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Research paper

Conceptual design of the new generation adaptive learning management system

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Abstract

Taking into account that each new day an amount of daily processed data grows exponentially, it is obvious that knowledge society needs flexible, effective and high performing tools to retrieve, learn and apply necessary information. Learning management systems become more and more intelligent and adaptive. Learning analytics instruments give course developers a possibility to assess and analyze learners' activities and behavior patterns within e-learning environment, allowing to propose them personalized self-paced learning path and types of learning objects. This paper discusses challenges in development of adaptive learning management system and outlines its prospective models and properties.

Keywords: *Adaptive information system; Feedback; Learning analytics; Personalized learning.*

1. Introduction

An amount of daily processed data grows each new day exponentially. Modern society, known as the knowledge society [1], needs new tools which could solve the problem of retrieving conformable information from the growing data flow and increasing requirements from employers regarding workforce knowledge level. Learning process and, consequently, learning management systems (LMSs), ought to become more flexible, intuitive, adaptable, and as a result, effective. LMSs carry out a wide range of data collections, which include both the information, directly provided by the students, and their activity data. Accordingly, the students are being provided by the system with the relevant learning content for further knowledge acquisition. LMSs become more intelligent and efficient. Contemporary educational organizations put the intelligence issue as the one of prioritized directions in technology enhanced learning and corresponding information systems [2].

Recent studies show that in digital age the change in learner characteristics (i.e. diversity, learning contexts, learners' goals, existing competence levels, belonging to digital natives' community) is one of the most important factors which impact knowledge transfer changes [3]. Stakeholders expect flexible and personalized approach to learning process and goals. LMS developers ought to take this into account when design new e-learning environments.

Learning analytics could provide students with data about their learning progress, possible learning gaps and steps needed to achieve their educational goals [4]. Recent findings clearly indicate learners' positive attitude and interest in individualized analysis of their study progress, activities and behavior patterns which could be done by implementing of learning analytics tools and methods [5]. Similarly, learning analytics could supply course developers and teachers with inestimable data about things to be improved in order to offer more personalized self-paced learning path and learning content to particular learner. Learner behavior and activity patterns assessment with multimodal learning analytics tools draw diverse learning trajectories [6]. It is recognized that "learning analytics has the potential to be enormously powerful for improving the student experience of university" [7].

Over the time the complexity of e-learning systems has increased. The key direction is shifted to learner interests and goals, trying to find tools which could cooperate with the student. E-learning systems are becoming more and more flexible and diversified. These systems, in order to adapt to the student, are derived from the student's direct actions and data provided by the student. Adaptive information systems take into account student's existing skills, prior knowledge and interests. They adapt to learner needs and profile, designing personalized learning path [8]. Accordingly, learning courses and content are also being adapted - the system "reads" the learners, thinks and decides instead of them about delivery of learning content which suites learners needs and could eliminate knowledge gaps.

Adaptive information systems could be considered as the powerful instruments to solve knowledge society educational challenges. These systems are aimed to advice students and help them reaching educational goals in the most effective, self-paced and personalized way. Adaptivity in these systems is reached by "greater correspondence between learner, goal and characteristics of the system" [9].

However, to ensure effective operation of adaptive ISs, instructional designers are faced with a problem which requires predefining various types of learning objects (LO) and rules related to users' learning styles and behavior patterns within the system. It is concluded that a lack of these predefined LO types may negatively affect the work of adaptive IS [10]. Moreover, despite several attempts to adapt learning styles [11, 12] there are no clear indicators which learning style aspects are worth modelling in the new

ISs [13]. This all indicates that development of the new adaptive learning management system remains actual.

2. Tools and methods

To develop conceptual design of the new generation adaptive learning management system, respective scientific publications were studied. Initial considerations regarding system's architecture and model components were made, and some separate model examples were created, verified and validated.

There is a variety of different types of adaptive ISs which all are aimed to adapt against users' behavior patterns and provide corresponding personalized system usage pathway. Oppermann advices [14] that the adaptation levels in information system vary from adaptive to adaptable ones (Fig. 1). Adaptive level means that the system initiates adaptivity without user control based on systems assumptions regarding user behavior. In turn, adaptable level means that users are able to change some system parameters depending on their needs. Just a few year ago following three main interacting models were viewed in generally as the irreplaceable elements in adaptive educational IS [15]:

- Learner model (domain specific and independent data with user profiling and modeling);
- Adaptive model (instructional rules and adaptation ones);
- Domain model (learning objects and course content delivery system).

Later, the number of models in adaptive ISs significantly increased and system developers defined their proper aims, tasks and functions. One of the most advanced developed system is named "Generalized Intelligent Framework for Tutoring (GIFT)" [16]. It has a service-oriented architecture, consists of several asynchronously communicating modules: gateway (connecting GIFT to third-party learning ISs and applications), sensor, learner, pedagogical, domain (performance assessment, pedagogical actions, course flow management), tutor (user interface for tasks, e.g. presentations, surveys, feedback, etc.), learning management system (storage and maintenance of learner records, biographical data, LO, etc.), user management system (user logging and management), and monitor (monitoring the state of system sessions) module. GIFT offers modular domain independent system allowing development adaptive ISs pursuant to research direction. At the same time, two main challenges are discovered [17]: necessity to find a way to reduce the time and competences to develop and manage adaptive IS, and optimization of adaptive educational process for individual persons and groups.

Further GIFT upgrade is seemed in creating of a powerful joint IS, called "Total Learning Architecture" (TLA). It is a set of specifications for accessing and using of learning-related data, and is aimed to ensure learning across multiple platforms and applications [18].

Other findings are dedicated to develop effective tutoring tools within existing LMSs which would enhance adaptivity. Thus, concept maps theory approach, implemented by several researchers [19, 20, 21], can offer a comprehensive set of intelligent agents for modeling learner behavior and emotions in intelligent learning ISs. Students may choose knowledge assessment pathways, offered by the system, which suite their learning style the most. In turn, teaching staff can improve course content and structure based on analysis of course results.

Useful solution was found in the real time color codes learning process assessment approach, implemented by Riga Technical University [22, 23, 24]. It suggests an enrichment of LMS with learning objects (LO) acquisition (understanding) level tool which indicates (Fig. 1):

• Green button – "done" (it shows that the learner has not any problem with particular LO acquisition; the task (e.g. learning materials appearing in different forms, as well exercises and tests) is done, and there is no need to render additional learning support in such case);

• Orange button – "in process" (it signalizes that the learner is still acquiring particular LO and any assistance is not needed at the moment);

• Red button – "problem" (the learner has faced with difficulties; tutor's assistance is needed).

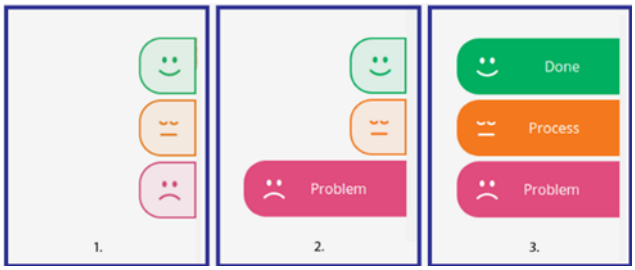

Fig. 1: Color code button states [24]

This method allows teaching staff to follow learner's study progress all the learning time and provide necessary assistance to the student when it is needed. In other words, during learning module the student probably has not any problem with LO and presses green button. Moving further the learner may encounter difficulties with next LO or task, and therefore presses red button. This ask requires teacher's attention. A pause during task accomplishment might be marked by pressing orange button which indicates that learning is still in progress (e.g. in time consuming cases). Users activity data are collected, processed and analyzed, and give useful recommendations to course teachers regarding necessary improvements.

3. Results and discussion

In order to improve learning outcomes and student engagement into knowledge acquisition process, it is concluded that existing learning management systems ought to be improved by assigning them new tasks and making them adaptive to the system users' needs. Proposed conceptual design of the new generation adaptive learning management system includes direct teaching & learning processes, user experience data collection, processing, and analysis, as well system adaptation against user behavior patterns within the system. To successfully cope with these tasks, the following models are considered in this conceptual design: learners model, teachers model, domain model, gateway model, learning environment model, multi-screen/multi-platform support system, sensors model, learning analytics model, and adaptation model, including its links with external frameworks (Fig. 2).

Learners model gives necessary analytical data including users' personal data (e.g. name, surname, learner ID, study group number, contact information, etc.) and, what is more important, their activity experience and behavior patterns data during learning process. Taking into account implementation results of the color codes learning process assessment method [24], we arrived to the decision to incorporate this approach into proposed model.

The learner indicates personal feeling about complexity level of each learning object (LO) of the learning course by pressing either green or orange, or red buttons. These data give necessary suggestions to the teacher in order to make appropriate improvements in learning content and/or offer to the learner other LOs which suite learner's needs the most. That all allow an adaptation of the particular user behavior patterns and offering to the learner personalized learning path. Accordingly, the most effective types of learning objects and learning environments are recommended.

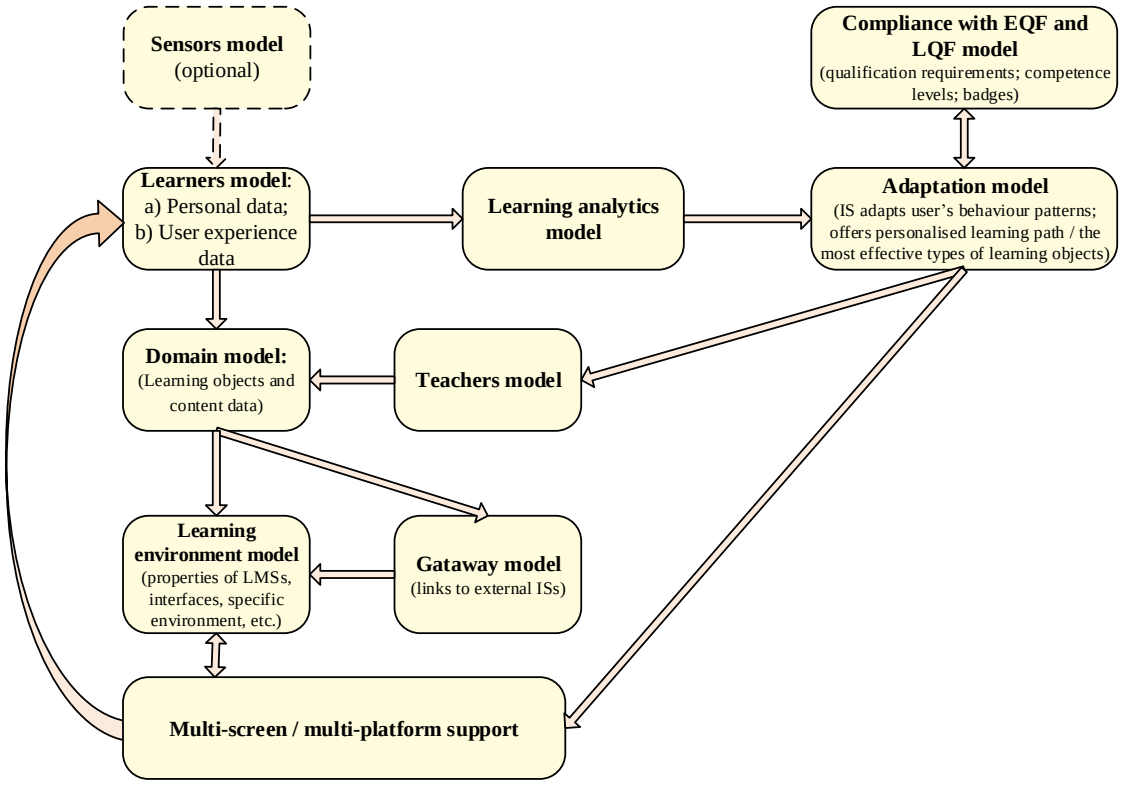

Fig. 2: Conceptual design of adaptive learning management system

Learners get personalized feedback on their performance, are able to review offered learning modules and objects, as well suggested learning pathways based on their proficiency level (indicated by green, orange or red buttons). During each learning session the learner is encouraged to press appropriate color button. This advocates the educator to recognize possible shortages in the knowledge acquisition process and particular learning objects (modules, themes). It is aimed to improve the curricula and learning objects, and make the whole learning process more personalized. Moreover, it opens a possibility for the learner to browse from the complete range of pathways and choose own, the most suitable way.

Learners model includes following properties of the system users-students: personal profile data, number of questions, learning speed (Mb/s), click numbers, new learning content acquisition, learning ability without interaction, background knowledge level, ability to apply knowledge (indicated in levels), LO type preference (clicks/time spent), dropout forecasting (tracking location), IP address, self-confidence level (participation in discussions, levels), ability to deal with abstract knowledge (levels), preferred device for LO content, focus persistence, emotion through sensors, including real time color codes learning process assessment, feedback quality and frequency.

Teachers model is supposed to provide necessary study support and includes following properties: creating LO (time spent), editing LO (time spent), assessing students' submissions (time spent), interactions, e.g. forums, posts, etc. (time spent), texts (character counts), processed video materials (length), number of files, number of links, types of files, types of standardized blocks or xblocks used, ratios for different types of LO (i.e. text/video, text/audio, tests/…, etc.), response time, feedback time (how frequently, how long), LO content update frequency, course teacher evaluation, students drop-out rate in particular teacher led classes.

The learner performs learning through domain model which offers learning content and ensures instructional design. Necessary learning content might be retrieved from both internal and external educational resources through gateway model. Learning process is implemented within learning environment model. During whole learning process efficacious multi-screen/multi-platform learning support, including regular feedback notes, based on the user activity data (e.g. reminder, encouragement, statistical, etc. text messages from the internal message database), is provided. Multi-screen learning support technology, known as the eBig3 technology [25, 26], is already approbated in a large scale pilots in Baltics.

Domain model includes properties of LO and content as follows: type by activity, type by media, LO size (time, character numbers; size vs. course credits), usability (length of scrolling points; click numbers), terms/abbreviations explanation, pathway from simplicity to complexity (levels), complexity of LO (levels), complexity measurement (levels), interlinking (relationship) with other LO, responsiveness to the platform and other devices (and society), learning objectives included and reached (binary), methodology (binary), assessment (binary), feedback (binary), readability/ease of learning, language proofing (binary), special needs/accessibility, effectivity (study quality vs. time consumed), engagement/attractiveness of LO, LO usefulness, adaptation feature, adaptive learning style, variety of learning scenarios, type of LO (simulation, serious game, xAPI, etc.).

Learning environment model includes properties of learning management system and specific learning environments: user friendly (number of complaints, raised problems), responsive design, multi-screen support, multi-platform environment support, various types of LO supported (experience based learning, serious gaming, simulations, etc.), interoperability with other platforms, data exchange provision with other platforms, reminding instruments both for students and teachers, adaptive scenarios (based on feedback), enrolment/registration by sending SMS. It is considered to enrich the model with learner supporting technologies such as virtual personal assistants [27] and hint bars which would give synchronous assistance and feedback to the student in cases when the tutor support is not available.

Learner activity data are analyzed within learning analytics model. It is considered that a sequence of events over time ought to be assessed and analyzed to find out system user's learning style, learning preferences types of LO and behavior patterns. That could involve noted before real time color codes learning process assessment, the number or ratio of preferred LO and their types, the sequence of acquired LO and learning modules, gathered data

from the sensor model, and so on. Analytics platform IBM SPSS Modeler might be implemented in this framework to ensure a wide range of data analysis related to learner's activities, preferred types of LO and learning styles. It might be used also to model the most appropriate learning path, personalized to each learner.

Then learner's activity data are compared against both European and Latvian Qualification Framework requirements in adaptation model, supporting educational badges initiative, and allowing adjustments of appropriate set of LO and their types for the learner. Adaptation model includes both instructional and adaptation rules which respond to system user activities and behavior patterns. This allows to use the most suitable LO delivery channels for appropriate system user and ensure fitting of learning content in accordance with learner's needs.

The sensor model is optional but highly recommended component within this project framework. It might be added to the proposed IS mock-up to make adaptive learning decisions more sophisticated. It could be used to discern various possible differences in learners' activities and behavior patterns, including also changes in their bio signal data. The sensor model might include keypad and mouse click counting, user eye-tracking, voice tonality and facial recognition tools, electroencephalogram equipment, and other sensors.

4. Conclusion

At the moment proposed conceptual design represents our vision and steps towards development of the new generation adaptive learning management system. Separate tools and models which would be used in proposed system, such as the multi-screen learning support technology and real time color codes learning process assessment method, were already successfully validated and verified.

Proposed conceptual design of adaptive learning management system outlines directions which could offer appropriate personalized solutions depending on learners' prior knowledge level, activity and behavior patterns data during learning, and as a result, allow to meet specific needs of learners. Prospective information system is aimed to enhance system users' motivation and involvement in knowledge acquisition process by recommending them corresponding content and personalized learning pathway which could suit learners' needs the most.

Personalized feedback on students learning progress enhances their engagement into learning process. Students are able to review offered learning objects and types, as well suggested learning pathways based on their proficiency level.

System users' activity types and behavior patterns could be assessed by embedding learning analytics tools and applications which would measure students' involvement level into knowledge acquisition process, as well learning content understanding state at each stage of the course.

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