A framework for monitoring the unsupervised educational process and adapting the content and activities to students' needs

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Abstract. The growth of internet and the evolution of supporting infrastructures motivated universities and other educational institutions to adopt new teaching methods. These unsupervised methods are focused on the dissemination of the educational material and the evaluation of the users through tests and activities. The user behavior is not monitored and the performance of users cannot be reasoned in most cases. We strongly believe that the monitoring and analysis of the users' behavior in a distance course may help on improving the course plan and the quality of the reading material. In this direction we define the framework for an unsupervised educational process that combines reading material and examinations and monitors the user performance throughout the educational process. We detail on how this framework can be implemented using web technologies, thus creating a web-based educational application. We additionally define the methodology and tools that can be employed for monitoring and processing users' data.

1. Introduction

The progress of network technologies and infrastructures helped the evolution of distant training and education. A feature of e-learning and e-education programs is the diversity of the educatees' learning abilities and needs. While in e-education, the tutor provides the content and the general directions and sporadically gives clarifications and advices to the class, in e-learning programs, usually, the educational process is unsupervised. The students deal with a predefined content and search for answers on precompiled answer sets, tutorials and the web. The problems that both programs confront are: a) Lack of direct contact between the student and the tutor, b) Difficulty in content personalization, c) Confusion of students due to the abundance of information.

This work presents a web-based educational system that monitors and analyses the students' behavior while they browse the ***educational material*** and answer the ***tests*** and ***problems*** of the worksheet. Usually tests are used for evaluating if students have acquired the offered knowledge. However, the successfulness of a worksheet in

achieving the educational goals is strongly related to the quality of the offered knowledge.
The innovative aspect of our work is that questions and reading material are used in combination to achieve the educational aims. The learning activities (LAs or student evaluation activities) reflect the educational aims and the educational material is the supportive means for achieving these aims. Low performance or participation in the test activities, from the users' perspective, is indicative of deficient material and inefficient educational and evaluation process. In this paper, we provide a methodology for detecting this deficiencies and correcting them in order to improve users' performance and facilitate knowledge acquisition. According to the methodology, which is applicable in both behaviorist and constructivist learning theories, students are free to selectively browse the learning material, to search the web or other sources, to discuss about the questions and to ignore certain activities. Students' behavior is being monitored and analyzed and the course is being rearranged, in order to increase the usability of content and activities and improve the impact on students.
In the rest of the paper, we refer to related systems, present our methodology and provide the framework for a self-adaptive educational process based on students' performance in learning activities. Finally, we conclude with the functional and architectural design of a web based system (WISE - Web based Intelligent System for Education) that supports the adaptive training process. The modularity of material and activities in WISE enforces reusability, offers flexibility in course set-up and encourages students' interactivity.

2. Related work

In the proposed work, the effectiveness of the educational material is examined under the prism of students' participation and performance in the tests. Intelligent tutoring systems, such as ActiveMath [12], ELM-ART [16] provide advanced support in problem solving and do not use the problems to increase comprehension. Adaptive hypermedia systems such as KBS-Hyperbook [8] and MetaLinks [15] capitalize on the presentation of content while neglecting the learning activities. [2] presents an adaptive web educational system, in which assessment activities are not related to the educational process.
As far as it concerns the evaluation of web based educational systems, several works limit their statistical analysis to the users' evaluation of the system's capabilities [10] or the interestingness of a module [3]. The same holds for approaches that use data-mining techniques for analyzing data [13, 4].
Test activities are powerful educational tools. They can be used for students' evaluation, they motivate students in structuring their efforts, they facilitate evaluation of teaching material and they reinforce learning by guiding students on the skills they should concentrate on. When activities are properly matched to the teaching material [9], it is necessary to be in a variety of forms that accommodate the various students' preferences. In the rest of the paper, there is no distinction between constructivist (experimenting, practicing, summarizing and reading) and behavioral activities. Worksheets may contain activities such as multiple choice or short answer questions, matching questions, true-false, problem solving etc, which are widely used

in web courses. The advantage of such activities is that they offer fast and automatic evaluation of students' answers.

3. Methodology

The proposed methodology divides the educational process into three phases: ***pre-assessment***, ***reading*** and ***post-assessment***. In each phase users undergo the same evaluation procedure and their actions are recorded. Users access the educational material, during the second phase, in the order of their preference.

Data collected in all phases is processed using statistical and data mining techniques. The undeniable evidence that the goals have been achieved is that the average scores of users in the evaluation activities increase. Analysis of users' performance in the tests may reveal deceptive and confusing questions that hinder users from acquiring knowledge and achieving the goals of the course. The methodology can be enhanced with constructivist approaches, i.e. by allowing students to submit test questions, or modify the test layout and the timings for each question set.

3.1. Definition of the course structure and the educational aims

The first step in an educational process is the *definition of aims*: what is expected from e-learners to know before the educational procedure (pre-requisites i.e. baseline knowledge and skills) and what will be their gain in knowledge and skills after the procedure has finished. A course outline, syllabus or concept map [6] should be the output of this process and will be used as roadmap for the web course.

Another issue is to define what *kind of assignments* and other activities will be made available for the students. In an unsupervised environment, long answer questions cannot be automatically evaluated and should be avoided. Multiple-choice or "point and click" questions can be monitored and evaluated more easily. Finally the proper *reading material* should be found and combined with activities in order to achieve the educational aims.

3.2. Preparation of teaching material and learning activities

The next step towards an adaptive educational process is to prepare the informative material, collect and organize sources in a meaningful and readable way. The material should be brief, clear and up to the point, so that it does not confuse novice users. Additional material can be offered to expert users upon request (and not by simply following hyperlinks). The material should be modular so that it can be easily composed and restructured by adding or removing hyperlinks [6].

Similarly, test activities should be created for the educational aims. Different type of tests, serving the same purpose (***synonym*** activities), must be made available. Both educational and evaluation material is accumulated into a database (Content Database), thus creating a knowledge base of teaching modules which can support the educational procedure.

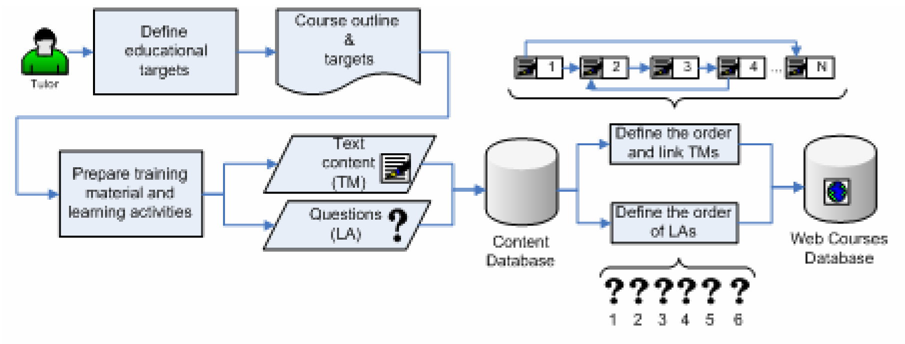

Fig. 1. Preparation of educational material, learning activities and courses

3.3. Organize the course

Once the content database is populated, the next step is to organize the course structure. The two basic types of modules used for the course are the teaching material (TM) and the learning or test activities (LA). For simplicity we assume that the TM modules are composed by a few paragraphs of text whereas the LA modules are multiple-choice and matching questions. The tutor initially selects, arranges and links the LAs and TMs, thus converting plain texts into web courses. The structure of every web course is stored in the Web Courses Database. The initial course structure gradually evolves as more students take the same course and more input is acquired.

3.4. Run the course

In every course the students pass through the following phases:

- ***Pre-assessment***: They preview all the questions in a predefined order and for a limited period of time. They are encouraged to answer only the questions they know and ignore those that are confusing or unfamiliar to them. Their answers, and the questions they omitted, are recorded in this phase. Since students have not accessed the TM yet, we get an indication on the initial knowledge level of each student.
- ***Reading***: Students start from an introductory page and browse the TMs by following the links created by the tutor. They go back and forward to the teaching modules (texts and multimedia), while in the same time they review and answer the questions without order or time limit.
- ***Post-assessment***: In this phase, students are able to revise their answers, without accessing the TM. In an alternate version, students may answer all the questions from start (without revision). This allows the teacher to know the knowledge incorporated by the students.

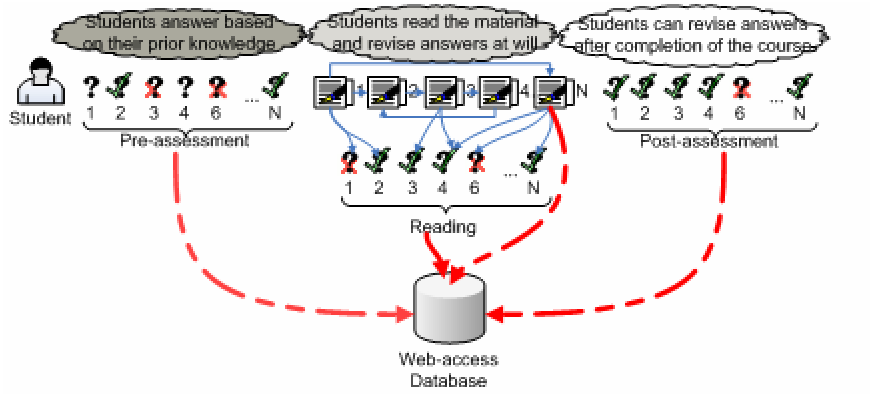

Fig. 2. Evaluation of students in the three phases of the educational process

The students' actions and answers are recorded in each phase and are stored in a database, in the form of access logs (web-access database). Specifically:

- In the pre-assessment phase we record: a) the LAs that the student failed and succeeded, b) the LAs ignored, c) the time spent in each specific LA.
- In the reading phase we record: a) the order of visit of the TMs and the time spent, b) the LAs answered whilst reading a TM and the success or failure, c) the time spent in a LA (subtracted from the time spent in the respective TM).
- In the final assessment we record: a) the revised questions, b) the correct and wrong answers.

Data analysis helps in locating bad or misleading content and questions and reorganizing the course in a more meaningful manner. Reorganization comprises of replacing confusing activities (with high failure degree) with synonym activities from the database, merging more than one LAs into a single unit and splitting a LA into smaller units. In an offline process, the tutor rephrases the unclear questions, creates new teaching material adds or removes links, changes the order in the LAs and TMs of a course etc.

The framework for analyzing the collected data and drawing useful results on the usability and clarity of the provided content follows. We define an indicative but not exhaustive set of measures. We emphasize on their semantics and on their combination in order to produce interesting results.

4. A framework for the analysis of the results

The analysis of the collected data can be performed using commercial -SPSS Clementine, Palisade StatTools, and other freeware tools. However, custom algorithms for statistical and web usage analysis can be implemented. The analysis can be of three types: 1) Statistical analysis of the teaching material's and the evaluation activities' accessibility, 2) Navigation pattern analysis, of the order in which users access the TMs and LAs, 3) Combined analysis on how the TMs affect success or failure in TMs.

The aim of the analysis process is to measure the validity and reliability of content and tests as stated by [7]. As far as it concerns the usability of a course we distinguish between ***activities usability*** (section 4.1) and ***content usability*** (section 4.2) and attempt to quantify them. Then we combine those measures to get an indication on the course impact (section 4.3) in users' performance [1]. Finally, we discuss on more complex factors (section 4.4) of the learning process such as time and sequence and give insights on how to improve course effectiveness.

4.1. Usability of activities

For each LA, during the three phases, we count the following: a) ***TotalAnswers***: the number of users that answered the LA (question), b) ***CorrectAnswers***: the number of users that correctly answered the LA, c) ***WrongAnswers***: the number of users that failed in the LA, d) ***TotalUsers***: the number of users that took the course.
Thus we have three indicators on the usability of an activity:

LA_Interest: $\frac{TotalAnswers}{TotalUsers}$,***LA_Success:*** $\frac{Success}{TotalAnswers}$,***LA_Failure:*** $\frac{Failure}{TotalAnswers}$

A question answered by many users (regardless of the result) is easy to comprehend and more possible to achieve its aim. A question of interest and high success rate in the pre-assessment phase is simplistic with limited value for the educational process and can be omitted or replaced by another question (not a synonym one). A question with high interestingness, but high failure during the pre-assessment phase is a challenge for the educational process. The aim is to maintain the interestingness in a high level, while decreasing the number of wrong answers by assisting users with the reading material.

4.2. Usability of content

For the usability of training material (TMs) we count the following: a) ***UserAccesses:*** The number of distinct users that access a node, b) ***AccessesPerSession:*** The mean number of times a page is accessed by the same user inside a session (a course). We then define the interesting and centrality of a TM, which indicate the usability of a content node.

TM_Interest: $\frac{UserAccesses}{TotalUsers}$, ***TM_Centrality:*** $\frac{AccessesPerSession}{Accessibility}$

Nodes with low accessibility are either difficult to reach (low connectivity) or are not properly described (i.e. wrong hyperlink titles are used). Nodes that are accessed many times inside the same session (by the same user) are either very important for the user (high centrality) or are very difficult to comprehend. The tutor should consider splitting the content into more nodes.

4.3. Impact on users' performance

We strongly believe when teaching material is properly combined with the learning activities the efficacy of the educational process is increased. The analysis on the accessibility of content should be done under the prism of the supported activities. We use the following measures:
TM_Impact: The mean number of questions answered while reading a TM.
TM_PositiveImpact: The number of questions, which were initially answered wrong and corrected after reading a TM node.

TM_NegativeImpact: How many questions were changed from correct to wrong after reading a certain TM node.
These TM nodes that exceed a threshold of negative influence should be rewritten and this must be done in accordance to the questions influenced.

4.4. Advanced analysis

By adding a time dimension into our analysis (i.e. the time each user spends in a question or web page) we get very interesting results. Complex and demanding questions should be reconsidered for their usability in the educational process. Content nodes which are neglected by the users should be omitted from the course. Additionally, if a specific TM does not help in answering a question, this is a fact that the node is of low importance.
The web-access data collected through the educational process has an inherent sequence dimension (sequence of accessing TM nodes, answering LAs, revising answers in the post-assessment phase). Analysis of these sequences (web-usage mining), leads to interesting access patterns [5].
The first step towards this direction is to define the "***path***" – the sequence of TMs – accessed by each user for answering a question. For simplicity, based on Miller's work [14] on the limits of human capacity in acquiring knowledge, we assume that a path contains the last 7 (at most) nodes that the user visited before answering the LA. We also define "***same paths***", those that contain the same nodes with the same order and "***similar paths***", those that contain the same nodes but with a different order.
We consider the ***participation*** of a node in the set (number of distinct paths it belongs to). For the paths that correspond to the learning activities, we define two measures: a) ***Path_Support:*** The percentage of users that used similar paths, b) ***Path_Confidence:*** The percentage of users that used the same path.
Finally, we define "***frequent paths***", with Path_Support over a predefined threshold and apply web usage mining algorithms on them.
A joint analysis of the above factors indices gives valuable hints on how content and activities should be organized. For example:

- A ***frequent path*** with 3 TM nodes that leads to a correct answer gives the following rule: Visitors of the first 2 nodes ***must*** visit the third node in order to successfully accomplish the learning activity. As a result, a hyperlink pointing to the third node can be added in both TM nodes.
- Paths with high support and low confidence indicate that the content of TM nodes should be read in total and thus the nodes should be merged in a single node. This is feasible only for nodes with low participation.
- TM Nodes with low influence and low participation can be either merged with others, deleted or converted to external references.
- A high LA_StayTime in an activity may due to the complexity of the activity but also to an ambiguous question definition. Such questions should be revised, rephrased or replaced by "synonyms".

5. Architecture and Technologies employed

The proposed methodology is to be implemented into ***WISE***, a ***W***eb based ***I***ntelligent ***S***ystem for ***E***ducation. The general architecture of the WISE system is a typical client-server one with a web server in the front and a database in the back-end. In the following, we provide suggestions on the technologies that can be used for the efficient delivery of web courses to remote students and give a simple sketch of the user interface. Finally we present our thoughts for transforming an e-learning tool into a learning community platform [11].

5.1. Educational material

The tutor creates the teaching material and the questions using a web page development tool or a custom application that generates simple HTML or XML documents (snippets). The use of XML for describing educational material and activities offers high adaptability and reusability. XML nodes can be easily transformed, split or merged in a new document. In the course design phase, tutors combine the snippets into a complete course by defining order of TAs and LAs, their alternatives etc, without special knowledge of web development tools. Material in other formats (pdf files, presentations, documents etc) can be provided through links.

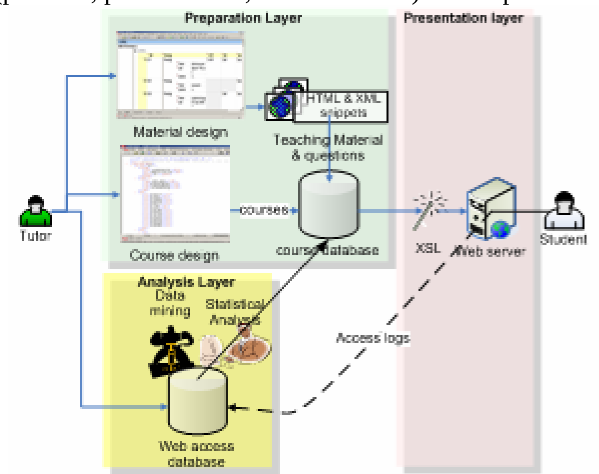

Fig. 3. The proposed architecture

5.2. Publishing web courses

Once the material and the questions have been stored in the database and the course and evaluation outline have been set up, the publishing phase follows.

Languages that transform XML to HTML (i.e. XSL) can be used to create presentation templates for a course. The templates are created once by expert web designers and reused through the educational process.

5.3. The student's interface

A simple user interface (web page) facilitates students' work while keeping their focus on the evaluation activities. A ***top frame*** that contains the reading material (text, flash animation, images, audio and video), a ***navigational frame*** (with navigation buttons for the course) in the middle for choosing the questions to answer and a ***bottom frame*** where the question will be presented are sufficient for the whole procedure. The bottom frame contains the evaluation activity, which may range from a simple multiple-choice question to a complex web component (activeX component or java applet) that simulates a point-and-click activity. The small frame on the bottom of the window contains the list of activities and a pair of navigation buttons for selecting activities. A sketch of the user interface is presented in Fig 4.

6. Conclusions - Future work

This work presents a methodology for adapting the reading material and test activities to the user needs and interests, as these are detected throughout the educational process. Intelligent monitoring of the users' actions inside the web-based teaching environment and in depth analysis of the collected data may expose the deficiencies of the material and activities and lead to reformulations.

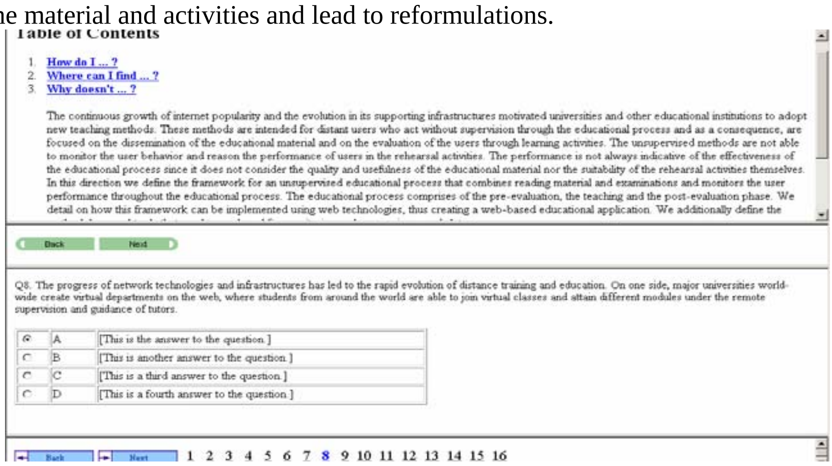

Fig. 4. The user interface

The framework for the analysis of collected data along with some measures and indications that can be drawn were presented. The next step is to define a concrete set of measures for course evaluation based on the literature.
The generic architecture of the WISE system (***W***eb based ***I***ntelligent ***S***ystem for ***E***ducation) was presented. The system is currently in the design phase, so we presented the technologies that we plan to use for the development. The development of the WISE system and its evaluation on a real educational process will allow us to define which measures are of importance for the evaluation and amelioration of the process. The next step for the WISE system is to support interactive design of courses, based on students' feedback and comments. This will provide a platform for building learning communities instead of simply supporting e-learning process.

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