Towards an autonomous, intelligent and adaptive e-learning system

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Abstract. *Autonomous intelligent and adaptive e-learning systems (AIAES) are a new generation of learning environments that model and implement the individuality and personalization of the student in the learning process in order to support the learning-oriented approach in learning with technology. The main objective of the AIAES is to establish an intelligent e-learning environment providing advanced services for educational process, which is able to adapt based on student's learning experience, learning styles, cognitive level, and personal preferences. The aim of this article is to present the core modules of the N-tier architecture of the AIAES along with a more detailed analysis of the services that individual modules need to implement.*

1 Introduction

The explosion of personal computers with the potential for internet connection in the second half of the 20th century revolutionized the way we communicate and has therefore profoundly influenced learning and teaching. Learning with technology, whether with a computer, mobile app, video, wiki, or an interactive learning content, etc., refers to learning practices when technology is used with the purpose of encouraging learning. The term "learning with technology" refers "to situations in which someone uses technology with the goal of promoting learning" [1] and reflects "a common impulse to (try to) use available technology for educational purposes" [2] by enabling accessing information in novel ways.

2 Learning with technology

In the last decade, universities have gradually introduced and used e-learning systems and tools in higher education for online courses, lectures, course materials, evaluation, discussion boards, etc. [4], [5]. Current forms of learning with technology include technology-based learning environments such as [1]:

1. *Computer-based training* with lessons, tests and feedback presented on a computer screen.
2. *Multimedia instruction* that consists of pictures (e.g. illustrations, photos, animation, or video) and words (printed and verbal words).
3. *Interactive simulation* providing some control such as being able to slow down an animation or set input parameters and observe the result.
4. *Hypertext and hypermedia* instructional material consisting of clickable links.
5. *Intelligent tutoring systems* that track the learner and are able to adjust the learning content according to the knowledge of the learner.
6. *Animated pedagogical agents* - a simulated human-like interfaces between the learner and the environment.
7. *Virtual environments with agents* - a form of visually realistic environments that simulate interactions with real people, often using natural language.
8. *Serious games*, which are intended to serve as an instructional strategy.
9. *Computer-supported collaborative learning systems* that enable one or more groups of learners to work together on common tasks.

According to [3] approaches to learning with technology can be distinguished into (1) the traditional or **technology-oriented learning approach** to learning, where the technology itself is at the center of education, enabling access to the latest learning technology, and (2) **learning-oriented learning approach**, where the focus is on learners and the technology is perceived merely as an aid or a tool for learning.

The technology-oriented learning approach underwent numerous important cycles of inflated promises and introductions into schools, followed mostly with failures. The primary problem of the technology-oriented approach is that technology remains self-serving, mostly because it doesn't consider the teacher or the student and it is usually not concerned with its actual purpose or the goals of education. Furthermore, in most cases the technology-oriented approach demands that teachers and students adjust to technology instead of vice versa. In traditional methods of e-learning technology and methods (in the technology-oriented approach), the individuality of the student is omitted [6]. The majority of traditional e-learning materials does not consider different factors that influence the learning habits of an individual; because of this, students cannot influence the course of their own learning [7] as cited in [8].

Taking into account previous disappointments in technology-oriented approach in teaching with technology, we must strive for an approach, which aims towards the learner. Moreover, the learner and his experience need to be placed at the center of the educational process [3]. In the learning-oriented approach, the main focus is in understanding students'

needs, learning styles and how they learn. In case of the learning-oriented approach the technology is a tool, capable to adapt according to the students' and teachers' needs in order to provide suitable contents and methods supporting an innovative one to one pedagogical approach [9]. The learning environment recognizes the learners as its core participants, encourages their active engagement and develops in them an understanding of their own activity as learners [3].

Intelligent tutoring systems (ITS) represent one of the most recent advancement in the field of learning technology [10]. ITSs are powerful adaptive educational systems providing services and modules for personalized learning for students with different backgrounds, abilities, behaviors and knowledge. For successful implementation of personalized learning the ITS must fully understand differences in individual's learning style [11] and they usually use artificial intelligence technologies to provide individualized/personalized instructions to students based on their profile and learning styles [11]–[13]. The goal of any ITS system is to provide an immediate and efficient solution to student's learning problems and to help the student to achieve maximum learning gain. To achieve this, ITS builds a model of goals, preferences and knowledge of each student, and uses this model to adapt the teaching style and provide a degree of intelligent assistance [11]. Each individual learner is provided with learning content and instructional methodology that suits his personal need.

In existing literature, researchers mostly agree that new learning technologies have potential to transform education and training. However, only few of the many strong claims made for the transformative potential of new technologies have been convincingly tested against research evidence [14] and only a few studies exist that support these beliefs in case of ITS. As claimed by [14] one of the reasons can be found in the fact that too often a technology-oriented, as opposed to learning-oriented approach is followed. For example, [15] showed that modern autonomous intelligent and adaptive e-learning systems can perform better when compared to conventional classroom teaching. VanLehn [16] compared a human tutor, an ITS and conventional classroom teaching and demonstrated, that teaching using an ITS can be almost as effective as human teaching.

3 Design of an autonomous, intelligent and adaptive e-learning system

Autonomous intelligent and adaptive e-learning systems (AIAES) are a generation of learning systems that include the individuality and personalization of the student in the learning process, similar to what happens in a traditional individualized lesson with one teacher and one student. This traditional human tutoring process has proven successful and has represented the most efficient method of learning and teaching since the beginning of teaching.

Computer systems such as IAES need to provide the same instructional advantages as a human tutor (teacher), which certainly implies the interdisciplinary of various fields, such as cognitive science, artificial intelligence and functional literacy to fields connected to education. Within AIAES the content is in accordance with the cognitive learning approach and the system provides services for intelligent analysis (collection of various variables and metadata) which enables machine learning and ability to adapt to the learning course based on learner's individual characteristics and abilities in the learning process. A recently published meta-analysis of effectiveness of such intelligent learning systems supported the claim that AIAES can be an effective tool for learning in all levels of school [17]. The AIEAS architecture should be designed with the following principles [10]: (1) who to teach (*student module*), (2) how to teach (*pedagogical/instructor module*), (3) what to teach (*domain module*), and (4) the user-system interaction environment (*interface module*).

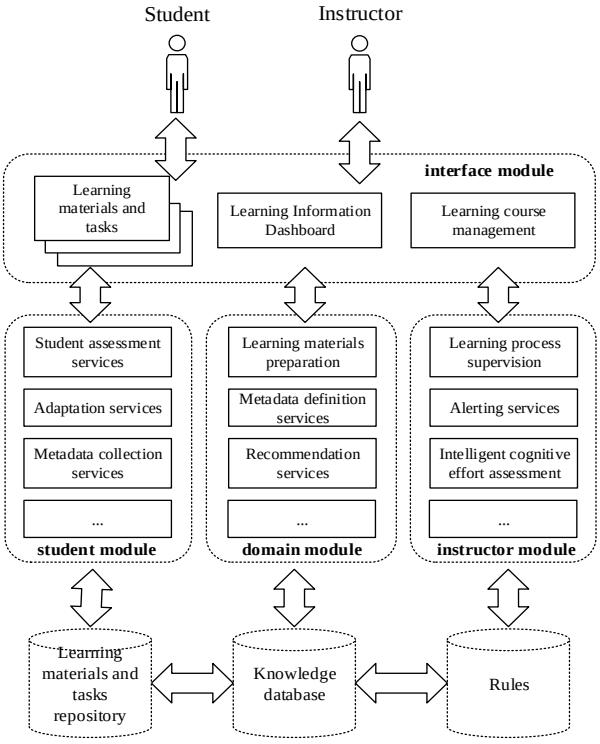

Figure 1. Design of an autonomous, intelligent and adaptive e-learning system

The AIAES system should provide e-learning services (see Figure 1) for both educators or instructors and students. Educators can use the system for creating and managing online courses, learning materials (contents and tasks), and metadata together with rules, needed for adjusting the difficulty of the learning content for students based on their achievements while performing learning tasks. The AIAES system should assist educators in planning and creating learning

materials, in providing information about reading strategies and functional literacy, and should serve as a validation service for checking e-materials created by educators. The validation services should evaluate attributes such as length of the text, organization and structure, etc. For the purpose of modeling student and instructor modules within an AIAES we can choose between different techniques and methods, such as ontology [18], [19], neural networks [20], data mining [21], [22], collaborative filtering [22], fuzzy logic [23], [24], intelligent agents [25], [26], Bayesian Network [18], [27]. However, the results of recent research favor Bayesian techniques and fuzzy logic in handling uncertainty issues in modeling students and instructors [10].

3.1 Student module

Student module is the basis for making the AIEAS adaptive and is responsible for managing the cognitive state through creating the student profile including information such as the student personal data, learning style, preference, current knowledge state, etc. The AIAES should provide advanced services, which will help the learner to consume learning materials and learn based on results of the intelligent assessment. The system should collect various metadata using qualitative and quantitative methods during different phases of the learning process and use advanced methods and techniques for intelligent metadata analysis of the data gathered during different learning phases. These services should provide assessment of learner's learning capacity, cognitive level, and current knowledge, which is the basis for implementing efficient adaptability services. The learning process should be fully adaptable in accordance to student's cognitive level, learning style and other factors. Additionally, the system should be able to assess the learner's emotional state based on keystroke dynamics and mouse movements [19] which can lead to further adaptation of the learning process, motivating a learner to stay focused on the content and similar.

3.2 Pedagogical/instructor module

The pedagogical/instructor module is responsible for decisions-making related to pedagogical aspects of learning such as (1) correct choice of the teaching methods and learning materials that suit best to individual student's profile, (2) deciding the right time to study the content, (3) assessing the cognitive state of individual student, (4) deciding whether the student is able to proceed to the next learning stage in learning, etc. The AIAES should implement an intelligent instructor providing services for monitoring and guiding the learner in the learning process. To achieve this, several services need to be implemented, such as services for:

- initial analysis and assessment of student's cognitive abilities and knowledge,
- supervision during student's studying process,
- collecting metadata during the supervision,
- alerting and advising the student,
- intelligent assessment of the student's cognitive effort during the learning process,
- assessment of student's learning style.

3.3 Domain module

Domain module is concerned with the knowledge of the particular domain to be taught. The AIAES system has to provide services for preparing the learning materials in appropriate structure, which can be used for aggregation and presentation to the learners in the learning process according to their respective level of learning capacity. Content, prepared by the educators, should guide the learner according to the current knowledge and learning capacity. The system should also implement recommendation services for providing learning content suitable to the learner's learning style.

3.4 Interface module

Interface module is responsible for providing environment for interaction between the system and the student. Based on the prepared learning content and collected metadata about the learners' status, an information dashboard should be designed to provide important data aggregations in a form of visual analytics [28]. The system has to provide fully adaptable user interface based on student's and instructor's preferences (e.g. device, which can be a desktop computer, laptop, tablet PC, smart phone, etc.).

4 Conclusions and future work

In this article modules and services of an autonomous intelligent and adaptive e-learning system (AIAES) were presented. Such e-learning systems provide environments that implement the learning-oriented approach in teaching and learning, where the learner and his experience are placed at the center of the educational process with main focus in understanding students' needs, cognitive level and how they learn. Such environments must provide various services that enable adapting content and methods to the students' and teachers' needs in order to support an innovative intelligent one to one pedagogical approach. Although previous research showed that Bayesian techniques and fuzzy logic can perform best in handling uncertainty issues in modeling students and instructors, we plan to conduct a systematical literature review and meta-analysis of efficiency of different methods and techniques in modeling student and teacher modules. In our future work, an AIAES will be implemented and tested during research activities under project "*Development, testing and validation of an autonomous intelligent and adaptive e-learning system for the improvement of information literacy of adolescents*".

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