supporting the Model-View-Controller (MVC) design pattern, hosts our Web application. In particular, the web application is implemented with the Grails [23], which is a framework fully-supported by Spring, and it uses Groovy as a programming language. Groovy is a high-level language based on Java.

The MVC pattern allows us to separate the architecture of the proposed system in three different layers: *Controller*, *View*, and *Model*. The Controller in the MVC pattern handles the HTTP requests from the client side, and gives information for further processing to the business logic of the application. The View compiles and presents results dynamically retrieved from the business logic. In our case, Groovy Server Pages (GSPs) are implemented. Also, some JavaScript functions are performed in the Web Client for validation purposes.

On the other hand, the Model in the MVC design pattern represents the business logic. In particular, it manages user data and roles. This component also handles evaluation resources, and controls the automated adaptation to students' needs. For the purpose of persistent storage of data and states, the open source framework Hibernate [24] was used. The underlying data are managed by the free available database system MySQL [25].

Figure 4 shows the diagram of the principal use cases for *AdaS*. Users can access the system and perform their role-specific tasks using a Web browser. The system considers three profiles: *administrator*, *lecturer*, and *student*. Administrator manages users' information, by activating or deactivating users as desired. Previously, both lecturers and students must register in the system, with the option of modifying their profile as necessary. The application has a private area for lecturers where they are able to create, modify, and remove the knowledge base with different pedagogical evaluation resources to be used. In addition, lecturers can evaluate the activities submitted by students. Also, they may communicate with students through the application.

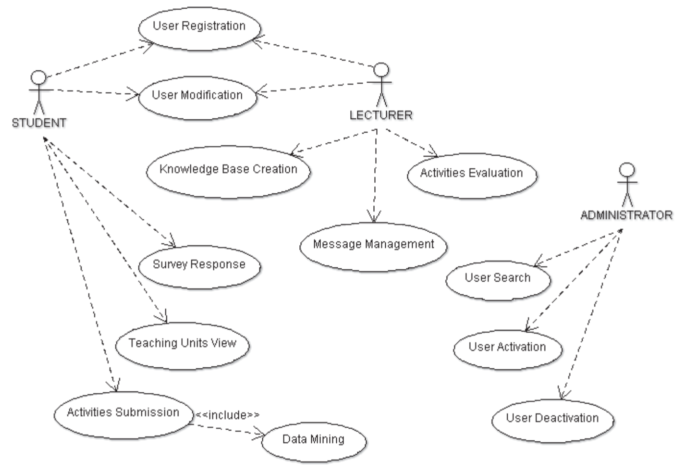

Fig. 4. Diagram of Use Cases in *AdaS* (Focuses on the Main actions of Student, Lecturer, and Administrator).

C. A Network Services' Example at UNED

The chosen subject to illustrate our approach is named "Management of Network Services in Operating Systems" (NetServicesOS), and it belongs to the "Communication, Networks, and Content Management" post-degree program in the Faculty of Computer Science at Spanish University for Distance Education (*in Spanish*, Universidad Nacional de Educación a Distancia, UNED) [26]. The scope of our proposed system is much broader, since this system has been designed and implemented as a modular system, which is independent of the design and implementation of specific activities. Therefore, it is not difficult to transfer the system to other contexts (e.g. Health, Humanities...).

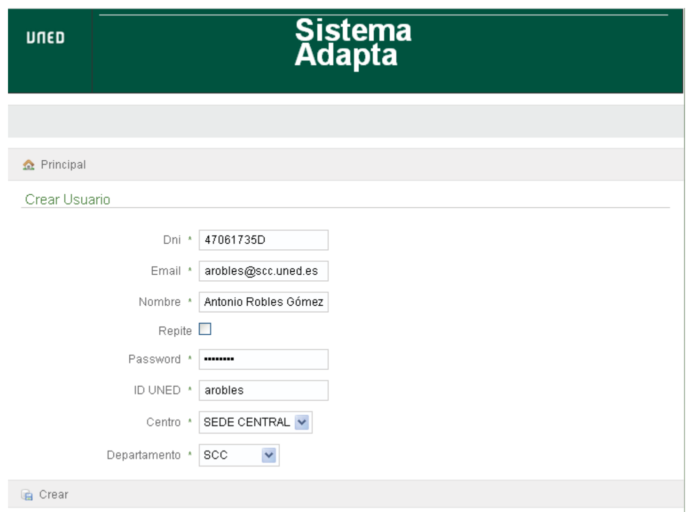

Fig. 5. Interface for the User Registration.

Our NetServicesOS subject provides students with an advanced knowledge on the configuration of the network services provided in a local environment. The UNED University has a virtual campus [27], named aLF, with more than 220,000 students. This on-line campus is based on the dotLRN platform [28]. All subjects belonging to degrees and post-degrees at UNED are also adapted to the context of the EHEA [3], [29]. Its maintenance is a task that not only implies the deployment of sophisticated hardware and software, but also allows the inclusion of new application services, in our case, new procedures for evaluation.

Next, some of the user interfaces of our proposed system will be shown. Graphical interfaces have been developed in order to interact with the system easily. As first example, Figure 5 shows the interface of a user registration (both lecturer and student). Here, the user role is selected, apart from other parameters, such as name, surname, identification number, e-mail, and so on. Once the user submits this form, the administrator will receive a message requesting the activation. After the administrator accepts this request, the user can access the system.

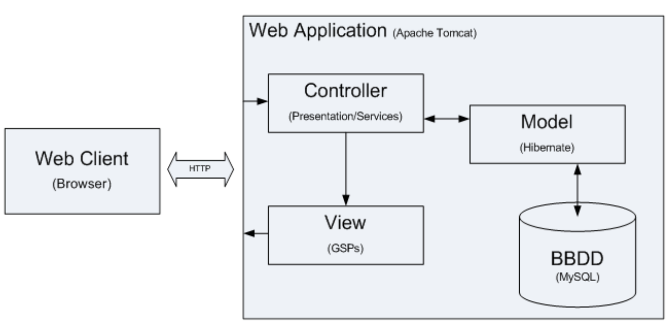

Fig. 3. The Proposed Architecture.

From the lecturers' view, lecturers can organize the evaluation resources. For instance, as Figure 6 shows, they can create a new resource to be added to the knowledge base. In this screen, the most relevant parameters of each activity for the students' adaptation are selected. From the students' view, as we can observe in Figure 7, they must answer in an initial survey, so that the system analyze their initial level of knowledge. Additionally, the system is able to adapt its evaluation activities to each student' progress in the course in terms of new acquired knowledge and experience, as observed in Figure 8. In our example, knowledge is related to the

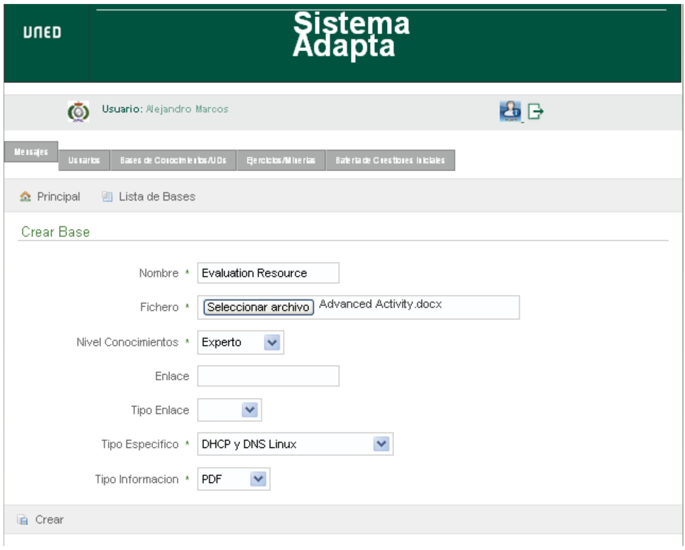

Fig. 6. Interface for the Creation of an Evaluation Resource for the Knowledge Base.

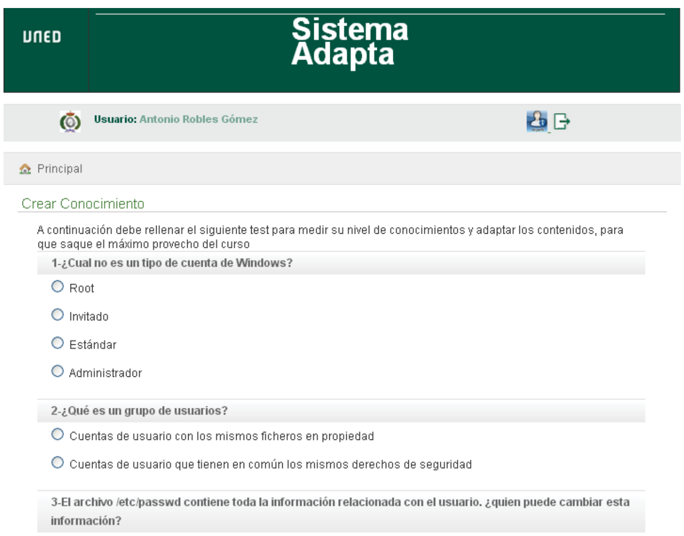

Fig. 7. Interface for the Students' Knowledge Survey.

configuration of network services on two of the most widely used platforms, namely Windows and Linux operating systems.

IV. Survey Results

In this section, the results from surveys conducted among students are presented. This has been done in order to obtain feedback from the students about the proposed *AdaS* in terms of the ease of use and usefulness of the system. The criteria used to choose the survey questions follows traditional guidelines as seen in other previous studies, such as [30], [31]. The survey has been conducted on 10 students of the NetServicesOS subject during the current 2012-2013 academic year. Each question has a five-point Likert-type scale, being 5 the best and 1 the worst.

Table I shows the questions of the survey along with the results we obtained. It can be observed that students are highly satisfied with the system and its user interface – 60% of

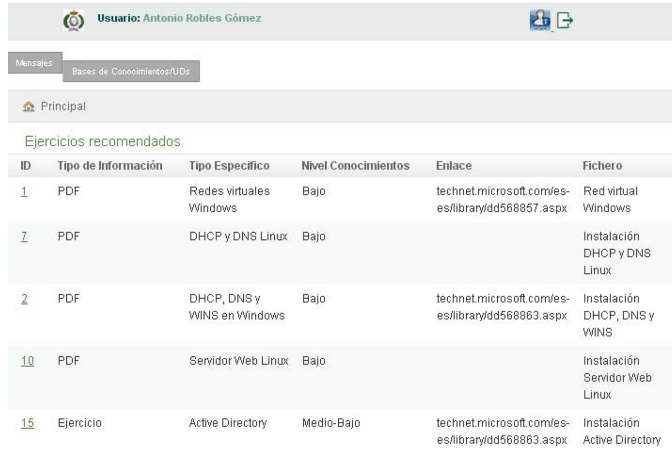

Fig. 8. Interface for a Student's Evaluation Activities.

students totally agree with their general satisfaction, and the rest of them agree. In this sense, only the 40% of students had strong previous experience on the use of this type of systems (they answered 5 to question 1). Furthermore, 80% of students are totally satisfied with the students' interface of the system. The rest of them partially agree with this issue.

As for the usability of the system, students think the system is useful; the 90% of students totally agree and the 10% of them partially agree. Also, 60% students partially agree about the ease of use of the system, and the rest of them totally agree. On the other hand, when students are questioned about the suitability of their interaction with the system, the 40% of students totally agree, and the rest of them partially agree (answered 3 o 4 to question 6). Finally, the 80% of students think these types of systems are very interesting for the education in Engineering. The rest of them think the system is really interesting.

These results underline the high quality of the system we developed, and encourage the use of this system in other subjects in Engineering Education.

V. Conclusions and Future Work

On-line education is nowadays supported by using e-learning platforms, which allow faculty to improve the process of teaching/learning. Some specific techniques are needed to analyze the students' needs and progress in order to make relevant improvements to a web-based course. Within the area of LA, our research focuses on using data mining techniques in the field of evaluation. In particular, this proposes an educational adaptive system, *AdaS*, that dynamically adapts the course evaluation resources to the students' knowledge level and progress. This system has been used for the evaluation of activities belonging to the NetServicesOS subject, but it would be easily transferable to other environments.

By means of this tool, the learning process can be automatically adapted to the students' knowledge level and skills (in terms of experience) in the system. Therefore, lecturers can dynamically follow the students' progress and grade their achievements for each proposed competences of a subject, in the case of Spain, in the framework of EHEA. Students are also able to rate the suitability of an evaluation resource, so

TABLE I. STUDENTS' SURVEY (5—THE BEST; 1—THE WORST).

Questions	1	2	3	4	5
1. Did you have any previous experience with these types of systems?	—	—	30%	30%	40%
2. What is your general satisfaction with the system?	—	—	—	40%	60%
3. What is your satisfaction with the user interface of the system?	—	—	—	20%	80%
4. Do you think this system is useful for their purposes?	—	—	—	10%	90%
5. Do you think this system is ease of use for their purposes?	—	—	—	60%	40%
6. Do you think your interaction with this system is suitable?	—	—	10%	50%	40%
7. Do you think these types of system are interesting for Engineering Education?	—	—	—	20%	80%

that lecturers receive feedback in order to improve the system or detect weaknesses of students. Moreover, we conducted a survey to test the quality of our developments in terms of its ease of use and usefulness. The main conclusions we obtained from the survey is that *AdaS* is easy to use and useful, which encourage its use in other subjects in Engineering Education.

As a future work, we plan to improve the functionality of the system by using alternative data mining techniques for the adaptation of activities to the students' needs, this way improving the adaptation of the evaluation resources to achieve a more intelligent curricula. Some of them can be sequential pattern mining, Markov models, and probabilistic latent variable models. On the other hand, our proposed approach will be integrated with our institutional educational platform in order to exhaustively be compared to other tutoring systems. Finally, different frameworks or contexts from EHEA, as the proposed ones by the ASEE Educational Research Methods (ERM) Division [32], could be explored within the *AdaS* environment in order to analyze if the results obtained are similar and/or it is need of making some changes.

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