Smart E-Learning School of the Future: Project Report

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***Abstract*—Web-based multimedia e-learning environments added new dimensions in designing course contents. However, even with these fascinating capabilities, a question still remains; how can learning systems properly utilize such capabilities for more effective learning outcomes? In other words, what are the best teaching methods to use for a specific student or group of students knowing that every one has his/her own learning objectives, motivations, knowledge, and skills?**

This article is a report on the current status of the six-year research project, Smart E-Learning Environments, which is working under the umbrella of the scientific chair of the Smart School of the Future in KAU. The main objective of this project is to employ AI techniques to advance e-learning forward towards the 5th generation e-learning as we envision it. The idea is to embed education methods and learning and cognitive theories into e-learning environments to provide a more intelligent and, hence, more adaptive and effective one-to-one e-learning environments.

***Index Terms*— adaptive e-Learning, Cognitive Models, Domain Ontology, Learning Objects, Learning Styles, Intelligent e-Learning environments, Student Models**

I. INTRODUCTION: OUR GLOBAL VISION OF E-LEARNING – A PARADIGM SHIFT IN EDUCATION

Distance Learning has gone through four generations over more than a century. Those four generations, though have elevated the level of interaction between the student and his distant instructor and classmates, are still lacking an essential component for effective teaching, namely customizing the delivery of a course in terms of the material and the style of teaching according to the student profile. In traditional classrooms, the human teacher utilizes his experience and intelligence to adapt the teaching method and style to meet the average student in the classroom.

The philosophy of our vision for e-learning is after empowering the student's learning ability as well as empowering the teacher for smarter course preparation and delivery. It introduces a new model for e-learning to achieve such objectives.

Our model for e-Learning, as shown in Fig. 1, focuses on the major triad of the learning process -- namely, the student, the teacher, and the material. This triad is a part of a learning community through which members should be properly coordinated for gaining maximum outcomes with minimum efforts through effective collaborative team working. This could be achieved through a collaborating e-learning environment [1] that is governed by the coordination protocols and rules of the educational organization in charge. Noteworthy, this learning organization works under three delimiters:

- The objectives and policies of the institutional educational setups at large,
- The currently available technology and its acceptance by the learning community, and.
- The current status of education, learning, and cognition theories and the pedagogical educational methods.

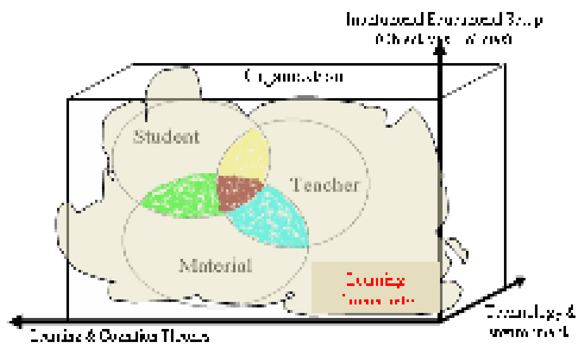

Figure 1: An e-Learning Model – Our Vision

The learning environment should provide necessary tools to coordinate the relationships between the different elements of the educational triad, namely, the student, the teacher, and the material, yet should still be governed by the umbrella of this whole infrastructure.

Fortunately, in the era of the Internet, open sources of information intensively exist; and hence, material and learning material became available and sharing and reusing them is gracefully allowed. Accordingly, instructors can use such learning material in preparing their courses. Sharing and reusing of teaching materials reduces the cost of designing new courses, saves the time of rewriting, and avoids duplicating efforts.

However, one of the most formidable tasks for educators is shaping their presentations of core knowledge to meet the individual needs of learners with varied and diverse cognitive and psychological traits [2]. In order to achieve such a goal, two issues must be considered. First, a detailed model of the individual student which is called student model (SM) must be maintained and, second, learning materials must be composed of small granular multimedia objects referred to as learning objects (LOs).

Student models should be used for tailoring the teaching strategy and dynamically adapting it according to the student's abilities and previous knowledge [3]. Student Models are often based on various different dimensions. The focus of our research group is on some of those dimensions, namely, the cognitive model: learning style, thinking style, etc. A learning style is defined, among many definitions, as "the unique collection of individual skills and preferences that affect how a student perceives, gathers, and process learning materials" [4]. In section 2, we give a more detailed description on learning style models and their impact on the effectiveness of the learning process.

Furthermore, each multimedia LO must be designed to suit a specific individual student according to his/her specified student model. However, those Learning objects may be drawn from repositories (LOR) that are specified using standard metadata formats, such as SCORM [5] and IEEE LOM [6]. Learning objects selection is based on proper identification of the appropriate values of metadata attributes specifying the required material. Our research suggests adapting the LO metadata standards by adding extra attributes necessary for supporting the concepts of student model, especially the dimension of the learning styles.

Our research envisions adapted LOs that accommodate the concept of learning styles as a central component to all processes throughout the lifecycle of e-learning, as depicted by Fig. 2. Course authors should design their courses with their students' styles in mind, course delivery should match the student style, and student assessment should also be adapted to match each specific student's learning style, while student portfolio helps identifying the student model. In addition, many education support tools could also be designed around the concepts of learning styles to reveal better results [7]. Examples of such tools that our research project is researching are Smart eNoteBook [8] and Smart OfficeHours Assistant [unpublished technical report].

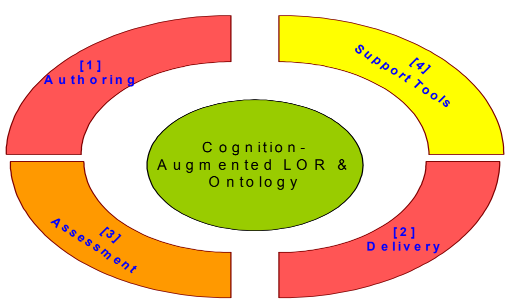

Figure 2: Adapted LOR is Central to the whole e-Learning Lifecycle

To match the theme of this conference, this article will only give a high level overview; however, the more interested reader will be referred to other publications giving more technical description.

II. SMART E-LEARNING ENVIRONMENT—THE RESEARCH PROJECT

Fig. 3 depicts the main stream of the Smart e-Learning environment (SELE), namely, course authoring and adaptive delivery. This main stream is composed of two main processes; one for authoring assistance — the Teacher Apprentice for Authoring (TAA) — and one for delivery assistance — Tutor Apprentice for Delivery (TAD). Two theories are utilized: first, the revised Bloom's instructional design theory [9] to adjust course objectives and accordingly organize course materials, and second, the Felder and Silverman learning style theory [10] for adapting course delivery according to each individual student model.

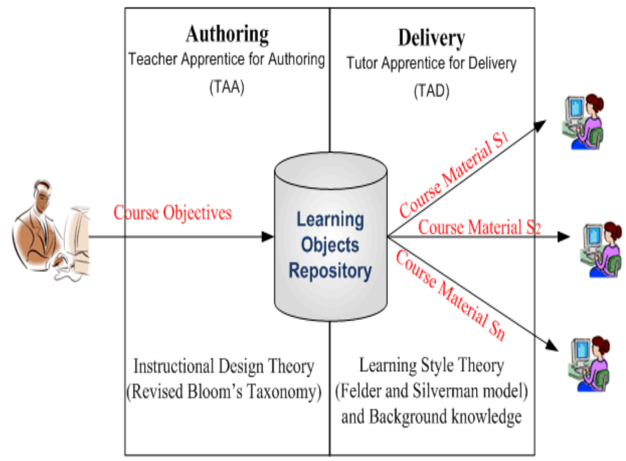

Figure 3: The General Model of the Main Stream of SELE

On one hand, during course preparation, the LOs selection process goes through a series of objectives rewriting steps each of which handles the specified objectives from a different angle. On the other hand, the LO delivery process goes through two main steps – namely, selection and sequencing strategy – according to each individual student's model. Fig. 4 depicts a bit detailed system architecture and provides a view of the interaction among the teacher's model including his/her learning objectives and teaching strategy, the student's model including student's learning style and background knowledge, and the domain ontology.

Central Knowledge-base Generation

Fig. 5 presents the two main processes of: (1) generating the SELE's knowledgebase—namely, the domain ontology and the LO Repository—out of the instructor submitted hypermedia learning material; (2) Identifying the main elements of the student model—the learning style and the background knowledge—for each individual student.

Accommodating Revised Bloom's Taxonomy and Felder-Silverman Learning Styles Model (FSLSM)

The Authoring Engine of SELE, which is activated during course preparation by the authors, receives a high level teacher's objective and then applies the revised Bloom's taxonomy (RBT) employing the specially designed ontology that specifies the pre-requisite relationships among the concepts in terms of Bloom's taxonomy levels. Several categories of rewriting rules are applied in sequence. Accordingly, we suggested adding some extra attributes to the LO's specification standard: classifying attribute, RBT level, teaching strategy, and the instructional role. The selection process depends mainly on the values of those specific attributes satisfying the rewritten objectives.

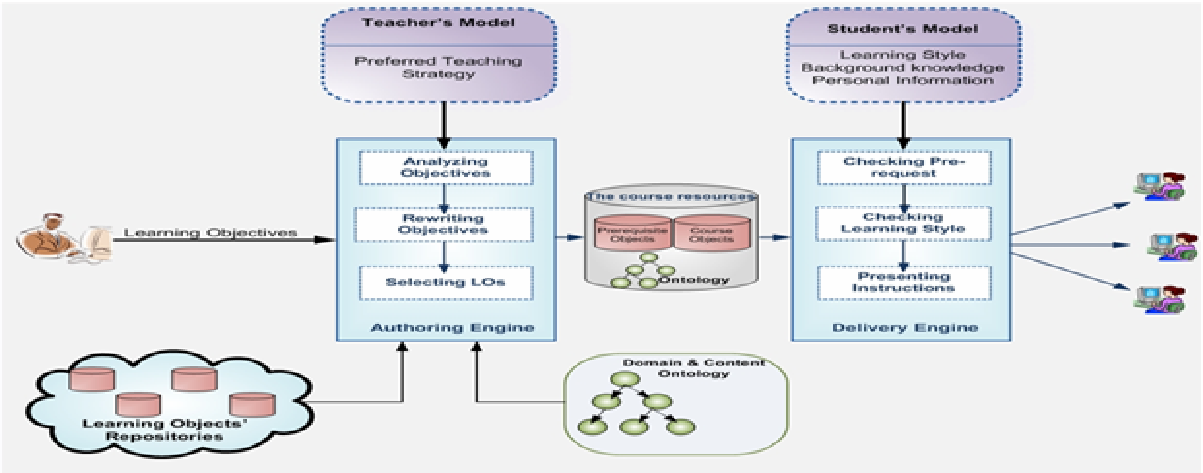

Figure 4: A High Level Architecture of the Main Stream of SELE

On the other hand, to support the teaching techniques as suggested by Felder-Silverman Learning Style Model (FSLSM) few extra attributes (instructional role, format, content type, depth, and supported concept) are added to the LO metadata. In this research, we focused only on three of the FSLSM's dimensions, namely, Global/Sequential, Sensing/Intuitive and Visual/Verbal. Those recommended attributes are used to guide LO's selection and presentation sequencing.

III. SMART E-LEARNING ENVIRONMENT AND PRODUCTS—CURRENT RESEARCH STATUS

For more than eight years, I led several research projects focusing on designing e-learning tools and environments that embed educational and learning theories and concepts. To establish higher shareability of learning materials among course authors, LO is another critical and central target of our research. Fig. 6 depicts the research efforts and demonstrates how those projects are centered around two important knowledge based components, namely LOR (or actually the LO metadata) and domain ontology, which are both adapted to embed the new models of the student model and the learning theories, especially learning styles a background knowledge. Of course such knowledge bases are not simple databases; they rather have intra-relationships that complicate the model.

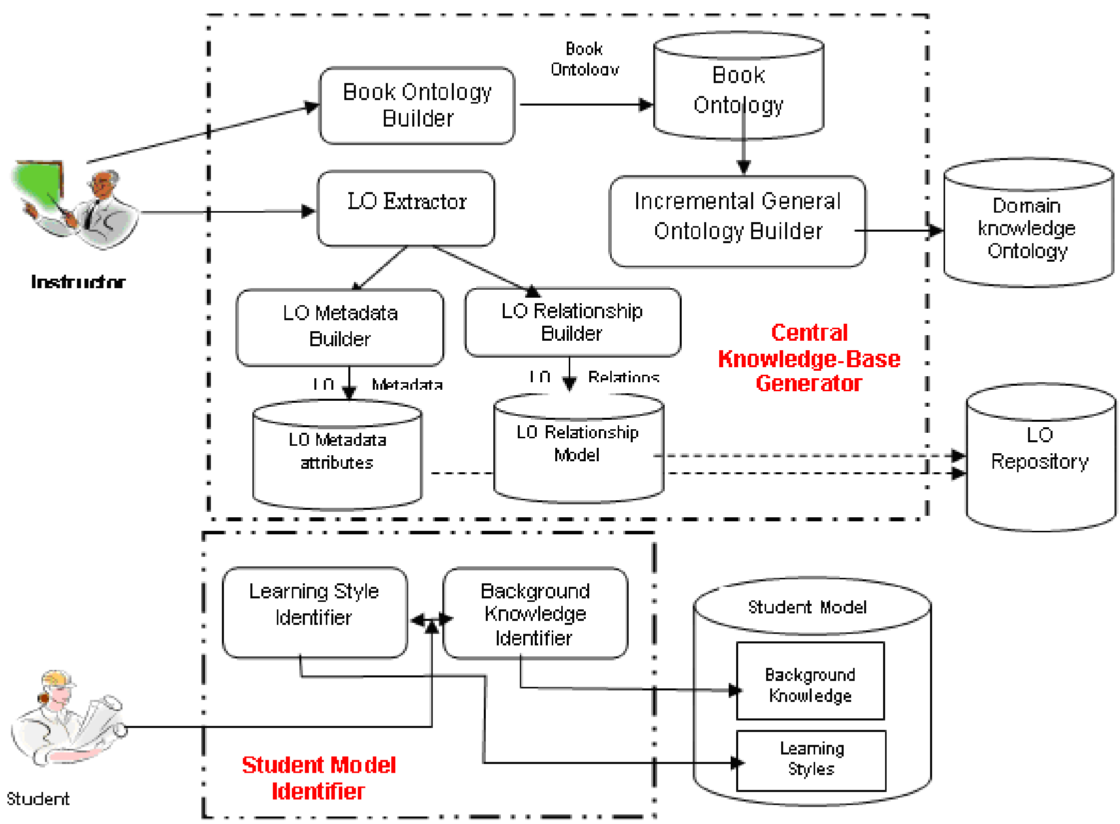

Figure 5: The Knowledge Base Building Processes

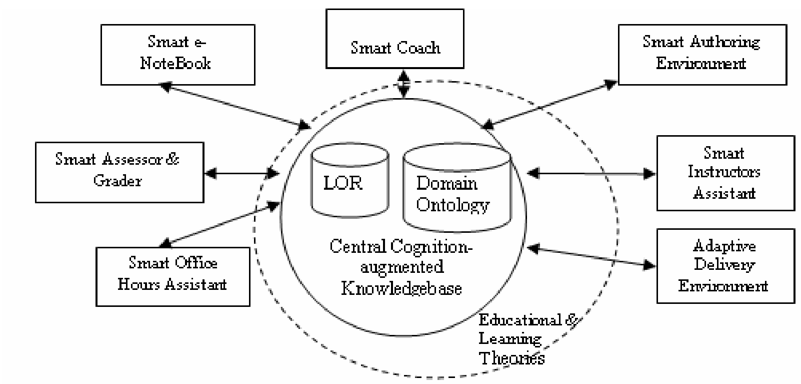

Figure 6: The Knowledge Base is Central to the Smart e-Learning Tools and Environments

During that period, we have worked out several components under different research projects to support our global vision of the new e-Learning paradigm. Components are viewed as supportive to the relationships among the different elements of the educational triad. A briefing on those components follows:

A. Learning Environment Architectures:

1. Smart Authoring Environment [11]: Supports teachers in properly authoring their courses and in selecting the appropriate course material and presentation techniques required to meet specific course objectives for a specific student or group of students knowing the exact student model of knowledge and skill set.

2. The Teamwork Coordinator (LetUs Assist) [1]: introduced an architecture, LetUs Assist, to aid the members of a learning community and a study group in maintaining a consistent common cooperation protocol.

3. Smart Instructor Apprentice [12]: provides instructors (authors and tutors) with intelligent Assistance in both Course Preparation and Delivery. SIA intelligently rewrites the course objectives according to educational theories (Bloom's taxonomy) and then adaptively selects the most appropriate Learning Objects (LO) from learning objects repositories (LORs) to align course objectives with students' models (Learning Styles).

4. Interactive Virtual Classroom (IVCR) [13]: Several implementations for synchronous e-learning environments are done under student projects. In these projects, virtual classrooms, net conferencing, and virtual meeting rooms are implemented.

B. Relationship Among Student, Teacher, and Material:

5. Smart e-NoteBook [8]: is an adaptive multimedia hyperlinked learning material management environment that supports students (or any users, such as researchers, teachers, writers, etc) during their different modes of use (study, review, or research). Smart e-Notebook takes the instructor-provided multimedia material that is not necessarily prepared for a specific person (let us call it e-Notebook), and generates many personalized editions of MySmart e-NoteBooks one for each individual student that better suits his personal student model.

6. The Smart Tutor (ST) [2]: is a web-based intelligent tutoring system. It is a prototype design for experimenting with the hypothesis that there are some important characteristics that are essential in designing an effective ITS, such as: adaptive teaching strategies, student models that are based on background knowledge and skills, and teaching approaches suiting specific skill sets.

C. The Relationship Between the Student and Teacher:

7. The Smart Coach (SC) [14]: is an intelligent computerized coaching system that monitors students' actions during problem solving sessions and advises them when needed. In this research, we introduced the concept of Intelligent Coaching Systems (ICS) that are supposed to integrate to the Smart Tutor (ST) for more empowerment.

8. The Smart Grader (SG) [15] is a computerized empowered intelligent grader that provides students with comprehensive explanations on their mistakes and what would a correct answer be. Intelligent computerized Graders would analyze students' steps in problem solving sessions, such as programming, and advise them when needed. In this research, we introduced the new concept of Intelligent Grading Systems (IGS).

D. The Relationship Between the Student/Teacher and Material:

9. Smart Office-hours Assistant [16]: is an Intelligent Question Answering System (IQA) tool which simulates the same role of the instructor in answering as much questions as possible. Answers are adapted to suit each individual student according to his/her specific student model: learning style, background domain knowledge, IQ, thinking style, and motivation.

E. The Student Model:

10. The Three Dimensional Student Model (3DSM) [3]: introduced the concept and architecture of a proactive student modeling system (3DSM). Being proactive means that the system should understand and predict the user interests and abilities and, hence, suggest a suitable roadmap for his career improvement and recommend courses to take at specific sequence.

IV. VERIFICATION AND ASSESSMENT

The evaluation of the concepts supported by this research and how they relate to suggested hypotheses has taken a considerable attention during this period of the project. The following is what has been accomplished.

Felder-Silverman learning style measuring tool (questionnaire) has been adopted and localized: Arabized and adapted to suite the Arabic culture. The tool is then verified for its validity for the Saudi society:

An experiment was then designed to evaluate the effect of applying the learning style of each student on the way a course is to be delivered to him:

- Subject groups were designed:
- Twelve groups of students with combinations of three learning style dimensions (visual/verbal, global/sequential, and intuitive/sensing)
- A control group (general)

A lecture subject is selected (a lecture on Binary Numbers in an introductory course to computer science students). The following was done:

The lecture material was prepared taking into consideration the needs of the different styles. The lecture was then converted into learning objects. The learning objects are rearranged to suite the different subject groups leading to the preparation of thirteen versions.

V. CONCLUSION AND FUTURE WORK

In this article we reviewed the current status of the research project that was initiated six years ago by the author as an individual effort with support of students and which was later supported by the e-learning chair of the Smart School of the Future at KAU for the last three years. The main theme of this research is focusing on employing AI techniques to promote e-learning from 4th to 5th generation. The research developed many Smart tools and environments centered on the student model and supporting one-to-one adaptive e-learning. It employed theories from cognition, education, and learning. Proactive student model is also developed to model student's traits, emotions, cognition, and background knowledge. A byproduct of the developed work is a methodology of incremental building of domain ontology and LORs out of instructor's submitted learning material. Another contribution is the enrichment of both the LO metadata structure and the ontology relationships to accommodate learning style theories and the revised Bloom's taxonomy.

It is worth noting that we are only employing educational methods and cognitive and psychological theories that belong to specialized scientists. Our work does not involve, by any means, in proving or verifying any of those theories and methods, but rather only utilizing them. If any of them showed to be incorrect or inaccurate, then it is the sole responsibility of its owner. However, the evaluation of the concepts supported by this research and how they relate to suggested hypotheses has taken a considerable attention during this period of the project and experiments were designed and being undergoing.

There are still many research directions to investigate under the same lines presented in this article. Integrating all tools developed so far is one major concern as adaptation to accommodate the central knowledgebase is required for those tools to integrate, which in turn will expectedly lead to updates in the knowledgebase model itself. Another concern would investigate methods for supporting students with special needs: super intelligent, retarded,…etc. A third direction is investigating how to develop those knowledge-bases (ontologies and LORs) automatically from instructor's submitted multimedia learning material.

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