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A Recommender Engine for Advanced Personalized Feedback in e-Learning Environments*

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The paper presents an educational recommender engine, which is fired by the feedback module of an e-assessment application for the project management domain. The recommendations consist in web pages related to the knowledge gaps of the students who took an e-test. The authors argue that using a recommender engine within the e-assessment would increase the formative values of the e-assessment, transforming it into an innovative educational instrument, which gives the students the opportunity to take control of their own learning and actively participate in the learning process. A short evaluation of the utility of the recommendations is also provided.

Keywords: educational recommender systems; personalized feedback; e-learning, e-assessment; project management

1. Introduction

E-learning plays an important role among educational instruments in knowledge society. Many definitions of e-learning exist. A useful set of such definitions is provided by Súilleabháin [1]: 'e-Learning—a term covering a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. It includes the delivery of content via Internet, intranet/extranet (LAN/WAN), audio- and videotape, satellite broadcast, interactive TV, CD-ROM, and more'(ASTD's Learning Circuits), 'e-learning is the systematic use of networked multimedia computer technologies to empower learners, improve learning, connect learners to people and resources supportive of their needs, integrate learning with performance and individual with organisational goal' (Peter Goodyear), 'e-Learning is the use of network technology to design, deliver, select, administer, and extend learning' (Eliot Masie) [1]. Taking into account the above definitions, there is a wide range of activities, instruments and materials in e-learning. Using e-learning services is no longer a real challenge, but choosing the most efficient ones for a specific purpose is. The creators and providers of e-learning services wonder how to efficiently guide students in the learning process. A solution for solving the problems of information overload and giving the students the possibility to choose the most suitable e-learning tools is given by recommender systems (RS) [2]. The issue of educational recommender systems is a real concern in Technology Enhanced Learning (TEL) domain: 'Since information retrieval (in terms of searching for relevant learning resources to support teachers or learners) is a pivotal activity in TEL, the deployment of recommender systems has attracted increased interest' [3].

The current paper describes the use of a recommender engine within the feedback module of an e-learning tool. The presented e-learning tool is an e-assessment application for project management domain, used in the preparation process by the students or the knowledge workers who want to obtain a project management certification awarded by the International Project Management Association (IPMA) in Romania [4]. The authors argue that using a recommender engine within the e-assessment would increase the formative values of the e-assessment, transforming it into an innovative learning instrument, which not only evaluates knowledge, but also creates knowledge. A set of personalized recommendations are given at the end of the e-assessment session, each time the feedback module fires the recommender engine. The recommendations depend on the students' behavior within the e-assessment session: wrong answers influence the recommendations, which consist in web bibliography meant to give students future learning directions. Students receive recommendations, but are not forced to use them, thus gaining the opportunity to take control of their own learning. The interaction between students and the e-assessment application is taken at an upper level, the final purpose being the quality increase of the learning process.

The article has several sections: after the introductory part, a short survey on educational recommender systems is made in the second section. Then,

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in the third section, the authors propose another educational recommender system, which consists in the e-assessment application for project management. The general architecture of the application is described and special interest is given to the feedback module. This module is the one which fires the recommender engine, thoroughly described in a special sub-section of the third section. For better understanding, a practical example on using the recommender engine is offered. Also, a short evaluation of the utility of the recommendations is presented. The forth section highlights the benefits of using a recommendations-based feedback in students' e-assessment. In the fifth section, conclusions and future directions are offered.

2. The recommender systems' use in e-learning activities

In the last years, numerous repositories of educational digital resources have been created, such as: MERLOT (with over 20000 educational resources and almost 70000 of registered users) [5], OER Commons (with approximately 18000 resources) [6] or European School net's Learning Resource Exchange (with over 43000 resources, from 25 countries) [7]. These repositories are added to the unclassified resources provided by Internet itself. In this overcrowded space of online educational resources, the e-learning users feel the need of services which can help them identify the proper learning objects. RS serve this purpose [3].

A RS guides the user to interesting objects (concepts) in a large space of possible options [8]. Usually RS must choose which of the items should be shown to the user or when and how the recommendations must be shown [9]. In educational area, RS started to spread more and more [10, 11]: some assist students to plan their semester schedule, by checking courses that comply with constraint regulation and with students' preferences [12], others are used at course ranking [13] or to give proper knowledge to proper members in collaborative team contexts, by respecting role, tasks, members' level of knowledge [14]. RS can provide books recommendations [15] or help ESL (English as a Second Language) students to learn English [16].

Interesting researches have been made for comparing existing educational RS, such as QSIA (Questions Sharing and Interactive Assignments), CoFind, ISIS, ReMashed, RACOFI (Rule-Applying Collaborative Filtering) [3] or eInkPlusPlus [2]. QSIA (Questions Sharing and Interactive Assignments) [17] is a system used for the distribution, evaluation and recommendation of educational resources, used by virtual communities, for promoting extensive collaboration. The recommendation mechanism proposed by QSIA is mainly controlled by its users: they decide what collaborative filtering service to use or who will receive their recommendations. CoFind uses resources available on Internet, but it applies labels for the recommendations [18]. ISIS uses hybrid algorithms for recommendations [19]: the data offered by other users are combined with the information provided by the students' profiles and their usual educational activities. ReMashed is designed for the students from the informal educational networks [20]: the recommendation algorithm applied by ReMashed is based on the labels and information provided by Web 2.0 services. RACOFI combines a collaborative filtering engine with a rules inference engine, which searches for associations between the educational resources and their use in recommendations [21]. The eInkPlusPlus project is used for e-books reading, using the data gathered from the users' interaction [2].

3. The recommender engine design

The current section describes an innovative learning instrument (an e-assessment application) for project management domain and the recommender engine which is fired by this tool. As project management knowledge has a tremendous impact on economical well-being, various efforts have been made to fill knowledge gaps in project management domain [14, 22]. Among these efforts, there are the ones made by the Romanian Association of Project Management [4], which provides an e-assessment application for certification exam preparation. The Project Management (PM) professional certification is based on the International Competence Baseline—ICB [23] of the International Project Management Association (IPMA). According to this competence standards there are four components and three categories for the PM competences. The PM competences *components* are *knowledge* (generally accepted practices of project management applied to specific technical disciplines), *skills* (the capability to apply knowledge in an efficient, effective, professional, and successful manner), *personal attitude* (the commitment to perform in an appropriate and acceptable professional and ethical manner) and *experience* (knowledge or skill that is gain from doing an activity).

The PM competence *categories* are:

- *Technical competencies* of delivering projects in a structured way, including the project management process.
- *Contextual competencies* in managing relations with projects within organisations, programmes and portfolios, based on the knowledge of project

characteristics, projects in the organizational context and project environment.
- *Behavioural competencies* for a positive, collective, and dynamic thrust in nurturing project management professionalism such as leadership, communication, results-orientation, ethics, negotiation and so forth.

IPMA chose to define the following four levels of competence:

- *IPMA Level A.* At this level, the individual has to have demonstrated successful use of the competence elements in the coordination of programmes and/or portfolios; guided programme and/or project managers in their development and in the use of the competence elements; been involved in implementing the competence elements or relevant methodology, techniques or tools in projects or programmes; and contributed to the development of the project manager's profession by publishing articles or presenting papers on his experiences or by outlining new concepts.
- *IPMA Level B.* At this level, the individual has to have demonstrated successful use of the competence elements in complex project situations. She/he has also guide (sub) project managers in their application and implementation of the competence.
- *IPMA Level C.* At this level, the individual has to have demonstrated successful use of the competence element in project situations with limited complexity. He/she might need to be guided in the further development of the competence element.
- *IPMA Level D.* At this level, only knowledge related to the competence element is assessed by written examination.

The levels provide a suitable framework for developing career paths and organizational maturity models as well as for personnel development programmes of individuals, companies and other organizations. The project personnel should continuously improve their project management competencies to meet the growth in demands and competition. Each project has its own specific needs which include the necessary competency needs of the project. Any gap between required and available competencies (in both internal and external resources) is a risk factor for the project's success.

Although no direct relationship exists between training and certification providers, the education and training institutions want to improve the chance of their scholars, students or course participants achieving a certain certificate, for example:

The project management programme of an advanced professional school or a training course aspires to prepare its students to develop their project management competences at level D.

A project management master programme or postgraduate course wants to ensure that its candidates develop their project management competences at Level C (or B).

3.1 The PM knowledge assessment platform

The prototype of the e-assessment application is presented in Fig. 1. The system has several components: the admin module, the trainer module and the student module. The admin module offers the possibility to accomplish operations on levels, competences, trainers, users or questions. The trainer module allows the creation of rules-based tests, visualization of previously created tests and visualization of students. The student module contains the web application used by the students to resolve online tests. These tests are created with various adaptation models (PSO based or Rules-based). The models are implemented by the Adaptive test building engine. In the PSO model, the goal at each iteration is to find the question having the difficulty level closest to the trainee's ability level and closest to the targeted test difficulty level, being the least exposed so far and checking a large number of concepts from the established learning objectives. In the rule-based model, a set of rules for building a test are established via the trainer module. Each rule has an initiation point (whether the rule is applied at the beginning of the test or after a certain question), an action (for example, the rule consists in showing

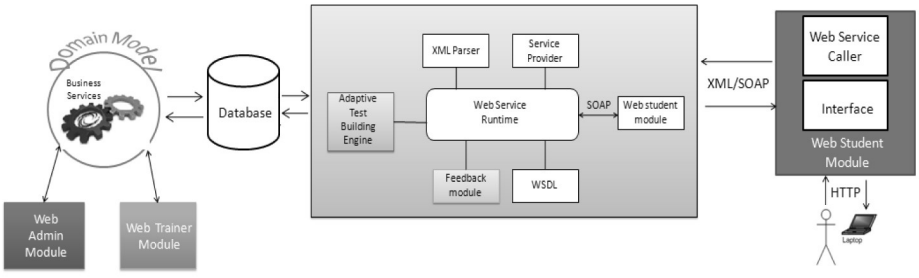

Fig. 1. The Architecture of the Adaptive Formative E-assessment System for Project Management

only the question of level D) and a set of conditions (for example, the rule is applied if the trainee has previous project management education). The tests are adapted to trainees' educational objectives, previous knowledge or courses. In the same time, the trainers gain the possibilities of reflecting on the assessment experiences and offering personalized tests for each student, thus motivating the students and helping them in the learning process.

Another important component of the system is the feedback module: after completing a testing session, each student has the possibility of revising the incorrectly answered questions and receiving future recommendations for filling the knowledge gaps. The admin and the trainer module communicate with the database via a set of business services. The trainee module communicates with the database via a web service. The web service can call the adaptive tests engine and the feedback engine. This service-oriented and components-based architecture ensures the system's flexibility.

The web module is developed in JavaScript, exploiting the Ajax technology offered by the Dojo library. The admin and trainer module are developed in C#, using the benefits given by nHibernate. The database used by the system is a relational database, with 12 data tables. The database is constructed using the IPMA Competences Baseline [23].

The tests offered to the students have multiple-choice questions, as one could see in Fig. 2: each question has five possible answers, which can be true or false. The score sheet has incorporated an automated feedback mechanism: the user can return to the incorrectly answered questions (which are marked with red in Fig. 2) or to the correctly answered questions (which are marked with green). The user can also ask for an exam report, which will give him a 'pdf' document (see Fig. 2) with the correct answers. The formative dimension of the test can be increased by pressing the 'Search on WEB' button from Fig. 2: a recommender engine will be called and the users will obtain a set of web documents related to the knowledge checked by the questions which were incorrectly answered. The algorithm standing behind this recommender-based feedback is an ontology-based clustering algorithm.

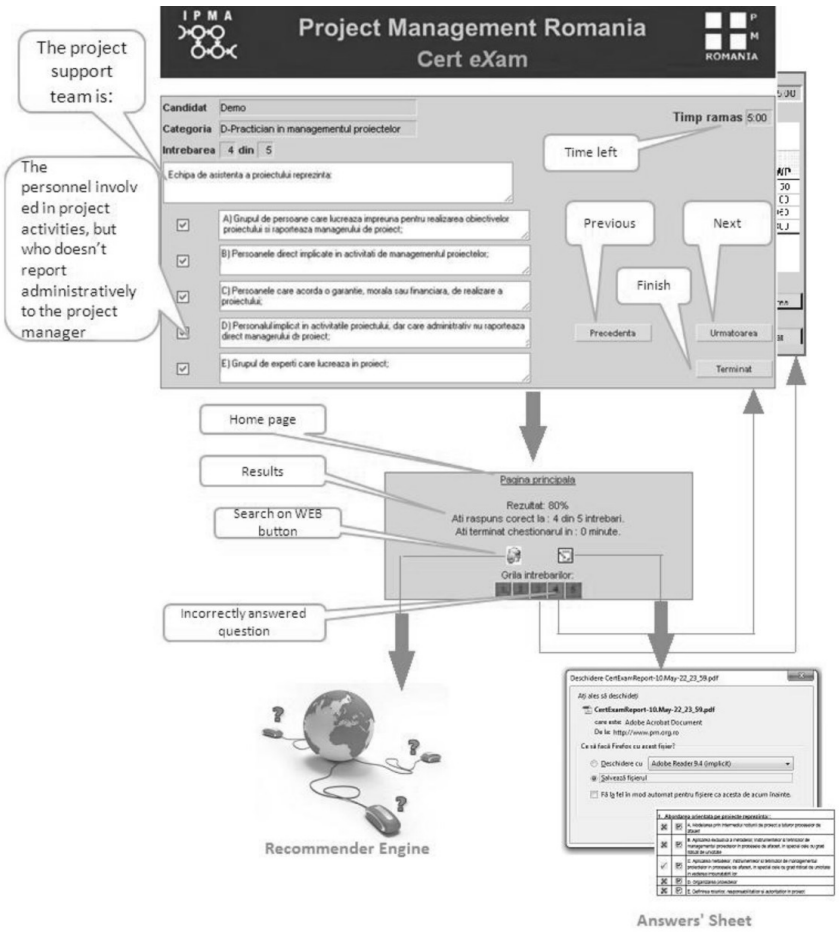

Fig. 2. Workflow in the Adaptive Formative E-assessment System for Project Management.

3.2 The mechanism of the recommender engine

Each question of an e-assessment session checks a certain number of concepts from the knowledge domain in project management. This knowledge domain is represented by an educational ontology [22], which is correlated with the relational database used to stock the educational content. The recommender engine should search for web documents related to the concept of the incorrectly answered question, but also for web documents related to the parent node of the concept in the domain ontology and other child nodes of that parent. The lexical instances of these concepts are the entry points for a clustering algorithm. Thus, the web pages are grouped into relevant clusters, offering the users a friendlier list of results. The concepts are converted to their lexical instances, using the educational ontology. The recommender engine is a C# web-service. The mechanism of the recommender engine is presented in Fig. 3.

According to Fig. 3, the following steps are available in the recommender engine mechanism:

1. The user takes the test.
2. The user finishes the test and the 'user profile' is built: a set of concepts related to the incorrectly answered questions.
3. The user profile is mapped in the domain ontology, taking account a λ parameter used as an entry data: according to that parameter, child nodes from the initial set of concepts might be chosen. For all chosen concepts, lexical instances are extracted and further used for web-search.
4. The web search is processed for the lexical instances from Step 3 and for the following admin parameters: the set of search engines to be used (the administrator of the e-assessment application can choose the available engines from a combo-box), the number of links per page, the number of clusters.
5. A clustering algorithm is applied. Clustering will be realized after a predefined number of iterations.

This number will be determined experimentally in order to find a compromise between computing time and quality of clusters obtained. By default, we make 6 clusters, the 7th cluster representing unclassified documents and we use a threshold value of 0.3 for classification of instances in clusters. After each clustering, we recalculate the centroids and we reset the clusters' components. The new centroids are calculated using the average weigh of words reached in that cluster.

A k-means clustering algorithm is used. The clustering algorithm has the following stages:

- Label extraction: for each clusters the sequence of words with the highest frequency will be assigned as label for that class. If a sequence of words is not found than a single word will be used instead.
- Creating the cluster structure: it will be done using both the size of the clusters and the weight of the pages inside the cluster. A measure of the cluster quality will be calculated.
- Results delivery: during the pre-processing phase, we extracted the root for the similar words and we eliminated the stop words, and some other modifications took place in order to make the document suitable for clustering. In order for the user

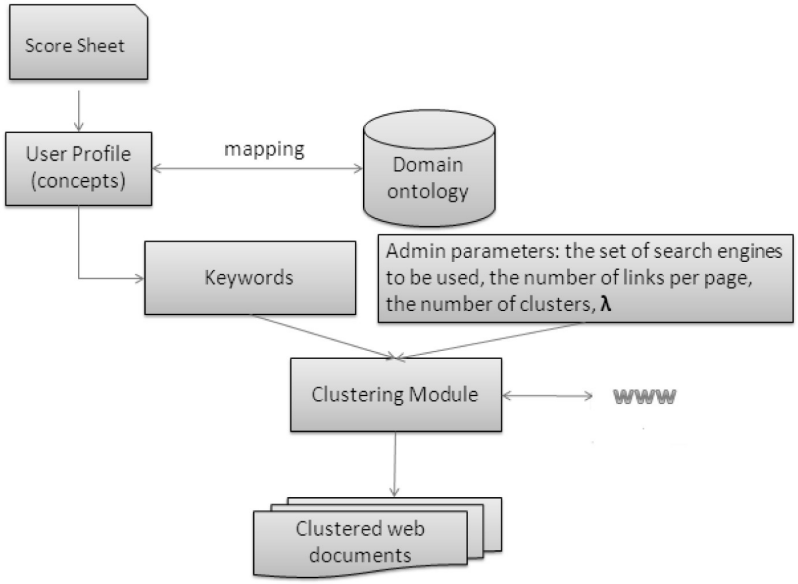

Fig. 3. The RS Mechanism.

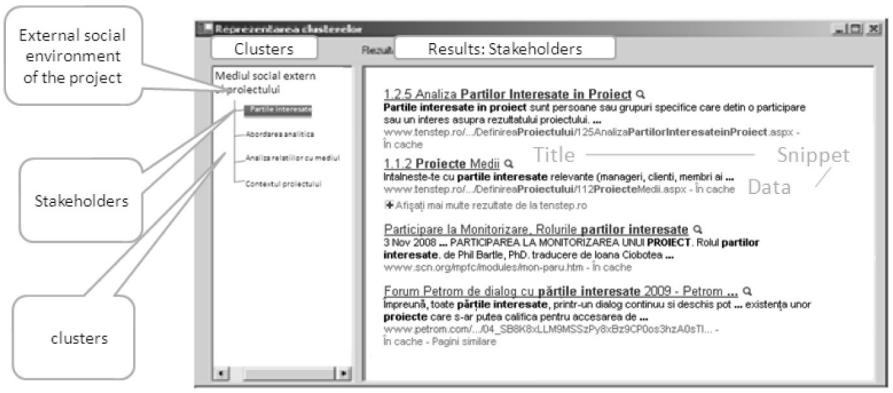

Fig. 4. Search Results delivered as Clusters by the Recommender Engine.

to understand what a page is about it must be presented with a short relevant description of that web page. In almost all cases the initial search result list provides a short description (the snippet). That description can be kept, and delivered to the user after clusters are developed, but it can also be enhanced with particular characteristics of the cluster.

An example of a clustered list of recommendations is available in Fig. 4.

The recommendations are given, because the user answered incorrectly the question 'The project support team is:' The correct answer would have been 'The personnel involved in project activities, but who doesn't report administratively to the project manager.' Instead, the user checked all the variants. After the match between question 4 and educational ontology was made, the 'MSE' concept was found as not understood by the user. The lexical instance of 'MSE' was found to be 'Mediul social extern al proiectului' (in English 'External social environment of the project'), which became the query given to the RS search engine, as one can see in Fig. 4.

3.3 The evaluation of the recommender engine

Taking into account the directives of the directives of the Australian Flexible Learning Framework, which drew the attention to the the tendency of developers and suppliers of e-assessment applications to be concerned only with the technical aspects of the success and usefulness of products in the learning process per se [24], we focused on the evaluation of the utility of the recommendations to the users. We calculate the utility of the recommended web documents using formula (1).

$$Utility_u = \frac{\sum_{i=0}^{n} P(u,i)}{n}, where\ P(u,i) \in \{0,1\}. \quad (1)$$

Where

$u =$ an user;
$P(u,i) =$ the utility of the document i to the user u;
$P(u,i) = 0$, if document i is considered useless by the user;
$P(u,i) = 1$, if document i is considered useful by the user;
$n =$ the total number of recommended documents.

The formula was successfully used by other researchers, too [9]. The central place of the evaluation is taken by the users. In order to apply the formula (1), we made a short experiment, at which 39 users of the e-assessment application participated. All the users were students in the second year of a project management master and were preparing themselves for taking the same type of certification in project management. The results of the experiment are available in Table 1.

Because of the novelty of the application (RS for an e-assessment tool), we couldn't compare it with other RS but we tried to whole the evaluation by a qualitative analysis made by the 39 users. 27 of them considered the toolset to be useful especially when preparing for the project management certification exam. The rest of them acknowledged the formative value of the toolset for their general training in project management. All of them said they browsed the recommendations, after being influenced by the cluster label.

Table 1. Utility of the Recommended Web Documents

Utility Value (percentage)	No. of users
>75%	21
[50%, 75%]	13
(25%, 50%)	3
> = 25%	2

4. Impact of receiving recommendations from the feedback module of the educational application on students' behavior

The possibility given to the users of returning to the incorrectly answered questions for finding out their exact mistakes empowers them with the capacity of choosing what they want to revise. The recommendations guide them to future learning activities, but they also let the users to choose whether they want or not to follow the recommended directions. The evaluation itself gave the users the central role in establishing whether the recommendations are indeed useful. All these aspects transform the students into dynamic agents in the e-learning environment: they can choose and they can decide. The recommender engine fired by the e-assessment feedback mechanism transforms the application into a knowledge creation one.

5. Conclusions

The article presents a recommender engine which is fired each time an e-assessment application is used. The recommender engine offers the users a list of web documents related to the mistakes they made during the e-assessment session. The documents are clustered, taking into account their content and the relevance of the content to the users' knowledge gaps. By using the RS engine, the feedback mechanism of the e-assessment application is highly improved: it gives proper knowledge (through reading recommendations) to proper users (users receive these recommendations, depending on their mistakes). The feedback mechanism is generally considered to be very important for the formative dimension of an e-test. The article states that, if it uses a RS engine, it efficiently adjusts learning: experimentation results are also provided.

In order to increase the usability of the solution, we should migrate the clustering process on the web and go for a distributed architecture: the ontology can stay on a machine, the clustering process on other machine and so on. For the moment, the recommender engine works only for Romanian language. In the future, it should be extended to other languages, too.

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