ADAPTIVE ASSESSMENT BASED ON LEARNING STYLES AND STUDENT KNOWLEDGE LEVEL

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Abstract: Traditionally, adaptive assessment methods and tools have been addressed only by application of computerized adaptive testing and item response theory as a key instrument for practical construction of adaptive test assessments. The present paper tries to give a broader view of adaptive assessment, where tests are not the only instrument for evaluation of learners outcomes gained during a course. It shows how adaptive task-based assessment may be combined with traditional adaptive test assessment for achieving better results and higher student satisfaction. Various types of tasks have been found suitable for adaptive assessment based on learning styles and student knowledge level. By means of constructing course storyboard with several branches for different learning styles, it has been proven that games, essay, observation, comparative analysis tasks, projects and auto-generated tests may be used successfully for a complex adaptive assessment. There have been explored approaches such as self-, peer- and teacher- (i.e., host) assessment by using appropriate types of estimable learning objects.

1 INTRODUCTION

Adaptive Web based learning plays a key role in modern technology-enhanced learning research and practical system implementation. First Brusilovsky has pointed out (Brusilovsky, 1996) that learners have different knowledge levels, needs and preferences which should be considered for realising personalized and adaptive hypermedia systems. Moreover, learning styles have been used as a base for creation of efficient adaptive hypermedia systems (AHS) in many approaches (Milošević et al, 2007; Velsen, 2008). Learning style adaptivity may be realised either by automatic generation of work paths for each student character or, more precisely, by construction of learning storyboards according chosen instructional strategies (Vassileva et al, 2009a). In general, it has been proven in practice that adaptation focussed on different aspects of learning character is able to provide a higher appealing and level of usefulness for the learner and, thus, to lead to a better learning learning process (Paramythis and Reisinger, 2003; Grimón et al, 2009).

Assessment is of key importance for both the teacher and the learner because it tracks the learning process, identifies strengths and weaknesses of the learner and, thus, helps teacher in planning learning steps. Introducing adaptivity to traditional assessment may provide benefits not less then these typical for AHS. However, until present, adaptive assessment did not necessarily make a part of adaptive hypermedia systems. Most of the present works on adaptive assessment are focussed on intelligent selection of questions based on prior knowledge of the learner shown during a test run. Thus, adaptive assessment tools use knowledge level and proficiency of learners to select next question within the test (Gouli et al, 2001). Testing is adapted interactively to order to match the ability level of any individual learner (Mansoor, 2006) by means of using item response theory (IRT). En efficient computer adaptive testing (CAT) system uses a calibrated bank of questions developed according an IRT model (Kovatcheva and Nikolov, 2009), initial and intermediate questions' selection methods, a scoring method, and terminating rules to stop (Gouli, 2001). For an intelligent selection of item (i.e., question) within an adaptive assessment run, proper metadata of LOs of type questions has to be used. In the approach of (Ibraheem, 2003), item metadata is divided into two parts - descriptive and psychometric.

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The present paper describes a practical approach of realization of assessment adaptive to both learning styles and learner's knowledge level and achieved within the scope of a platform for adaptive content delivery based on learner both character and knowledge. An adaptation control engine chooses within a course storyboard appropriate work paths best suited to given learner style. In the course of the work path, the engine shows to the learner only learning objects (LO) having a difficulty appropriate to the individual learner, and tracks these objects. At a control page, the engine selects questions related to the learning objects shown to the learner in an adaptive mode. Besides adaptive tests, the approach includes a more general adaptive assessment based on learning styles - it includes assessment of estimable learning objects such as essays, projects, single- and multi-user games, comparative analysis and others – all appropriate to a given learning style. Experimental results are obtained for applying adaptivity for Honey and Mumford (Honey and Mumford, 2000) styles comprising of theorist, pragmatist, reflector and activist. Authors argue the appropriateness of such tasks to given learning style and assessment method, such as self-, peer- and teacher assessment.

2 ADOPTA – MODEL AND PLATFORM

The assessment adaptive described in this paper is implemented with the ADOPTA (ADaptive technOlogy-enhanced Platform for eduTAinment) platform for building edutainment (education plus entertainment) content for both universities and industry implementation. The triangular model of ADOPTA is based principally on AHAM reference model (De Bra et al, 1999) and its main idea is explicitly separating narrative storyboard from the content and adaptation engine. It adds some features of contemporary adaptive e-learning systems as support of different learning styles, learning content and pedagogical strategy metadata and support of several standards and more specifically LOM (Krull, 2004), SCORM (Rey-López et al, 2006) and OMV (Vassileva et al, 2009).

The triangular model has hierarchical structure with two levels (fig. 1). At each one level, it consists of three sub-models. Thus its first level is divided into the following three main models:

- Learner model – it structures data for learners and it is divided into three sub-models - *Goals and preferences*, *Learning styles* and *Knowledge and Performance.* They provide data for learners, which are used from adaptive engine for adaptive content delivery.
- Adaptation model - it consists of following three sub-models: *Narrative metadata*, *Narrative storyboard*, and *Storyboard rules*. The sub-model *Narrative storyboard* described course storyboard graphs through directed graph. Each node of this graph is narrative page or control page (CP). Respectively narrative pages contain listed learning object defined in different ontology graphs of the Domain model, but CPs consist of randomly chosen test questions which are based on visited learning object of students. Each path from one CP to another CP is called working path (WP). Each WP is associated with a weight for each one learning styles. These WP weights present how much they are suitable for a particular learning style. The metadata of narrative storyboard graphs are described in the sub-model *Narrative metadata*. It includes for example thresholds for each WP. These thresholds gives the minimal results of test in CP where the learner may continue to the next CP. Rules for passing through narrative storyboard graphs are stored in the sub-model *Storyboard rules*. These rules define formulas which adaptive engine used to calculate the most suitable WP for a learner and conditions under which a learning object is visible for a particular student.
- Domain model – it is responsible for creating of learning objects (through the sub-model *Learning objects*), for structuring it in ontology graphs (through the sub-model *Ontology graph*) and description of ontologies and learning objects metadata (through the sub-models *Content Metadata*). The sub-model *Learning objects* determines several types of learning objects such as *narrative content, projects, tasks, essays, games, assessment questions*. Each of them has level of difficulty (easy, medium, difficult, more difficult, and most difficult). Using this, the instructor of a course defines for what test results in CP are visible various in difficulty learning objects. The other sub-model *Ontology graph* organized learning object in ontology graphs. In these graphs learning objects are connected between themselves by two types of links:
  - *is-a* – it is used for connection between learning objects of type *narrative content*
  - *has-a* – it defined reference relations and learning object of type *projects, tasks, essays, games, assessment questions* can be associated with one and more learning objects of type *narrative content.*

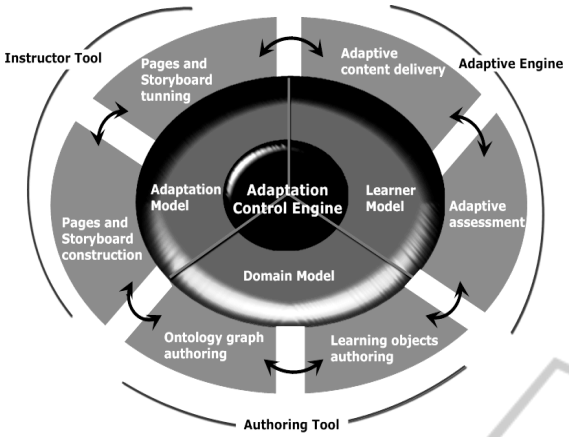

Figure 1: Principal model and system workflow.

The architecture of ADOPTA system consists of three main modules (fig. 1) – *Authoring Tool*, *Instructor Tool* and *Adaptation Control Engine*.

The *Authoring Tool* is responsible for implementation of functionalities of the Domain model. It is used by content author for creating of learning, for designing of ontology graphs and describing of theirs metadata. For the last, this module applies an inheritance mechanism.

After the learning content is created by the content author, the instructor uses the *Instructor Tool* for construction and for tuning of different parameters of narrative storyboard and pages.

Finally, the *Adaptation Control Engine* uses all available data for learning objects and storyboard graphs for adaptive content delivery and adaptive assessment. It can be used by instructor for monitoring of the learning process, for controlling it – adaptation behavior can be start or stop, for correction of WP weights, for analysis of learner performance, etc.

Each module includes three layers- persistence, business and web (or client) layer. Each of the layers is responsible for different specific problems. The persistence layer stores and edits objects and it is implemented with the Java Persistence API. The business layer is build by EJB technology. The business logic of application is presented by stateless EJBs.

Finally the last web layer communicates with the beans where the business logic resides with web services and it is build with FLEX technology.

3 ADAPTIVE ASSESSMENTTO LEARNING STYLES AND KLOWLEDGE LEVEL

Realization of adaptive assessment within the ADOPTA platform is a joint effort of content authors, instructors and course supervisors. The workflow phases are authoring of content for adaptive courses, construction and tuning of storyboard adaptive to learning styles and student knowledge level and, finally, adaptive content

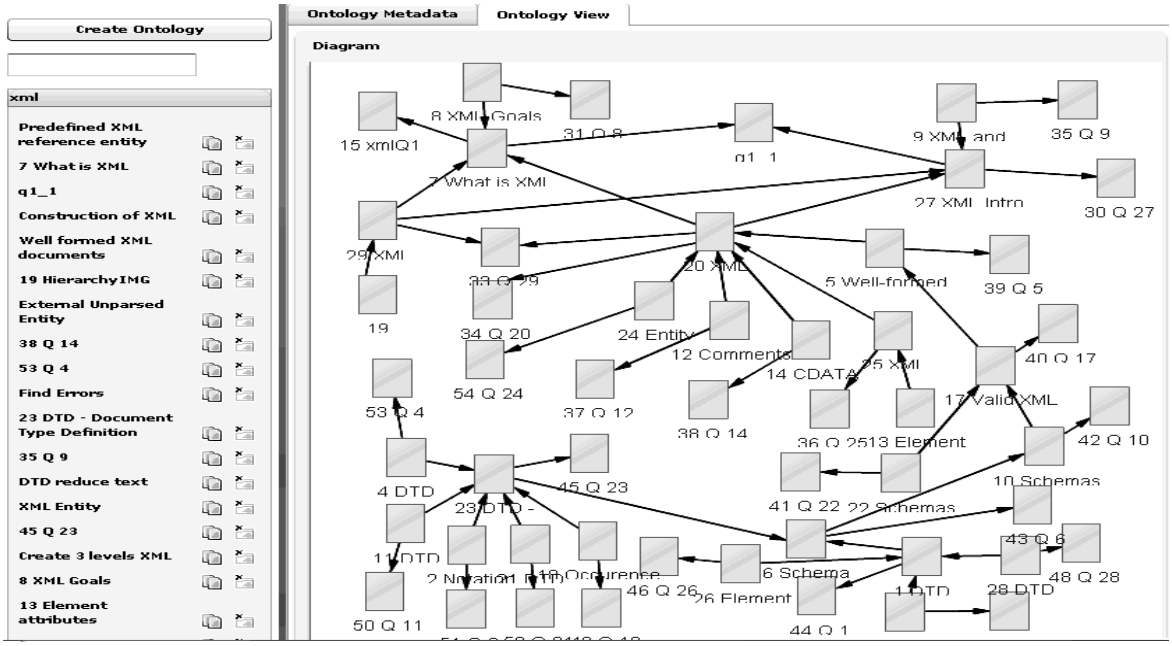

Figure 2: Partial view of ontology of the ADOPTA ontology authoring tool with LOs of a XML technology course.

delivery and assessment by means of estimable LOs such as essays, projects, test, etc.

3.1 Content Authoring

Content authoring is possible by means of special authoring tool providing LO metadata support based on inheritance (Vassileva et al, 2009). Here, the author should provide many LOs of various types such as narrative LO (lesson), exercise, project, essay, problem solving and others, in order to be used next by instructors when creating course storyboard graphs by means of the instructor tool.

The author organizes LOs within a domain ontology having two main types of relationships: IS_A and HAS_A. Fig. 2 shows a partial view of such an ontology for a course of XML technologies given to bachelor students. Questions are special types of learning objects in the ontology and may be related to the narrative LO they concern. While IS_A relations are used for typefication of most LOs of the course, HAS_A relations link question LOs to the objects they refer to. Like the approach of (Wen, 2007), we use for types of relations "Enable", "Disable", "Plus" and "Contradictory". As well, there may be used another types, as follows:

- Complementary – relation of such a type links one question to other questions which are complementary to the first one; means that one of complementary questions may be used after the first one;
- Opposite – links one question to another being opposite of the first; means that these two questions are adversative.

As well, for each of the LOs of type question the author is supposed to provide item metadata divided into two parts - descriptive and psychometric as specified in (Ibraheem, 2003). For an easy manipulation of LO metadata, non-monotonous inheritance support is provided meaning metadata is inherited within the ontology while some of the fields may be overridden or added for given LO.

3.2 Course Storyboarding

While designing storyboard graphs by means of the ADOPTA instructor tool, the instructor is supposed to be concerned about two issues:

- development and tuning of a storyboard graph containing paths with pages containing LOs appropriate for different learning styles
- selection and distribution among the graph pages of LOs with different level of difficulty in order to be delivered next to learners with appropriate knowledge level.

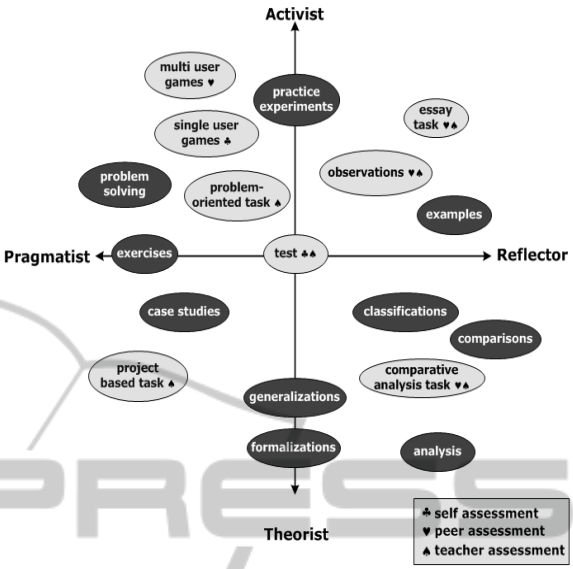

Figure 3: Partial view of XML course ontology.

The first task is not so trivial, as far as there is no existing stable mapping between LOs types and learning styles. Fig. 3 presents a possible mapping of types of LOs to the four basic learning styles of Honey and Mumford resulted from practical experience of the paper authors in teaching students for many years. It has been found that games, essays, projects, problem-solving, comparative analysis and observation tasks may be used for assessment not less efficiently than traditional tests. Thanks to their appropriateness to different learning styles, LOs of these types are selected as candidates for assessment adaptive to learning styles and have names shown in black letters while narrative LOs have names in white labels. For example, games and problem-solving tasks are suitable for assessment of both pragmatists and activists, while comparative analysis tasks are mostly suitable to theorists and reflectors. Note, that these types are distinguished according their suitability for one or more of the assessment approaches mentioned in section 2:

- for self assessment – there are nominated single user games and test (auto-generated based on the ontology relationships);
- for peer assessment – there are used multi-user games (the opponent of a learner appears as peer assessor), essay, observation, and comparative analysis tasks;
- for teacher assessment - essay, observation, and comparative analysis tasks plus projects and tests.

At the very beginning of the storyboard design process, the instructor is guided only by possible learning styles of students. For this purpose, the storyboard graph has to have a few initial nodes or to start from a node giving basic information and, next, to fork the working (i.e., learning) paths (WPs) within the graph designed by the instructor tool. For construction of the adaptive course storyboard graph, the instructor may follow a strongly connected storyboard approach or graph design using parallel branches. Educational content with the branch for predominant activists contains more examples, while materials for theorists are given with more detailed explanations and formalization within another branch. LOs intended for pragmatists are presented by practical tasks and exercises, while these for reflectors are reporting, analysis and comparisons.

Finally, the instructor has to tune the weights for the existing working paths. Each weight consists of values for activist, theorist, reflector and pragmatist, stating the level of suitability of the path for each style. As well, the instructor has to select LOs of various level of difficulty in order to meet different student knowledge levels.

3.3 Adaptive Content Delivery and Assessment

Before starting a course, individual learners pass through a pre-test determining their learning character. Usually, a learning character contains a combination of the four learning styles expressed in different degree by different weights. Next, the adaptation control engine will select a path best suited to individual learner character of given learner. According distribution of LOs types to learning styles, different students will receive different narrative and estimable LOs. Estimable LOs will be used for a total adaptive assessment where students with different styles will receive different tasks (essays, projects, problems to be solved, etc.) as shown in fig. 3. There different tasks will be used for a complex final grade of the course. Of course, adaptive assessment tests do participate into the final grade – in control pages the control engine generates automatically adaptive tests by selecting questions related to the LOs delivered to a learner via the work path. The selection is based on the relation types explained in section 4.1.

After solving the test at a control point, the learner is passed back to the previous control point if his/her result is less than the threshold set for passing this control point. In this case, the adaptation control engine will select a different path for this learner. Otherwise, to the learner there is proposed a new path leading to the next control point and most appropriate to his/her learning style. The result of the assessment (equal or greater the threshold set for passing that control point) will be used by the engine for selection of LOs with appropriate level of difficulty. Thus, individual learners undergo assessment process adaptive to their learning styles and, as well, knowledge level.

4 PRACTICAL RESULTS

The ontology, LOs, and storyboard shown above in this paper have been used for preparing a part of an adaptive course in the domain of XML technologies. This part of the course has been given to more than 70 bachelor students (fourth year) by means of ADOPTA as both adaptive courseware delivery and adaptive assessment, while the rest of the course has been presented as a traditional non-adaptive course. Students have passed separate assessments for both the adaptive and non-adaptive part of the course. Next, they have filled an inquiry with many questions aiming at revealing their attitude to the adaptive and non-adaptive e-learning approaches. Having summarized the inquiries and assessment results, we are able to conclude the following:

- Students have shown better results when dealing with adaptive content delivery and testing than with non-adaptive ones;
- Students do prefer adaptive content delivery and assessment based on learning styles and knowledge level than traditional methods;
- All the learners like much more complex assessment based on various types of tasks given adaptively according learning styles, than traditional test-based assessment;
- Students do prefer having self- and peer assessment before official assessments;
- Students appreciate very much inclusion of games - both single-user such as hangman, quizzes, and word puzzles and multi-user games within the ADOPTA platform
- Students require mobile games, tasks and assessments to be included into the adaptive e-learning process.

5 CONCLUSIONS

Until present, researchers and practitioners regard adaptive assessment mainly as application of computerized adaptive testing. Such systems make use of item response theory as a key instrument for practical construction of adaptive assessments based on adaptive tests. The present paper presented a broader view of adaptive assessment, where tests are not the only (and, eventually, the best) instrument for evaluation of learners outcomes gained during a course. It has shown that adaptive task-based assessment may be combined with traditional adaptive test assessment for achieving better results and, not last, student satisfaction and approval.

Authors have explored suitability of various types of tasks for assessment adaptive to learning styles and student knowledge level. By means of constructing course storyboard with several branches for different learning styles, it has been proven that games, essay, observation, and comparative analysis tasks plus projects and auto-generated tests may be used successfully for a complex adaptive assessment. There have been explored the approaches of self-, peer- and teacher- (i.e., host) assessment by using appropriate types of estimable learning objects.

The future works on adaptive assessment by using the ADOPTA platform will explore the abilities of more types of relationships among questions for realization of adaptive test assessment. As well, authors plan to develop and experiment more types of games for both self- and peer assessment.

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