

# Recommendations for Building Adaptive Cognition-based E-Learning

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**Abstract**—Adapted e-Learning systems try to adapt the learning material based on the student’s preferences. Course authors design their courses with their students’ styles and 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. To the best of our knowledge, no clear recommendation for building community wide adapted and personalized e-learning systems. This paper presents recommendations to add adaptation and personalization to one of the most common open source Learning Management System (LMS), Moodle. The adaptation features are based on using learning styles, ontology, and cognitive Bloom Taxonomy in building and presentation of the e-learning material (Learning Objects). This is helpful to establish adaptable and cognition-based Learning Object repository and course development centers.

**Keywords**—Adaptive e-learning; learning objects, learning styles; student models; open source LMS; Moodle; personalized teaching model

## I. INTRODUCTION

E-Learning is taking a great attention worldwide. It is supposed to contribute to enhance the traditional education if properly implemented. It can be beneficial to most forms of e-Learning, e.g., training, girls’ education, continuing education, open education. It can even be used as a supporter and enhancer for traditional in-class education.

As each learner has different learner’s characteristics; so, utilizing diverse educational settings may be more appropriate for one group of learner than for another. So, adaptive e-learning is an e-learning system that is more effective by adapting or personalizing the presentation of information to individual learners based on their preferences, knowledge and needs. This sort of e-Learning systems tries to acquire knowledge about a particular learner and offer personalized services and enable one-to-one delivery [1], [2].

Learners are the main actor in the e-Learning environment and they are usually having varied and diverse cognitive and psychological traits. One of the important facets of the adaptive model of e-Learning is to adapt the presentations of the learning material to meet the needs of each individual learner during the course delivery process. To achieve such goal, we need to detect the learner profile to adapt the content and presentation of the learning material. This profile is called

Student Model (SM). Also, the learning materials are composed of small granular multimedia objects referred to as Learning Objects (LOs), to achieve a high level of adaptation.

Student model should be used for tailoring the teaching strategy and learning material for dynamically adapting it according to the student’s abilities and his/her previous knowledge. Student model is often based on various different dimensions. In this project, we focus on the student model in one dimension, namely, the cognitive model, especially the learning style. 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 processes learning materials” [3]. Therefore, the concept of student model, especially learning styles, is considered as a central component in this research’s implementation. 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.

Learning Objects are stored in what is called Learning Objects Repositories (LOR). Learning objects are drawn from an LOR based on a certain criterion, which is described in terms of metadata attributes that are used to specify the selection criteria of the appropriate required material. In this research we suggested adapting the LO metadata of a standard LO model such as SCORM by adding extra attributes necessary for supporting the concepts of the student model, especially the dimension of the learning styles.

Learning styles mean that individuals differ in regard to what mode of instruction or study is the most effective for them [4]. So, they are distinct individual patterns of learning that vary from person to person. It is necessary to determine what is most likely to trigger each learner’s concentration, how to maintain it, and how to respond to his or her natural processing style to produce long term memory and retention [5].

There are many learning style models exist in literature, e.g. the learning style model by Felder and Silverman [6], Kolb [7], Mumford and Honey [8]. They agree that learners have different ways in which they prefer to learn. After a comprehensive study of the e-learning environment, we selected Felder and Soloman’s Index of Learning Styles (ILS) [9].

Bloom's Taxonomy of the Cognitive Domain Bloom's taxonomy is possibly one of the best known and most widely used models of human cognitive processes [10]. It includes Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation levels. A revised version of the taxonomy was published in 2001 [11].

The adaptive and artificial intelligent tutoring systems (ITS) are developed using Web 2 [12]. The systems are developed to adjust the contents as per the effective learning styles that are identified using self-organizing maps (SOMs). Artificial intelligent systems behave like human beings. Supervised, unsupervised and reinforced are three types of artificial intelligent systems. Supervised system needs examples and a teacher to train. Unsupervised system is trained without a teacher and it rectifies itself after a mistake is reported. Reinforced system needs a mentor to guide the system that the answers are true or not. Unsupervised learning is selected to train the tutoring systems because it does not require a teacher and Felder-Silverman Learning Style Model (FSLSM) are used. The intelligent and adaptive tutoring systems are equally portable to run on web and mobile platforms.

Intelligent educational system (INES) is one of the components of an electronic learning platform [13]. Semantic management of users and contents, BDI-based (believes, desires, intentions) agent, an inference engine, ontologies and learning contents are the main components of INES. INES is used to identify the credentials of each student and check the status of his/her learning progress. The core objective of this exercise is to recommend a student whose progress of learning is not satisfactory.

An intelligent information access system (IIAS) is engineered to introduce new learning theories for the undergraduate students [14]. Concept, case and internet based learning theories are taken into account while developing the proposed system. IIAS identifies and marks important notes about an experimental medical case and it also assists in conducting objective assessments. The complexity of test assessment can be tailored according to the semester number of a student.

A similar study is conducted while developing an educational system [15]. The proposed system depends on abilities of students and degree of interaction between students and instructor [15]. The proposed educational system uses multi agent domain ontology to measure the progress of learning and judge the abilities of a student. A student interacts with the system to describe his/her opinion about a topic and it is matched with the data of text book. The system displays the mistakes of a student and it also suggests improvement in the course material.

Escudero and Fuentes [16] propose a general purpose tool that can be used to design courses for an intelligent tutoring system regardless of the platform. The platform independent courses are interoperable to easily call and use. The idea of such courses will help the practitioners to deal with a single course as an independent software component and it will incorporate known advantages of component based

development into ITS such as reusability, time saving and economical.

A study is conducted to propose a new idea to deal with the (ITS) [17]. Escudero and Fuentes [17] propose a general purpose tool that can be used to design courses for an intelligent tutoring system regardless of the platform. The platform independent courses are interoperable to easily call and use. The idea of such courses will help the practitioners to deal with a single course as an independent software component and it will incorporate known advantages of component based development into ITS such as reusability, time saving and economical. The general purpose tool is tested using two ITSs to conclude the results.

El-Bishouty et al. [18] recommend developing an e-learning system that is intelligent, adaptive, and customizable. The proposed e-learning system should have the features to generate courses and recommend improvements according to the level of interacting student. The proposed system will use behavior, learning style and cognitive skills (BLC) of a student to train. El-Bishouty et al. [18] recommend that it is vital to consider BLC as a basic building block to develop an effective and efficient e-learning system to achieve the desired results.

A research is conducted to model and adapt the user in a virtual environment [19]. CUMULATE is a general purpose student modeling server that is developed by Brusilovsky et al. [19] to describe the e-learning architecture and knowledgetree in a distributed environment. Knowledgetree is software that is used to provide online services. Subject based search is used to infer using CUMULATE and QuizGuide during the self-evaluating quizzes.

By investigating these systems, we can conclude that: None of the above literature addressed the following subjects which shape the objectives of our research:

- 1) Automatic generation of a course syllabus, Table of Contents (TOC), and course material.
- 2) Automatic adaptation of the course syllabus: generation of adapted course syllabus, adapted TOC, and adapted course material according to the student background knowledge.
- 3) Adapted course delivery according to the student model.
- 4) Adapted student assessment: placement of quizzes during the course, assessment of prerequisite knowledge, post course assessment according to the student model, especially the student learning style.
- 5) Integrating the concept of Bloom's taxonomy to enhance the comprehensiveness of the domain ontology. This adoption and enhancement to domain Ontology affects all the learning components of authoring, delivery and assessment.
- 6) Utilizing m-Learning to the system.
- 7) Support tools for building LORs and creating LOs from existing learning material.
- 8) Adaptive open source LMS.

In this paper, we present recommendations to add adaptation and personalization to one of the most common

open source Learning Management System (LMS), Moodle. The adaptation features are based on using learning styles, ontology, and cognitive Bloom Taxonomy in building and presentation of the e-learning material (Learning Objects). This is helpful to establish a nation-wide adaptable and cognition-based Learning Object repository and course development centers. The rest of the paper is organized as follows: Section 2 presents the adaptive e-Learning System (KAU-AES) developed at King Abdulaziz University. Section 3 is directed to the knowledge base building recommendations and Section 4 presents the recommendations of the authoring system. Section 5 discusses the adaptive course delivery system recommendation. Section 6 gives the recommendations for assessment system, and finally Section 7 presents the discussion and conclusion.

## II. ADAPTIVE E-LEARNING SYSTEM: KAU-AES

The major objective of this paper is to give recommendations based on theoretical and practical experience to build adaptive e-Learning environment community. Instead of building an environment from scratch to support all the educational services required by the educational institutions, we used Moodle because of its popularity as it is used in several universities. Moodle also is known as simple and easy to adapt and customize to the needs of the educational system. Therefore, Moodle is integrated to many of the components that were developed to compose the Adaptive e-Learning Environment, as shown in Fig. 1.

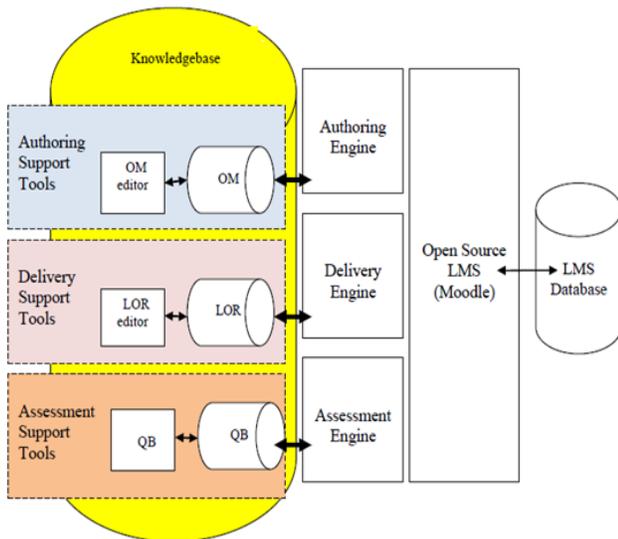


Fig. 1. High Level Architecture of the Adaptive e-Learning Environment

Three main subsystems in the proposed adaptive e-Learning system are integrated to the open source Moodle, namely, Authoring, Delivery, and Assessment engines. Each of those main engines works smartly with the aid of the Knowledge base. This knowledge base, in turn, is composed of three main knowledge bases, namely, the Ontology Model (OM), the Learning Object Repository (LOR), and the Question Bank (QB), each of which is maintained with the aid of a specially designed editor. Finally, the normal database of Moodle is updated to accommodate more data as required by the adaptive environment, such as:

The student information is updated to accommodate the Student Model (SM) by adding both his/her background knowledge, learning style model, and some other data, such as, preferred language, etc. The course information is also updated to include the Course Learning Outcomes (CLO). In addition, the Moodle itself is adapted to accommodate and seamlessly integrate to the different components of the adaptive e-Learning Model. For instance, the following was implemented to augment Moodle with adaptation:

The student page is updated to allow for editing and updating the student model.

The Teacher page is adapted to allow him to edit the course LOs, CLOs, and Generate the Course Syllabus.

When the student registers in a course, the course CLOs are automatically adapted to suit this specific student according to his/her student model. His/her course syllabus and course table of contents are adapted accordingly. Therefore, the Moodle page for the student is adapted to display the student adapted CLO, the adapted Course Syllabus, and the detailed adapted Course TOC.

The following steps are recommended to build the adaptive e-Learning Environment: Design and build the core Knowledge base.

Design and build the knowledge base and tools:

- The LO specification and meta-data structure.
- The Domain Ontology network structure so as to augment Bloom's Taxonomy.
- The Student model components and dimensions.
- Design and build the authoring support tools.
- Design and build the adaptive delivery engine.
- Design and build the assessment engine.

## III. KNOWLWDGE BASE BUILDING RECOMMENDATION

All components of the adaptive e-Learning Environment are centered on the knowledge base. As shown in Fig. 2, the Knowledge base is composed mainly of three major components: the system knowledge base; student database; and course database. The Knowledge base is composed of the Learning Object Repository (LOR) and the Ontology Model (OM). While, database is composed of the Student Model (SM) and the Course Model (CM), which themselves are further decomposed. The SM is composed of two components: the student's Learning Style Model (LSM) that is defined in terms of the four dimensions of FSLSM [6] and the SBDK representing the knowledge that the student captures with an acceptable cognitive depth for the domain of study. In addition, the CM is composed of three components: the CLO, the Course Syllabus, and the TOC.

Two database components that are essential to the adaptive processes, namely, the Student Model and the Course Model, which maintains data along those two models for each student and each course, respectively. The student model has two major components in addition to few other attributes. The

course model has three components; each is having two levels, generic and adapted to suit each student.

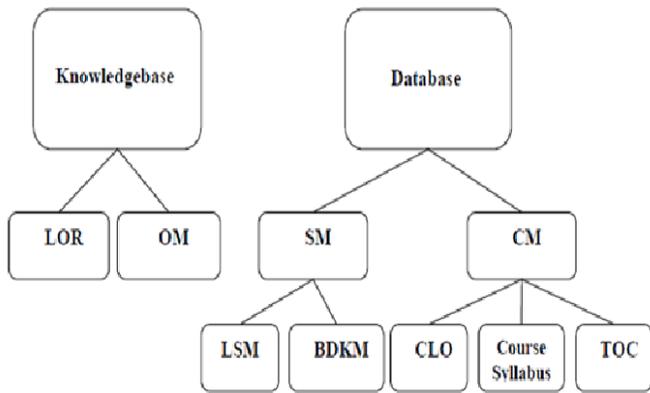


Fig. 2. The Knowledge base

The Student’s Learning Style Model (LSM): Each student has his/her own learning style model which is defined in terms of the FLSM’s four dimensions (Visual/Verbal, Global/Sequential, Active/Reflective, Sensing/Intuitive). The LSM is identified for each student once, at the time he/she joined the e-Learning system. The LMS is identified through the index of FLSM questionnaire (<http://www.engr.ncsu.edu/learningstyles/ilsweb.html>) which is considered an easy way to identify the learner’s learning style in more details. This questionnaire contains 44 questions and describes the learning style dimensions by using scales from -11 to +11; while zero indicates the origin of the axis, each direction on the axis refers to one of the two properties of the dimension.

Instead of asking the student to fill the questionnaire in sequence (the 44 questions), we grouped the questions related to each two dimensions in a single group of questions as shown in Table I. From the practical experience with students while they are filling the questionnaire, this enables them to choose the most related to their preferred learning style as they sometimes find some confusion in understanding each question separately.

The Course Model is composed of three components, two of which, namely, the course syllabus and the TOC are generated automatically by manipulating the Course Learning Outcomes that are defined by the course designer. Moreover, the Course Model has two levels of data: the highest level is more generic and concerns the course from a generic perspective, i.e., one course fits all, while the other is the adapted course for each individual student according to his/her Student Model.

This generic course model is simply a course syllabus that is automatically generated from the course’s CLOs with the aid of the Domain Knowledge Ontology Model. It is generated for all students with no guarantee it matches the student model of any of the students. In addition, the course’s generic TOC is automatically generated to match the teacher’s teaching style. On the other hand, the lower level of data of the Course Model are the adapted Student’s CLO, the adapted Student Course Syllabus, and the adapted Course TOC, which are

adapted for each individual student according to his/her student model.

TABLE I. GROUP SELECTION FOR FELDER LEARNING STYLE DIMENSIONS (ACTIVE/ REFLECTIVE/NEUTRAL)

A	B	C
Active	Reflective	Neutral
I understand something better after I try it out. When I am learning something new, it helps me to talk about it. In a study group working on difficult material, I am more likely to jump in and contribute ideas. In classes I have taken I have usually gotten to know many of the students. When I start a homework problem, I am more likely to start working on the solution immediately. I prefer to study in a study group. I would rather first try things out. I more easily remember something I have done.  When I have to work on a group project, I first want to have "group brainstorming" where everyone contributes ideas. I am more likely to be considered outgoing. The idea of doing homework in groups, with one grade for the entire group, appeals to me.	I understand something better after I think it through. When I am learning something new, it helps me to think about it. In a study group working on difficult material, I am more likely to sit back and listen. In classes I have taken I have rarely gotten to know many of the students. When I start a homework problem, I am more likely to try to fully understand the problem first. I prefer to study alone. I would rather first think about how I'm going to do it. I more easily remember something I have thought a lot about. When I have to work on a group project, I first want to brainstorm individually and then come together as a group to compare I am more likely to be considered reserved The idea of doing homework in groups, with one grade for the entire group, does not appeal to me.	

The student’s BDKM is used to adapt the student’s CLO and Course Syllabus, while his/her LSM is used for adapting the Course TOC. The Course CLO represents the goal outcomes of this course as specified by the course designer. It takes the form of a list of items, each of which is described as follows:

“By the end of this course the student will be able to: <Revised Bloom Taxonomy cognitive level> the <Concept name/id> at a complexity level of <depth level>”.

For example,

“By the end of this course the student should be able to Apply the concept of Stack at a complexity level of 2”.

With the aid of the OM, the generic course syllabus is generated. The syllabus is composed of numbered sections which in turn are composed of subsections, while the TOC adds sub-subsections which go into pedagogical details. For instance, a section on Stack may contain a subsection that explains the concept of “LIFO”, while the TOC may further break down the “LIFO” subsection into many sub-subsections, like an definition, an application of LIFO from real life, etc.

Using the Background Domain Knowledge Model (BDKM) of the Student Model of a certain student, the CLO will be adapted to match this specific student (hence is named Student Learning Outcomes (SLO)) by adding unknown prerequisite concepts, and removing well known concepts. Again, the Authoring System will use the adapted SLO, with the aid of the OM, to automatically generate the adapted course syllabus, which will then be the input for generating the adapted student's course TOC.

The Cognition-Augmented Knowledge base has two main components, namely, the LOR and the Ontology Model (OM). Those two components are main drivers of the adaptation. OM derives the Authoring Process, while LOR derives the Delivery Process. Both components play an important role during the pre and post assessment processes.

A subject matter expert course author, who is very much familiar and knowledgeable about the subject domain knowledge, knows much invaluable information about those concepts and the best ways of teaching them to a certain group of students with a specific average profile. For instance, the expert author should know what the best break down is for a certain specific topic; what the best sequence for certain topics would be; what topics would achieve the goals of a certain course; what the best depth is for each topic/subtopic; when to introduce exercises, quizzes, and tests, etc. to stimulate students' enthusiasm and learning effectiveness. One goal of this research is to support course authors in doing the authoring job professionally, even if they lack the sufficient expertise.

In the e-Learning Model, that in-depth knowledge regarding a specific knowledge domain is accumulated in the OM, which is assumed to be incrementally and/or cooperatively designed by the domain experts. In fact, OM is a Key Player in the e-Learning Model. It is a comprehensive model of interrelationships among concepts/topics. This comprehension gives more flexibility to the authoring process in composing a course. Moreover, it gives an automation power to the authoring process.

So, it is recommended to design OM with the objective of supporting not only course authoring but also course delivery and assessment as well. To achieve this goal, the traditional Ontology net scheme is extended to accommodate two extra updates to the classical scheme:

- Adding a measure of depth/complexity to each concept node in OM [20].
- Embedding the concepts of the instructional design theories and the Revised Bloom's Taxonomy [21, 22].

**Complexity Level Extension:** In OM, the concept's node is a complex structure. Each node is given a complexity value (F=Fundamental | M=Medium | D=Advanced) that is intended to guide the design of a course according to the course's complexity. To explain, a 200-level course wouldn't have the same topics/concepts as those higher-level courses; as the course level increases as the complexity of the concepts increases.

However, usually a higher-level course would also introduce those concepts of a lower complexity. Therefore, for the navigation through the OM net during the course design processes, it is recommended to use the following simple rule.

In a course of a complexity level "c", all concepts of a complexity higher than "c" wouldn't be included in this course. For instance, if the course is a medium-level course, all advanced concepts (Marked with D) would be ignored; only F & M concepts are included.

**Embedding RBT in OM:** The second improvement in OM is the accommodation of the RBT [22]. Each concept node is made of six levels corresponding to Bloom's levels. This will make OM as a multilayered diagram; one layer for each of the Bloom's levels. This extension is intended to guide the course design phase in which the course objectives specify the target Bloom's level for each concept covered in the course. Accordingly, this concept's OM's layer is employed and the relationship links are followed. Most importantly of those links is the prerequisite link which might reference a specific layer of another concept, as shown in Fig. 3, where the "Depth-Limiting Search strategy", for instance, is having complexity level "M" and whose RBT's level of "Understanding" requires, as a prerequisite, "Depth-First Search" at RBT's Level of "Applying".

Noteworthy, not only the course authoring is intelligently impacted by the extended OM but also many other components in the Knowledge base. For instance, the student's BDKM is updated to accommodate the six levels of RBT. Accordingly, OM plays an important role in the adaptation of the course delivery in two ways:

- A more accurate evaluation of the student knowledge as compared to the prerequisite requirements, and
- Compensation of missing prerequisite knowledge.

This feature is implemented with only the first tree levels in the RBT and the compensation of the missing prerequisite knowledge is done through "recall" branch as in Fig. 3.

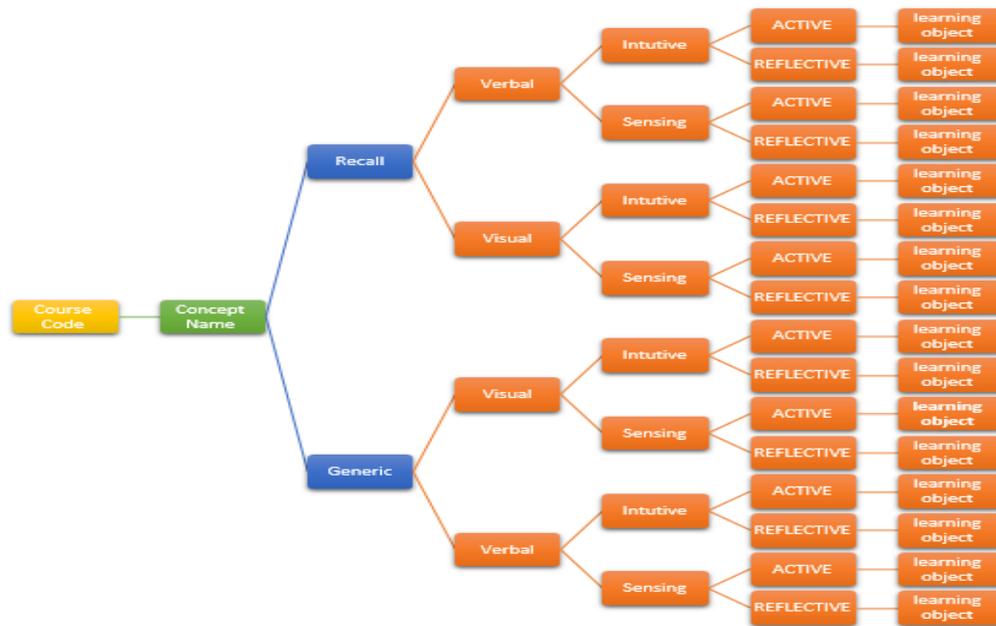


Fig. 3. Learning Object Folder Structure

Each Learning Object is described, and hence selected, using a set of metadata attributes. The LO Metadata Model extends the standard metadata model of SCORM by adding few extra attributes to accommodate the adaptation theme of the e-Learning Model. In other words, the LO Model has extended the standard metadata model of SCORM by:

1) Adding extra attributes necessary for supporting the theories it implements, such as Learning Style Model, Revised Bloom's Taxonomy, etc. Of course, these attributes are not contradicting with any LO standard, but rather they are complementing them,

2) Employing some of the SCORM's attributes after stretching their space of acceptable values.

In general, these Metadata Attributes are used for two main purposes:

3) Searching and retrieving the LOs easily and precisely either manually or automatically.

4) Aiding in the process of adaptation and personalization through choosing the proper LOs meeting specific criteria.

The Metadata Model: The adaptation process applies different theories such as Learning Style, instructional design, and cognition theories, a knowledge that are usually applied by an expert instructor who happened to know them through study or by experience. Inexpert instructors, on the other hand, though are subject matter experts, usually lack such knowledge. The e-Learning Model attaches a set of metadata attributes to each LO in order to aid the adaptation process. Those attributes are so simple and naive in such a way that they don't require an expert to define them, yet are used by the expert system to deliver courses with a similar quality like that of an expert instructor. Each LO is described in terms of several metadata attributes.

#### IV. AUTHORING SYSTEM RECOMMENDATION

Once the course is added to the system and its CLOs are defined, the algorithm of the "Generic Course Syllabus Generator" runs to generate the generic course syllabus, while the algorithm of the "Adapted Student Course Syllabus Generator" runs once the student registers in a specific course. The files are placed in an agreed upon folder and named with an agreed upon naming convention. The idea of the Generic Course Syllabus Generator is summarized as follows:

1) For each Concept in the CLO, consult OM to identify its "ISA" and "Prereq" linked concepts. Those concepts should be added to the syllabus before the concept as "recall" concepts so that they are briefed to the student before start teaching the concept itself.

2) For each Concept, its "ComposedOf" (or sometimes called "PartsOf") relationships in OM are followed to identify the breakdown of this concept.

3) Those subordinates of the concept (its ComposedOf concepts) are ordered using the "follow" relationships among them.

4) Only subordinate concepts of complexity level less than or equal the level specified in the CLO are considered.

5) This procedure is recursively done so that the same is done for all concepts added to the syllabus.

At the level of the generic syllabus, the Cognitive level is considered only when following the relationships. The relationships (e.g., "ISA", "Prereq", "ComposedOf", "Follow") should be traced in OM starting at the appropriate cognition level as specified by the CLO.

The Generic Course Syllabus is adapted for each specific student to guarantee:

- No concepts/topics are not included if the student already knows them at an acceptable level.
- All concepts/topics that are pre-required for teaching the concepts of the Generic Syllabus and that are not known by the student at an acceptable level are added to adapted syllabus in order to be taught before teaching the bespoke concept. This step is recursive to capture all missing levels of the pre-required knowledge.

Therefore, the idea of the Adapted Student Course Syllabus Generator can be summarized as follows:

1) Starting at the course CLO and given the student's BDKM, the following is done to adapt the CLO into a specific student's SLO:

2) For each concept in the CLO, consult the student's BDKM, and OM:

3) If the student already knows this concept at an acceptable level of mastering, then remove it from the SLO.

4) If student's BDKM misses any of the concepts predecessors ("ISA" and "Prereq" relationships), then add this concept to the student's SLO at the same cognitive and complexity level as described in the CLO for the specified concept.

5) This last step is done recursively until is terminated by a concept that is well known to the student as per his/her BDKM.

6) Starting at the adapted SLO, do the following to generate the Adapted Student Course Syllabus:

7) For each Concept in the SLO, consult OM and his/her BDKM:

8) If the concept is known by the student, then remove it from the Adapted Syllabus.

9) Identify the concept's "ISA" and "Prereq" linked concepts, if those concepts are not known by the student's BDKM, they should be added to the Adapted Syllabus before the concept as "recall" concepts so that they are briefed to the student before start teaching the concept itself.

10) This step is done recursively to visit all pre-required concepts and their pre-requirements.

11) For each Concept, its "ComposedOf" (or sometimes called "PartsOf") relationships in OM are followed to identify the breakdown of this concept.

12) Those subordinates of the concept (its ComposedOf concepts) are ordered using the "follow" relationships among them.

13) Only subordinate concepts of complexity level less than or equal the level specified in the CLO are considered.

14) This procedure is recursively done so that the same is done for all concepts added to the syllabus.

15) The steps above are to be repeated for each time a concept is to be added to the system.

## V. ADAPTIVE COURSE DELIVERY SYSTEM RECOMMENDATION

The Course Delivery System (CDS) adapts the delivery of the course to the student according to his/her student model.

The Delivery System takes it from the Adapted Student Course Syllabus, to generate the detailed Adapted Course TOC, and then to the presentation phase where the appropriate LOs are presented to the student, as shown in Fig. 4. Each student would have his/her personalized TOC. The TOC is structured into: Chapters, Sections, and Sub-Sections. Chapters and Sections come from the Adapted Student Course Syllabus. Sub-Sections are identified in this phase according to the student's LSM.

### LSM Adaptation Guidelines:

The LSM adopted by the e-Learning Model is FSLSM [23] as it has applicability to e-learning and compatibility to the principles of interactive learning systems design [18]. A student's learning style will affect the adaptation process in two directions, namely, the selection and sequencing of the LOs during the course delivery.

"Selection" can be identified at large by the answers to few questions, which mainly direct the adaptation process through the selection of the appropriate LO based on the "Technical Format" attribute:

What type of information does the student preferentially perceive?

Sensory (sights, sounds, physical sensations).

Intuitive (possibilities, insights, hunches).

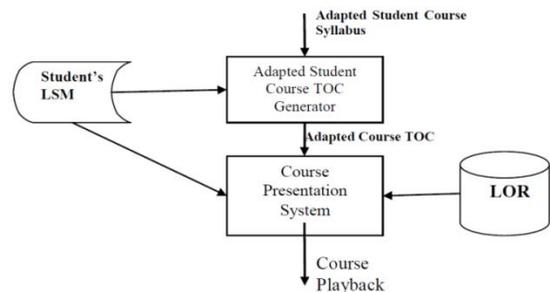


Fig. 4. The Course Delivery System Architecture

Through which sensory channel is external information most effectively perceived?

Visual (pictures, diagrams, graphs, demonstrations).

Verbal (words, sounds).

How does the student prefer to process information?

Actively (through engagement in physical activity or discussion).

Reflectively (through introspection).

How does the student progress towards understanding?

Sequentially (step by step)

Globally (in large jumps, holistically).

The guidelines governing both the Selection and Sequencing procedures are presented in [24]. Accordingly, translating these guidelines, TOC templates are designed for each of the LSM dimensions.

## VI. ASSESSMENT SYSTEM RECOMMENDATION

The assessment module gathers information about the student using a test tool. LMS uses assessment tools to provide instructor with facilities to assess e-learners based on multi-type tests and exams, to track achievements in those exams and tests and to provide online grade books. The CAS displays questions from the Question Items Repository (QIR) in an adaptive way based on learner style and preferences. It is recommended to have two types of assessments: assessment after each LO presentation; and an evaluation exam for the whole presented learning section. Exam items are presented in a manner related to the learner by presenting question objects following the student's preferences. The Question Objects (QO) are parts of the question item.

The QIR is the central storage for that module, which is to be shared among instructors that maintain a collection of reusability test items to measure different levels of knowledge and skills in different difficulty levels. The CAS is adapted based on FLSM to select, present and sequence the question objects to the preferred student learning style. We are employing a simple overlay student model. It reflects the student's estimation of current knowledge levels for a student in concepts in the current domain and prerequisite concept in every level of RBT.

The instructor is responsible to identify elements of criteria for the test which are: the domain knowledge (the current course), concept to be measured and under any level of RBT (cognitive domain) wanted to measure this concept to determine the behavioral objectives, some adaptive rules related to the adaptation and evaluation process.

The engine generates the question items tailored to the student ability and based on the test objectives and instructor rules. To measure the specific level of RBT, we must measure the test objectives which are matched with this level. The grade of proficiency is set to 1 if the student has knowledge and set to 0 if the student does not have knowledge. We start to measure the objectives from a simple level to the more complex levels of RBT or vice versa depending to the concept to be measured. There are two cases, if the concept to be measured is for the current course then start from the lowest (simple) level of RBT to the required level of RBT. The other case, if the concept to be measured is for the prerequisite course, then we start from the required level of RBT (more complex) in the objectives to the lowest level of RBT.

We recommend to add assessment with many options with the following important fields:

Quiz or Exam field (Quiz or Exam) that specify if the assessment is an exam or quiz.

Question Selection field (Manual or Auto) that specify if the assessment question will be selected by the teacher (Manual) or by the system (Automatic selection) , if auto is selected then the teacher should specify number of question and their difficulty level in the fields (Number of Low Level Questions, Number of Mid-Level Questions , Number of High Level Questions)

Type field (Pre. or Post.) that specify when to view the quiz before learning object playing or after viewing it.

Concept field that shows the concept related to the assessment.

## VII. DISCUSSION AND CONCLUSION

We have designed sample lectures the Web Programming course (CPIS358) at the department of Information Systems with Faculty of Computing and Information Technology at King Abdulaziz University. For web Programming course, some topics, such as JavaScript, PHP, HTML are discussed and presented based on the domain ontology prepared for the course.

The system guides the teacher throughout the course design process by helping him/her to:

- Understand the student(s) model: cognitive modes, skills, and traits;
- Determine the concepts to be covered to achieve the course learning outcomes;
- Determine the best methods and pedagogy to present those concepts to the students according to their cognitive models; and
- Search for the best available assets and learning objects that achieve such criteria.

In addition, the system helps the student during the course delivery process for the goal of making the learning process more pleasant, efficient, and effective. It will help him/her through:

- Adapt the course syllabus to match his/her background knowledge yet to meet the course objectives;
- Choose the most appropriate presentation style and pedagogy that best suits each individual student;
- Select the most appropriate course content and learning objects that suits the student the best;
- Choosing the best sequencing of the learning material;
- Identify the proper time and amount of exercises, quizzes, tests, and exams that best suites each individual student's style of learning; and
- Assessing students according to their cognitive abilities and preferences.

The following results were recognized and were conceptually proven:

- Integrating instructional design theories (e.g., RBT) and psychology and learning theories (e.g., Learning style models such as FLSM) into the adaptive learning process has been demonstrated feasible.
- Employing computer science technology to implement an intelligently adaptive authoring and delivery courses is proven feasible. Technologies such as Ontology, Learning Objects, and Expert Systems were used to achieve such goals.
- A reasonable student model was designed in such a way to achieve adaptability in delivering courses to each specific student to match his/her profile as possible for more effective and efficient self-learning process.

To the best of our knowledge, we did not find similar integrated work in our region. By carefully inspecting of some related work, we can deduce the following comparative of our system KAU-AES with other systems in the literature as shown in Table II.

For our future research directions, we may have the following points:

- Use educational data mining techniques to investigate and predict students' trends and attitude.
- Making In-Depth Analysis of the Felder-Silverman Learning Style Dimensions for our Arabic region and compare it with foreign regions.

TABLE II. COMPARISON OF ADAPTIVE SYSTEMS AND TOOLS

System	Adaptive Courses	Learning styles	Authoring Tool	SCORM Courses	LMS	Bloom Taxonomy	Ontology	Open Source
EDUCA [12]	√	Felder & Silverman	√		√			
INES [13]	√		√					
[14]			√				√	
[15]	√						√	
[17]	√		√					
[18]	√	Felder & Silverman	√					
[19]	√		√					
Moodle				√	√			√
KAU-AES	√	Felder & Silverman	√	√	√	√	√	√

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