ASSA: Adaptive E-Learning Smart Students Assessment Model

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Abstract—**Adaptive e-learning can be improved through measured e-assessments that can provide accurate feedback to instructors. E-assessments can not only provide the basis for evaluation of the different pedagogical methods used in teaching and learning but they also can be used to determine the most suitable delivered materials to students according to their skills, abilities, and prior knowledge's. This paper presents the Adaptive Smart Student Assessment (ASSA) model. With ASSA instructors worldwide can define their tests, and their students can take these tests on-line. ASSA determines the students' abilities, skills and preferable Learning Style (LS) with more accuracy and then generates the appropriate questions in an adaptive way then presents them in a preferable learning style of student. It facilitates the evaluation process and measures the students' knowledge level with more accuracy and then store it in the student's profile for later use in the learning process to adapt course material content appropriately according to individual student abilities.**

Keywords—*Adaptive e-learning; e-assessments; adaptive assessment; smart assessment; Learning Style (LS)*

I. INTRODUCTION

There are different types of e-learning systems; the most recent one is an adaptive e-learning system [1]. In the traditional e-learning system the main criteria in the most cases the implementation of courses follows a "one-size-fits-all" approach, which means all students receive the same content in the same way being unaware of their particular needs. An adaptive e-learning system was proposed to solve this problem. This system tries to adapt to each individual by presenting learning materials dynamically depending on characteristics and learn style of the student [1]. The purpose of adaptive e-Learning is to provide for students the suitable content at the right time, means that the system can determine the knowledge level and organize content automatically for each student [2].

Assessment plays a very important part in any type of the education system, teaching and learning [3]. It aids instructors to evaluate the student's ability level of knowledge. Without an effective assessment, it is impossible to understand the progress of a student, the quality of education that he/she has attained and how effective these courses can be used in his/her

future studies [4]. Haken in [5], described assessment as essential in ensuring educational institutions achieve their learning goals. The researcher also found that assessment was crucial in giving the necessary evidence required to seek and maintain accreditation.

Recent advances in computer technology and theories have accelerated the change of test format from traditional tests to Computerized Adaptive Testing (CAT). Traditional tests are typically "fixed-item" tests in which the examinees answer the same questions within a given test. The desire for computerized administration of tests extends beyond using computers to present material and collect responses. It also extends to adding some "intelligence" behind the ways test tasks are presented and the ways they are scored. Within the testing industry, adding intelligence to the selection of test tasks is called "Computerized Adaptive Testing", where the selection of tasks and questions are related to the characteristics and abilities of each individual student [6]. Student's prior knowledge and abilities are important factors to consider in managing the testing and questioning adaptation process. Assessment adaptation takes place on both levels of the test itself and the selected questions of the test [7].

The aim of our paper is to develop an adaptive web-based tool to assist students in the assessment process. In this way, we propose to make the advantages of CATs readily available worldwide, and to allow instructors to define their tests and evaluate exactly their students with a minimum of effort. We have called this tool Adaptive Smart Students Assessment (ASSA) model. The tool that we have developed can be used in two different ways: as a test editor, so instructors can define their tests in an easy way, and as an assessment tool, so students can take the tests online. ASSA determines the students' abilities, skills and preferable learning style with more accuracy and then generates the appropriate questions in an adaptive way, then presents them in a preferable learning style of student.

The rest of this paper is organized as follows. Section II defines background review. Section III describes the proposed assessment model "ASSA". Section IV presents prototype implementation of our model. Finally, this paper concludes in Section V.

II. BACKGROUND

A. Computer Adaptive Testing (CAT)

CAT is designed in such a way that it makes use of the computers to build adaptive tests in which the selection of each question and the decision to stop the process are dynamically adapted to the student's performance in the test [8]. The theory used in this system is Item Response Theory (IRT), in which the methodology followed is very straight forward, questions that are posted to the students need not be too difficult or too simple [8]. This is obtained by adjusting the questions to the examinee based on his/her previous answers. The degree of difficulty of the subsequent question is chosen in a way so that the new question is neither too hard, nor too easy for the examinee. When the examinee attends his/her first question the capability of him cannot be predicted but gradually when he/she attempts to the second question the computer can analyze very well the knowledge level of the examinee [9]. The advantages of Computer Based Assessment (CBA) and CAT remain the same, but CAT has certain extra functionality that makes it very efficient and effective compared to the other assessment. There are different platforms available for designing and deploying CAT [10]. Reisinge et al. [10] propose software architecture that enables the development of completely customizable CAT tools with respect to domain-specific item design and visualization as well as deployed CAT algorithms. CAT retains the advantages of CBA, but there are additional benefits that make CAT a very efficient and effective means of assessment [11]:

- Reliable and accurate estimate of the efficiency of the student.
- Reduce the time of testing.
- Avoid easy / difficult items that may cause stress.

There are several types of adaptive tests but all of them are derived with two steps: question selection and score estimation [8]. Question selection is the integral part of the assessment in which the questions are collected and compiled based on the student's performance level. These questions are forming a pool which will have the collection of questions that was asked to any particular student at a single time. The next step is the score estimation in which the student performance is complied with the responses given by them and it's refined at regular intervals. This allows the questions asked next to be more appropriate still. This cycle continues until either a specified number of questions have been administered or some measure of score precision is reached. Several adaptive testing systems have been developed such as: The SIETTE [12].

Developing of multistage adaptive test (MST) panels is a hot topic today and it has encouraged new developments. The most commonly used approaches for MST: bottom-up and top-down [13]. In the bottom-up approach the whole test divided into several unit, and each unites is constructed first, then all unites are gathered to get the whole test, while the top-down approach trails the reverse direction. Both methods have their pros and cons, and sometimes neither is convenient for practitioners [13]. The advanced mix strategy presented in [13] is to build best multistage adaptive test (MST) panels. In

[14], two different approaches, CAT with a shadow test approach and computerized multistage testing have been proposed to ensure the satisfaction of subject matter experts. In the shadow test approach, a full-length test is assembled that meets the constraints and provides maximum information at the current ability estimate, while computerized multistage testing gives subject matter experts an opportunity to review all test forms prior to administration.

B. Adaptive Questions

This technique generates dynamically sequenced questions based on the student's response. Question selection is based on several predefined rules as well as the student's current responses [15]. Therefore, highly structured pools of questions are required for rules to have enough information to select questions. As opposed to adaptive testing, this approach presents instructors with more flexibility in including didactical and personal methods. This is done by creating appropriate rules [15]. Several adaptive questions systems/tools have been developed such as, AthenaQTI [15] and CoSyQTI [16].

C. Adaptive Presentation of Questions

This method present questions in the appropriate format and structure that matches student learning style. Students have different way to understand assessment materials this called learning style. More formally, learning styles represent a combination of cognitive, affective and other psychological characteristics that work as relatively stable indicators of the way a student perceives, interacts with and responds to the learning environment [17]. Fortunately, many Adaptive e-Learning researches assumed that personalizing or presentation of the question to match the student's learning preferences, especially the learning style, would aid the student's understanding. Several systems have been developed that provide adaptive presentation for assessment materials, such as: INSPIRE System [18] and PIAT [19].

III. ADAPTIVE SMART STUDENTS ASSESSMENT (ASSA) MODEL

ASSA is one of the components of the Adaptive e-Learning Environment. Instead of building that environment from scratch, the decision was to use an Open Source Learning Management System (LMS). Moodle was chosen because of its popularity as it is used in several universities (https://moodle.net/stats/). Moodle also is known as simple and easy to adapt and customize to the needs of the educational system. We can see in Fig. 1, the basic architecture of the Adaptive e-Learning Environment. Three main engines in the adaptive e-Learning Environment 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 which contains the information about the botanical domain and is being incrementally built using web forms by different users in diverse locations. Each component, including the KB, has an independent web-based interface that allows the whole system to be used both as a learning tool and as an independent assessment tool.
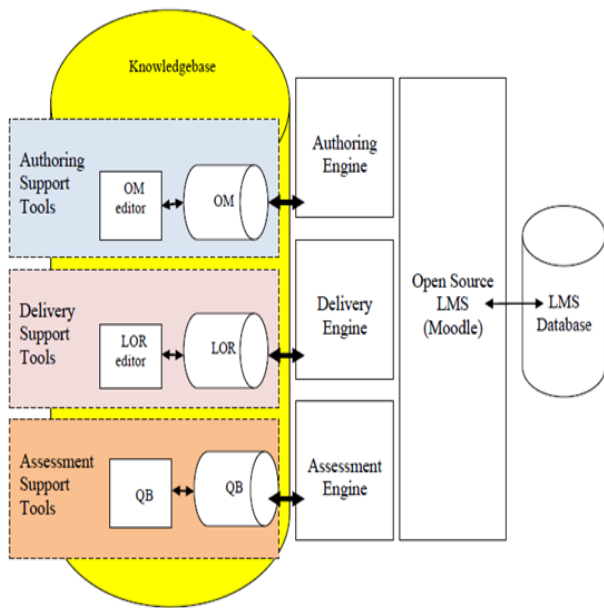
Fig. 1.   Architecture for the adaptive e-learning environment.

A. Knowledgebase

As shown in Fig. 2, the Knowledgebase is composed mainly of four major components: the LO, QB and domain ontology knowledgebase; student database; and course database. The knowledgebase is composed of the Learning Object Repository (LOR); the Ontology Model (OM); and the Question Bank (QB). The QB is composed of two components: Smart Learning Question Repository (SLQR), and Smart Constituents Learning Objects Repository (SCLOR). The SLQR is data base that hold a collection of Smart Learning Question (SLQ) objects. A question is not an atomic object, but rather question object integrates the question constituents. Those constituents may wholly or partially be drawn from SCLOR. The 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 three dimensions of Felder & Silverman Learning Style Model (FSLSM) and the Student's Background Domain Knowledge (SBDK) representing the knowledge that the student captures with an acceptable cognitive depth for the domain of study. In addition, the Course Model (CM) is composed of three components: The Course Learning Outcomes (CLO), the Course Syllabus, and the Table of Contents (TOC).

The main objective of assessment is to measure knowledge level of student which will be used in adaptive e-learning environment to adaptive learning materials. So, we need to measure score of each concepts/topic to determine knowledge level of student. This is generally done through providing questions to the students to answer them. Once the student submits his/her an answer of a question, this answer will be evaluated. Then constructive feedback and result will be provided to student. ASSA determines the students' abilities, skills and preferable learning style with more accuracy and then produces the suitable questions in an adaptive way, then

presents them in a preferable learning style of student. A high number of learning style models was proposed to define learning style of student, we have selected the Felder model as the basis of our research and we focused only on three of the FSLSM's dimensions, namely, Global/Sequential, Sensing/Intuitive and Visual/Verbal. Therefore, there are 8 (2^3). The question can be presented in three different ways to match three dimensions of student learning style. Therefore, if question is not clear, student can ask rephrasing question to match another dimension of his/her learning style.
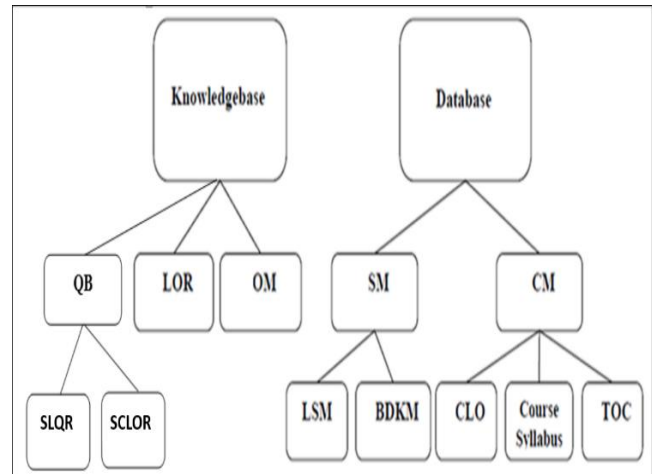

Fig. 2.   The Knowledgebase.

ASSA facilitates the evaluation process and measures the knowledge level of students with more accuracy and then store it in the student's profile for later use in the learning process to adapt course material content appropriately according to different student abilities. ASSA used Ontology Model (OM) to direct the assessment process to assess the student's knowledge and skills, and it also uses the Revised Bloom Taxonomy (RBT) to navigate upward and downward the cognition pyramid to determine the student's cognitive level. ASSA can be used in two different ways:

- Instructors and/or domain experts can use ASSA to develop the tests, that is, to define their topics, questions, parameters, and specifications.

- Students can use ASSA to take the tests that are automatically generated according to the specifications provided by the examiner.

B. The Question Bank (QB) Model

Question Bank (QB) contains a collection of questions of test that are stored in SLQR, and may be supported by components from SCLOR, and then presented to the student according his/her Learning Style Model (LSM). SLQR is an essential storage (data base) that maintain and hold a collection of Learning Question (LQ) objects. LQ like an LO, is specified through a set of metadata attributes to facilitate question selection and manipulation. LQ metadata which is described with SCORM metadata. The LQ Model has extended the standard metadata model of SCORM by: adding additional attributes essential for supporting the theories it implements, such as Learning Style Model. SCLOR is a

repository which holds a collection of objects that support and constituting the question. Some of these objects are multimedia objects in different format. Like SLQR, it is described by SCORM metadata standard and extra attributes.

C. The Question Model

The Question is described in terms of many dimensions: Question type, Question purpose, and Question structure.

1) Question types: Reviewing the different types of questions in all types of tests, the following question types are recognized:

- MCQ,
- T/F,
- Fill-in the spaces (may take one of two forms; free answers or like MCQ, i.e., selecting from a given list of possible answers),
- Matching two groups,
- Problem solving.

Grading is a critical determinant of the types of questions to be used in a test. The number of students, nature of the test, availability of expert graders, etc. are critical determinants. Classical automated grading natively covers the first four types of questions with simple correct/no correct evaluation, while Smart Grader addresses grading of the fifth question type.

2) Question's assessment purpose: Each question serves a purpose in the assessment process. Fig. 3 describes the interrelationship of a question to the different elements of assessment. The question is tied with M-M relationships to the course educational objectives and outcomes, knowledge topics, and skills that it assesses.
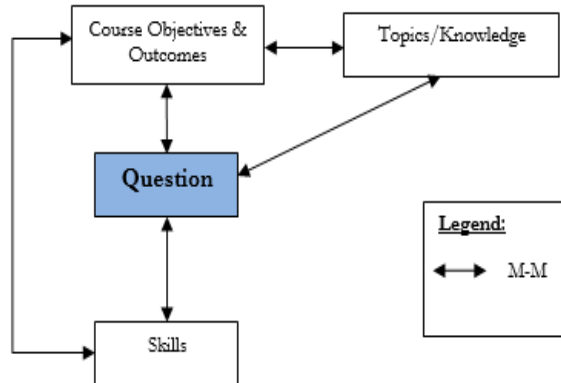

Fig. 3. Question has different assessment elements.

3) Question structure: The structure of a Question is shown in Fig. 4. A question is composed of three main components: Question Header, Question Details, and Question Answers. Each of these components has a different structure for the different question types. This is normal due to the differences in their nature. Noteworthy, the problem-solving

type of questions is more complex and requires special intelligent handling. In answering such questions, the student follows an action plan strategy that the grader must recognize for proper evaluation.
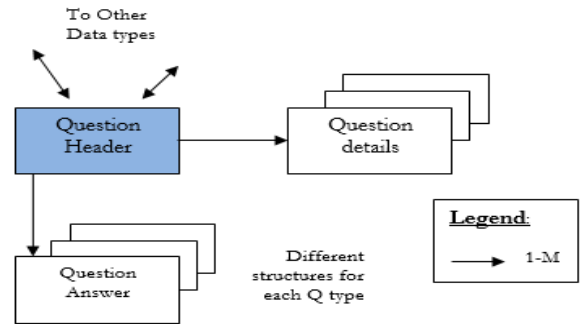

Fig. 4. A question structure.

D. Grading and Assessment Analysis

When student submits his/her answer, assessment engine will pass answer to simple or smart grader depends on question type. A simple grader covers the four types of questions, namely, T/F, MCQ, Matching, and fill in- the-spaces while smart grader developed for assessing problem-solving and proving type of questions. When the grading process is complete, the evaluation engine provides the student with his/her result and appropriate feedback.

Most question types are simply graded except the problem-solving type. Smart Grader (SG) is developed to assess and evaluate problem solving question (such as programming exercise). This is generally done through providing programming exercises for the students to answer them. To assess these exercises effectively, it is necessary for the SG to analyze any solution provided by student and compare it with instructor/expert solutions. Then SG provides constructive feedback and result to student. The programming exercise do not have a unique strategy to solve it, but it can be solved in many ways. Therefore, in evaluation phase matching a program line by line is not effective method of analyzing it. The evaluation process of programming exercise questions requires the instructor to define all possible strategies of solution to compare them with student solution. Therefore, evaluation of problem solving question is complex process and it requires special intelligent handling.

Problem solving is seen as a series of steps that can be used to reach a goal (answer). In each step, multiple actions are possible leading to other step. Therefore, in answering problem-solving questions, the student follows an action plan strategy. To assess these exercises effectively, it is necessary for instructor/expert to define plan that contains all possible strategies of answer. Then, SG detects the solution strategy that the student follows by analyzing his/her action plans in answering the question. As shown in Fig. 5, when student submits his/her solution, SG must first analyze student solution and recognize action plan behind it. Then, SG compares student action plan with instructor/expert action plan of solution. After that, SG provides constructive feedback and result to student.
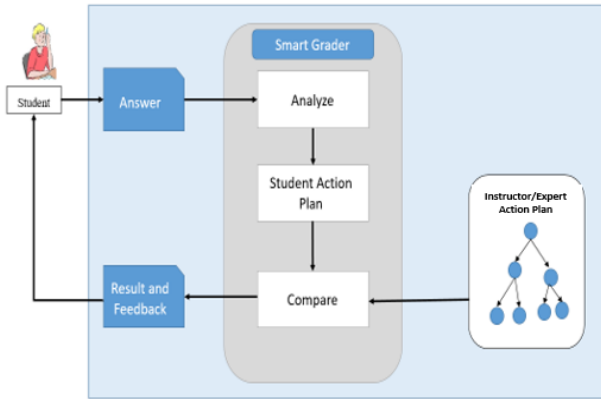
Fig. 5.   Evaluation process of problem solving question.

The instructor/expert action plan of possible programming exercise solutions specifies using grammar and production rule and represents using tree where root is goal and internal nodes is non-terminals and leaf represent terminals. The production rules to the goal (answer) is useful to specify instructor/expert action plan of solutions. The first rule starts with goal as following:

Start → Goal (answer)

The goal can be reach using multiple strategy, therefore second rule will be as following:

Goal → Startgy$_1$ | Strategy$_2$ | …. |Strategy$_n$

These strategies can also be divided into other sub-strategies. Each strategy has series of steps that can be used to reach a goal (answer). In each step, multiple actions are possible leading to other step. An action can be decomposed into more actions at a later stage. When student submits his/her answer, SG recognizes action plan that followed by student which is a set of one or more rules that satisfy the goal. If the student action does not match a production rule action, the SG provides immediate feedback to student.

Suppose we have problem P and set of problem solving strategies of the form:

S_1 or S_2 …or S_n.

The solving problem space represent by using and-or tree. The associated and-or tree is a set of labelled nodes such that:

- The root of the tree is a node labelled by P.

- The alternative sets of children corresponding to alternative strategies (S_1 or S_2 … S_n) of solving are grouped together by an "or".

- For every node Si may have a set of children nodes ($S_{i,1}$ … $S_{i,n}$) corresponding to alternative sub-strategies of solving and they are grouped together by an "or".

- For every node (S_i or $S_{i,j}$) there exists a set of children nodes N_1, …, N_n. Each node represents one strategy step of the problem solution. The nodes are conjoined by an arc, to differentiate them from other nodes that

might be related with other strategies. Also, these nodes are arranged in order to reflect step order in solution.

- The terminal leaves are the actions.

Suppose we have problem P that can be solved by two strategies (S_1 or S_2). There are three steps (a, b and c) in S_1 and two steps in S_2 (a and b). The solving problem space of P represent by and-or tree as shown in Fig. 6.
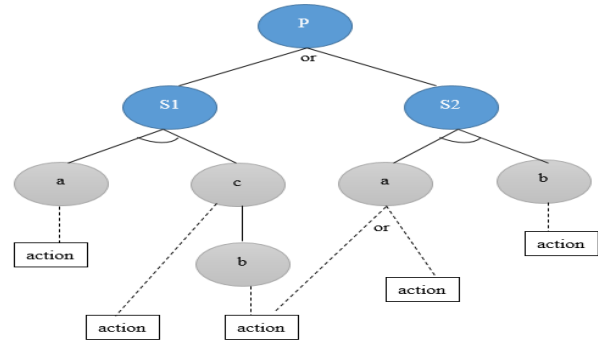

Fig. 6.   Tree of solving problem space.

IV.   PROTOTYPE IMPLEMENTATION

We implement ASSA prototype using PHP and oracle Database. ASSA allows producing and delivering adaptive and smart test through web interfaces. It works inside web-based adaptive e-learning systems as a diagnosis tool. It based on a 2-tier client/server platform for adaptive student assessment. Fig. 7, explains the 4-layer architecture of ASSA platform. Four subsystems have been developed, which accessed by four types of users: admin, experts, instructors and students. Through Web browser (Presentation layer), users communicate with the corresponding Web application on the Application Server where dynamic Web content is created using PHP (Application layer). The system Database is located on the Oracle Database Server (Data layer).
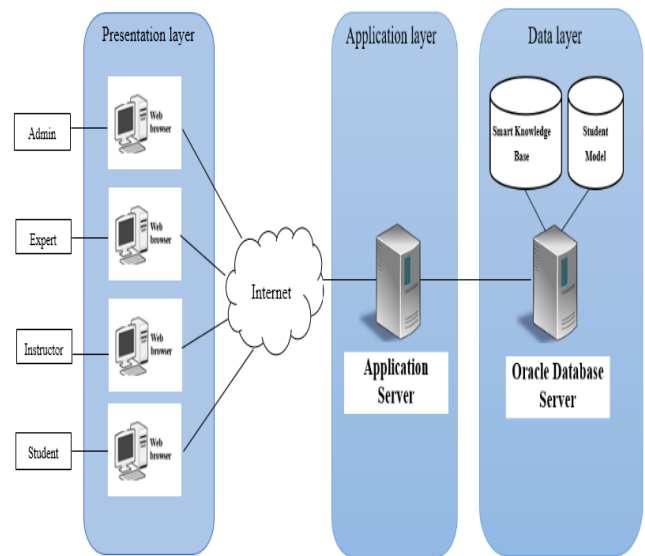

Fig. 7.   ASSA prototype architecture.

A. The Admin Sub-System

This sub-system provides the admin with web-based services to add (update or delete) the basic data needed for the other sub-systems (as shown in Fig. 8).
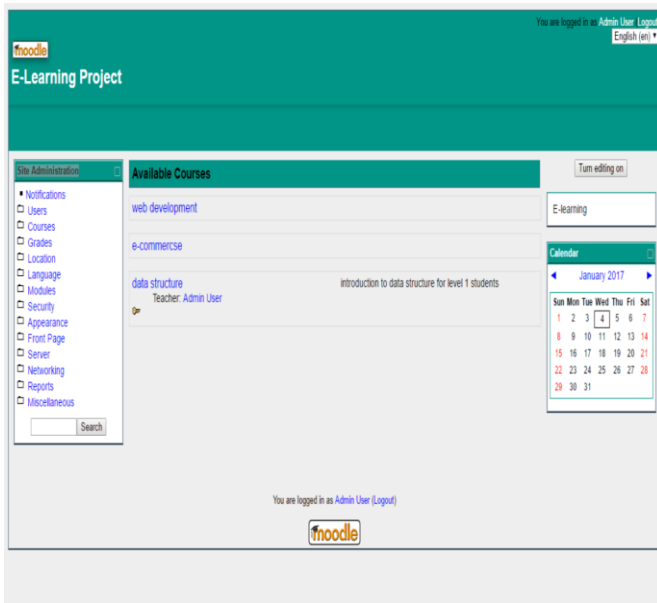

Fig. 8. Admin sub-system.

B. The Expert Sub-System

This sub-system provides the expert with web-based services to build Ontology Model (OM) by adding concepts/topics and specifying hierarchy and relations connecting them with other. As shown in Fig. 9, the expert can add new concept to the course and store the following data for each concept: name, description, complexity level and he/she can determine and specify relation that connects this concept with other concepts.
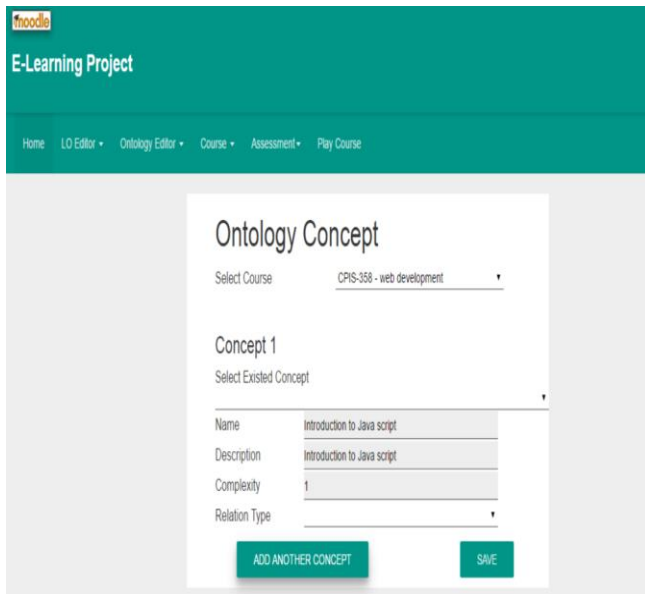
Fig. 9. Add concept interface.

Also, this sub-system provides expert web-based services to builds the Question Bank (QB) based on the Question Model. QB contains collections of SLQ. Adding SLQ requires several steps from expert. SLQ specified through a set of metadata attributes to facilitate questions selection and manipulation. **The first important step** is to create SLQ requires expert to specify this metadata attributes of smart questions (as shown in in Fig.10).
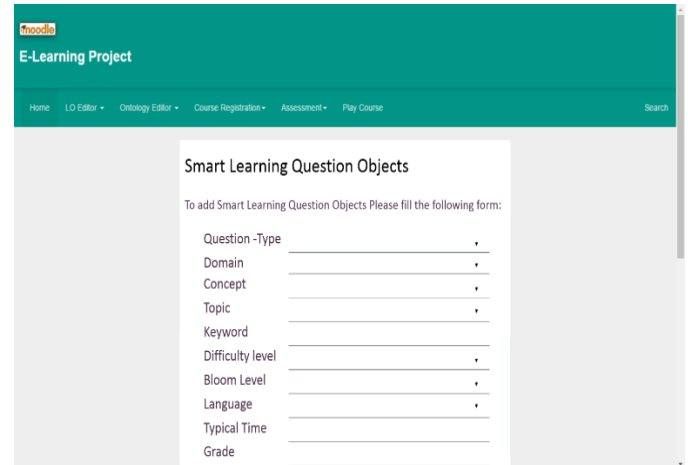

Fig. 10. SLQ metadata attributes interface.

As shown in Fig. 11, creating question constituent's objects is **the second step** to create SLQ. As mentioned before, the question object is an abstract framework that specifies and integrates the question constituent's objects.
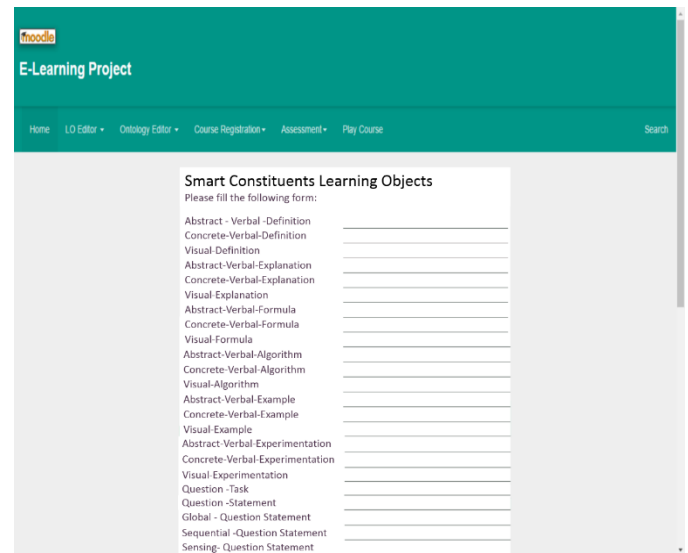

Fig. 11. Question constituent's objects.

The last step to build SLQ requires expert to add details and answers of questions. Our model covers many types of questions as mentioned before, such as: T/F, MCQ, fill-in the spaces, matching two groups and problem solving. Each of these components has a different structure for the different question types. Fig.12 displays structure of MCQ.
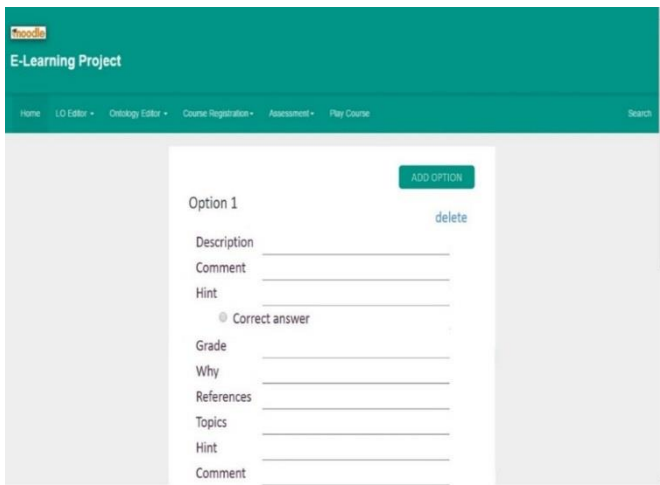
Fig. 12. Structure of MCQ.

Fig. 13 displays structure of fill-in the spaces questions while Fig. 14 presents matching two groups questions structure.
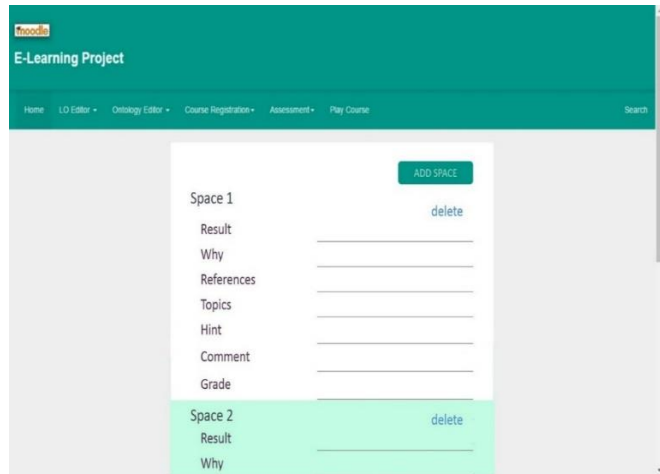

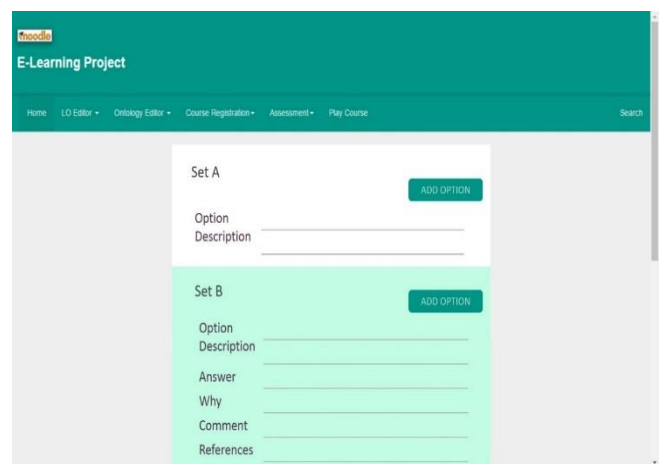Fig. 13. Structure of fill-in the spaces question.

Fig. 14. Structure of matching two groups question.

As shown in Fig. 15, the problem-solving type of questions is more complex and requires special intelligent.
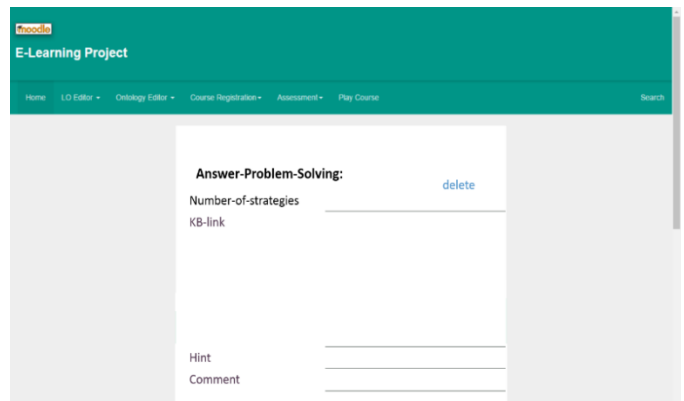

Fig. 15. Structure of problem solving question.

C. The Instructor Sub-System

This sub-system provides the instructor with web-based services to create two types of assessments Quiz and Exams with different types of questions from. As shown in Fig. 16, in "Assessment" menu item instructor can find the following options:

- Add Assessment.
- View Course Assessment.
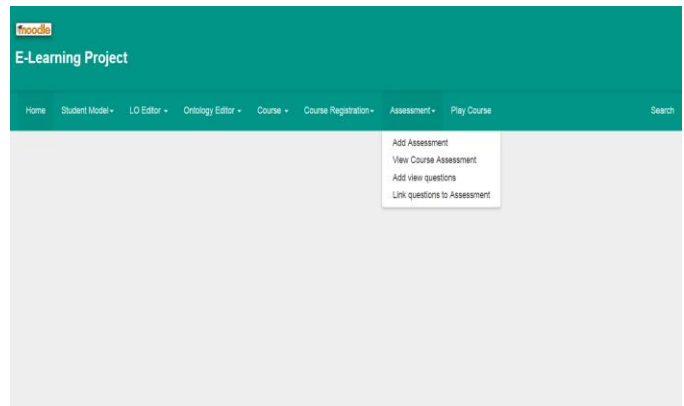- Add view questions.
- Link questions to Assessment.

Fig. 16. Assessment menu.

Fig. 17. View students in course interface.

From Course Registration instructor can view students registered in this course as shown in Fig. 17.

D. *The Student Sub-System*

Student can open the Moodle application (in browser) and Login with student username and password then select the course as shown in Fig. 18. This sub-system allows student to take quiz that contains different types of questions with different difficulty levels. These questions are presented to the student in a sequential manner commensurate with his abilities and level of knowledge. Also, these questions are presented in a way that suits the student's preferred learning style.
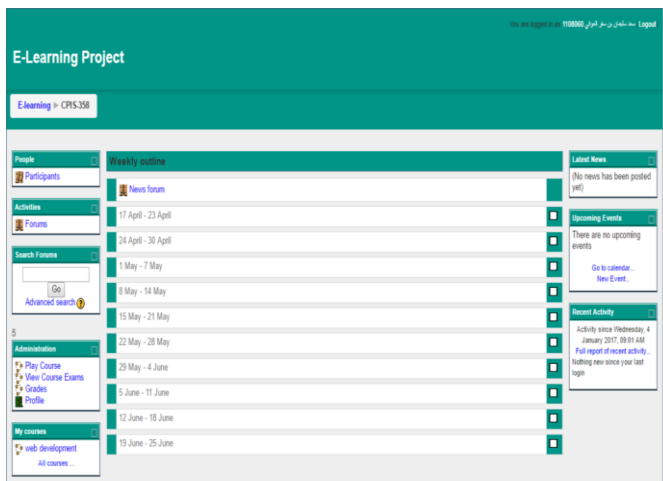

Fig. 18. Students interface.

V. DISCUSSION AND CONCLUSION

In adaptive e-learning system the assessment is very important, it is used to measure students' knowledge level to adapt course material's according it. Therefore, this type of e-learning requires smart assessment model that determines student knowledge level with more accuracy. This paper presented Adaptive Smart Students Assessment model, named ASSM that works inside web-based adaptive e-learning systems as assessment tool. ASSA can be used in two different ways: as a test editor, so instructors can define their tests in an easy way, and as an assessment tool, so students can take the tests online. This model simplifies the assessment process and measures the students' knowledge level with more accuracy and then stores it in the student's profile for later use in the learning process to adapt course material content appropriately according to individual student abilities.

The adaptation in this model includes sequences of questions to avoid questions that are much easy or much difficult to student. Also, adaptation include presentation of questions to match student learning style. ASSA determines the students' abilities, skills and preferable learning style with more accuracy and then generates the appropriate questions in an adaptive way, then presents them in a preferable learning style of student.

ASSA differs from other adaptive models in several issues. In this model, the idea for providing adaptive presentation of question statement was developed. Also, in ASSA three dimensions of the FSLSM are considered rather than using

only one of them. This allows providing more accurate adaptivity by incorporating different aspects of learning styles as proposed by the learning style model. Also, this model differs from other adaptive models because it contains all types of questions. Simple grader developed to assess simple type of questions, while smart grader developed to assess complex type of questions (such as programing exercises). The smart grader has ability to define many solutions for single programing exercise.

We implement ASSA prototype using PHP and oracle Database. ASSA allows producing and delivering adaptive and smart test through web interfaces. It is based on a 2-tier client/server platform for adaptive student assessment.

The future work includes incorporating other types of questions (such as: comparing, critiquing, discuss, describe etc.) which require language processing researches.

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