A new competency-based e-assessment data model

Implementing the AEEA proposal

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Abstract. **There are two unsolved problems in the field of virtual learning environments: a set of new types of assessment is required for learning management systems (LMSs), and there is a need for a way to assess lifelong adaptive competencies. Proposed solutions to these problems need to preserve the interoperability, reusability, efficiency and abstract modeling already present in LMSs. This paper introduces a competency assessment data model (CADM) being developed as part of adaptive evaluation engine architecture (AEEA). AEEA is designed to solve the above-mentioned problems while fulfilling all quality requirements. The CADM is described with a data centric model using XML for each assessment scenario.**

Keywords: Competencies, Adaptive Assessment; Competency Assessment Process; New Assessment Types; Virtual Learning Environment.

I. INTRODUCTION

IMS question and test interoperability (IMS-QTI) [1] is an open technical e-learning specification to support the interoperability of systems and the reusability of assessment resources. Items and testing can be expressed and interchanged using IMS-QTI assessment. IMS learning design (IMS-LD) [2] is a specification for a meta-language which enables the modeling of learning processes, and is designed to express many different pedagogies. The activities to develop in a learning design can be expressed with IMS-LD.

In order to support new types of assessment in an e-learning process while preserving interoperability, reusability, efficiency and abstract modeling, new models to extend the current e-assessment specifications are required. In [3] and [4] a UML model is proposed to extend and combine IMS-QTI and IMS-LD specifications. [5] - [8] show how an outcome variable of a QTI test can be coupled to an IMS-LD property, and how assessment application tools can be integrated with IMS-LD as services. [9] and [10] propose the creation of a new layer over IMS-QTI and IMS-LD data, thereby establishing a new specification by building a high-level assessment process modeling meta-language. The LAMS project [11] is another kind of proposal based on IMS-LD and IMS-QTI specifications, but a totally new specification is being built to support a whole range of possibilities in e-assessment.

The development of lifelong competencies is a global tendency that uses the e-learning process to eliminate space and time barriers. This is the background against which new pedagogical models supported by new assessment process models are needed.

These two ideas were taken into account in [12] when adaptive evaluation engine architecture (AEEA) was proposed. AEEA is a competency-based adaptive assessment process for to judge the competencies of learners in a virtual learning environment. The process is supported by extensions for educational specifications and for integral user modeling. In order to implement AEEA, four data models must be integrated: a competency data model [13] and [14], a user model [15] [16] [17] [18], a competency assessment learning design model [19], and a competency assessment data model (CADM). The design of a CADM, which includes the entire data model for e-assessment scenarios proposed in AEEA (formative peer assessment, formative teacher assessment, self assessment and summative assessment), is presented in this paper. It is described with a data centric model using XML for each assessment scenario.

The assessment items metadata and the test metadata are based primordially on the IMS-QTI specification and complemented with XML data on the appraised competencies.

The paper is structured as follows: in Section 2 the relationship between competencies and e-assessment is described. In Section 3 an AEEA overview is presented. In Section 4 a competency data model, user model and competency assessment learning design are explained. In Section 5 the new competency assessment data model is proposed. In Section 6 conclusions and proposals for future work are laid out.

II. COMPETENCIES AND E-ASSESSMENT

Competency acquisition is the process through which people engage in activities or solve everyday problems in a professional or work context, through the joint exercise of three types of knowledge: know-how, knowing how to learn and knowing how to be, accompanied by critical awareness and the taking of responsibility for actions undertaken [20].

Competencies based on a virtual learning process join theory and practice, contextualize training, guide the organization of content and activities, promote comprehensive education (the three types of knowledge) and establish

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mechanisms for rigorous ongoing assessment based on performance in problematic situations in the relevant context (discipline, social, scientific, etc.). To address a competency acquisition process, LMSs need to transform their learning design and assessment methods.

To carry out a competency acquisition process the traditional summative assessment provided by an LMS must be complemented with other types of assessment. Formative assessment, self assessment, peer assessment and 360-degree feedback might all be considered. This information is stored within a portfolio assessment to obtain an all-round measurement of the level of competency acquisition.

- Assessment can be considered *formative* when the feedback from learning activities is used to adapt the teaching to meet the learner's needs or to encourage students to take control of their own learning.
- *Self assessment* is where students make judgments about their own work. Students critique their work and form judgments about its strengths and weaknesses.
- *Peer assessment* is student assessment of other students' work, both formative and summative.
- In e-learning *360-degree feedback* refers to feedback that comes from all the different actors around the student. The name refers to the 360 degrees in a circle, with the student at the center of the circle. Feedback is provided by subordinates (e.g., where the student is leader of a team), peers, and teachers. It also includes self assessment and, in some cases, feedback from external sources. Fig. 1 shows the relationships between participants in 360-degree feedback in e-learning.
- *Portfolio assessment* provides evidence of the learning process as an active demonstration of knowledge. It is used to evaluate learning processes and learning outcomes, as well as to encourage student involvement in their assessment, their interaction with other students, teachers, parents and the larger community.

During a course each type of assessment produces at least one outcome variable linked with some assessed competence. The set of outcome variables allows student classification. Based on this classification, an adaptive decision is made about changing the path and resources for students in their learning design. Fig. 2 shows the proposed competency acquisition run time process

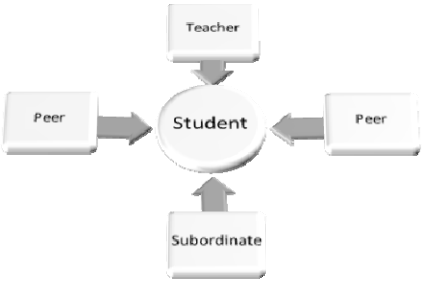

Figure 1. 360-degree feedback in e-learning

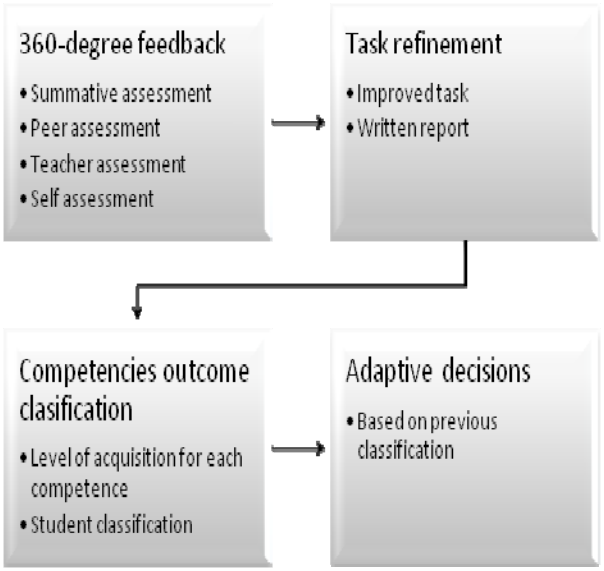

Figure 2. Competency acquisition run time process

III. AN AEEA PROPOSAL OVERVIEW

The main aims of AEEA [12] are: 1) to create an adaptive assessment structure in the learning design based on a definition of the competence element; 2) to build repositories of assessment items and tests with additional meta-information about the competencies assessed; 3) to build different, new, assessment engine software tools integrated within an LMS; and 4) to define a set of rules to drive learning design adaptations aimed at producing an adaptive competency e-assessment process.

AEEA is composed of two packages: an *Author Assessment Package* to support design time process steps and a *Monitoring Assessment Package* to support the run time process steps.

The first package proposed in AEEA, the *Author Assessment Package* (Fig. 3), covers the first three steps of an e-assessment process at the design stage:

- *Competency Assessment Plan Design*: to select the sequence of appropriate assessment types to demonstrate students' competencies; to construct and define decision rules and assessment policies for adaptation.
- *Items Construction*: to prepare items of evaluation in different assessment authoring software tools.
- *Tests Construction*: to build units of assessment for each type of assessment proposed in the assessment plan. The unit must assure the type and value of the expected response in the plan.

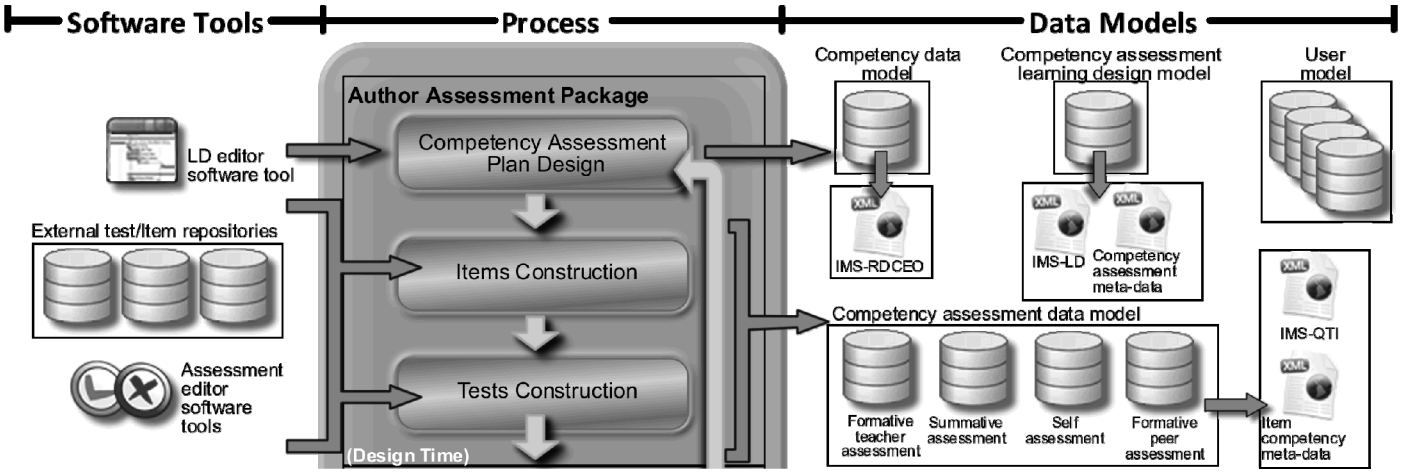

Figure 3. The Author Assessment Package of AEEA

Four data models are required for the implementation of the *Author Assessment Package*:

- *Competency data model:* this is a data model to describe the hierarchy of competencies, their characteristics and relations. Its basic specification is IMS-RDCEO [21].
- *User model:* this is a data model to describe a system user's relevant data, such as demographic information, learning style, background, etc. The basic specifications are IMS-LIP [22], IMS-AccLIP [23], and ISO-PNP [24].
- *Competency assessment learning design model*: this is a data model to describe the assessment plan and its adaptive rules. The basic specification is IMS- LD [2].
- *Competency assessment data model (CADM)*: this is a data model to describe e-assessment scenarios (formative peer assessment, formative teacher assessment, self assessment and summative assessment.) and students' results.

Three kinds of software tools are required for the *Author Assessment Package:*

- An *LD editor software tool* is used to configure the LD assessment plan where outcome variables of QTI can be coupled to LD properties.
- *Assessment editor software tools* are used to design assessment items and tests.
- *External test/item repositories* are used to store assessment items and tests.

In the *competency assessment plan design* step, an *LD editor software tool* is used to configure the *competency assessment learning design*. The *competency data model* and the *user model* are also set up inside this step.

In the *item construction* and *test construction* steps *assessment editor software tools* are used to define and to recover assessment item and test metadata from the *CADM* data model stored in the *external test/item repositories*.

IV. Competency Data Model , User Model and Competencies Assessment Learning Design

Some of the data models needed for AEEA were built by the BCDS research group before or parallel with development of the CADM.

The *competency data model* [13] [14] describes the elements of information that can be used to specify how a specific competence can be defined, developed and monitored in an LMS. The model was constructed through the analysis of different competency models and based on curricular design theories.

IMS reusable definition of competencies and educational objectives (IMS-RDCEO) is the language used to represent and exchange competency definitions. In order to implement the model proposed, a service for competency definition [25] [26] [27].was developed in dotLRN, a well-known open virtual learning environment

With a different research purpose, a complete *user model* has been developed [15] [16] [17] [18]. This model takes into account several different user characteristics and constructs a profile for each user.

The learning style profile is an enriched abstraction of Felder's categorization and is inferred through the application of his index of learning styles [28] to users. From the 44 questions in the Felder and Silverman approach considered as input, the user model is constructed as described elsewhere [29].

Two types of competency are inferred for the competency profile by analyzing the user's interactions within a number of LMS tools. Collaborative competencies are defined by analyzing the user's behavior in tools such as forums, chat rooms and e-mails. For specific competencies, three levels – novice, average and expert – are considered. These levels are related to one or more of Bloom's objectives [30].

The growing interest in mobile and ubiquitous systems has attracted researchers' attention to other dimensions of the access device profile, such as user location, physical environment, social context, and affective state. Our approach

[31] considers a number of characteristics of the user access device, in particular hardware features such as screen size and the capacity to show images, colors, and to reproduce sounds. It also considers software characteristics such as the mime types supported, character codification, availability of java and browse capacity such as the possibility of using frames, tables, java applets, and java script.

We have developed a number of projects to determine any special needs our users may have, such as learning difficulties and sensorial limitations.

The competency assessment learning design model [19] is achieved by inputting the user modeling and learning process specification.

So far, we have developed learning designs (LDs) in a deterministic way, using a competency definition and learning object metadata. The learning design generated is a cognitive but not a specific assessment design.

However, our ultimate aim is to enrich our work through the use of different retrieval algorithms and thereby increase the complexity and the specified level of LD generation and to facilitate the teacher's design task.

V. COMPETENCY ASSESSMENT DATA MODEL (CADM)

Learning management systems usually have a standard package for summative assessment. The CADM proposal therefore focuses on the development of data models for the other three types of assessment (formative peer assessment, formative teacher assessment and self assessment).

XML schemas describe, with a high level of abstraction, the structure of and restrictions on the contents of XML documents in a very precise way, beyond the syntactical rules of XML [32]. Different XML schemas are proposed in a CADM to provide the extensibility, interoperability, reusability; efficiency and abstract modeling required for the new data model. These XML schemas become an extension of the IMS-QTI specification used for summative assessment.

For each new assessment scenario, a CADM proposes two XML schemas, the first to represent assessment items and the second to represent tests. The scenarios and schemas are explained below. The schemas are shown as tables (for space reasons) emphasizing their most significant elements.

A. Schemas for formative peer assessment

Formative peer assessment (FPA) can be developed in three modalities: *individual,* when students complete their assignments alone and other students on the course peer review their work; *intra-group,* when the students work on a collaborative task in groups and each member is judged by the others; and *inter-group,* when the students on a course are divided into subgroups to carry out a task and the peer review of one group is performed by another. FPA schemas need to allow for data modalities to be set up.

The actors in this scenario are the teachers who direct protocol evaluation as e-moderators, the peer reviewers and the learners. FPA schemas need to allow for grants to be set up for these participants.

[33] suggests that to be successful, the peer evaluation process should first involve students in a discussion of the rating scale and the construction of the evaluation form. After this, the peer review can be done. As a final step, learners make changes to their work and write a report justifying the changes accepted and those rejected. This means FPA schemas should allow a rating scale to be set up and assessment items on the evaluation form to be enabled or disabled. [34] declares that peer forms must contain rich, detailed, qualitative feedback information about strengths and weaknesses, and not merely a mark or a grade. The schemas should also allow rating data and comments about strengths and weaknesses to be saved. Rating data are defined using a rubric to score the quality characteristics of the evaluation items.

Table I presents the characterization of the elements and sub-elements of the schema for FPA items and Table II presents the characterization of the elements and sub-elements of the FPA test schema.

B. Schemas for formative teacher assessment

Formative teacher assessment (FTA) must take place for all tasks on which students are assessed, so it could be carried out for individual or collaborative tasks. Assessment items represent quality characteristics linked with a level of competence acquisition. A rubric score is stored for each assessment item.

Table III shows the characterization of the elements and sub-elements of a schema of TFA items and Table IV shows the characterization of the elements and sub elements of a TFA test schema.

C. Schemas for self assessment

Students take a short test to assess their interests, skills, abilities and competencies in every task. Assessment items are linked with competencies and qualified with a general rubric score.

Table V shows the characterization of the elements and sub-elements of the item schema. Table VI presents the characterization of the elements and sub elements of the test schema.

TABLE I. ELEMENTS OF THE SCHEMA FOR FPA ITEMS

<quality_characteristic> <title> <description> <competence_knowledge> <competence_context> </quality_characteristic >	This describes a quality characteristic that can be evaluated in a student's work. Each quality characteristic is linked with a competence.

TABLE II. ELEMENTS OF FPA TEST SCHEMA

<modality> <type></type> <number reviews> <anonymous> </modality>	This describes the type of modality, number of peer reviews and a Boolean element to say whether the learner can know their peer reviewers or if the evaluations are to be anonymous.
<outcomes> <outcome> <name> <value> <competence-id> </outcome> </outcomes>	This describes the outcomes of the assessment. Each outcome is linked with a competence.
<grants> <teacher></teacher> <peer></peer> <learner></learner> </grants>	This describes each actor's or user's grants at the FPA interfaces. It determines whether a user can insert new items or areas of assessment, vote on items to include in the form, make a review or read results.
<rating scale> <min-value> <max-value> <number categories> </rating scale>	This describes the rubric score applied to assessment items. The rubric score is defined with the minimun value, the pass value, the maximun value, and the number of categories.
<items> <item> <id></id> <path></path> <weighting> <grade></grade> <item> </items>	This describes the set of items linked with an FPA test. The items are quality characteristics evaluated with a scoring rubric and a percentage weighting.
<strengths> <comment> <peer-reviewer-id> <notes> </comment> </ strengths >	This describes the reviewer's comments regarding strengths in the evaluated work.
<weaknesses> <comment> <peer-reviewer-id> <notes> </comment> </weaknesses>	This describes the reviewer's comments regarding weaknessess in the evaluated work.

TABLE III. ELEMENTS OF A SCHEMA OF FTA ITEMS

<quality_characteristic> <title> <description> <competence_knowledge> <competence_context> <rubric1-info></ rubric1-info> <rubric2-info></ rubric2-info> <rubric3-info></ rubric3-info> <rubric4-info></ rubric4-info> </quality_characteristic >	This describes a quality characteristic that can be evaluated in a student's work. Each quality characteristic is linked with a competence. The description of the rubric score scale is saved within the item.

TABLE IV. ELEMENTS OF A FTA TEST SCHEMA

<task> <type></type> <name></name> <task-id></task-id> </task>	This describes general data on the task: type of task (individual or collaborative), name and task identifier.
<outcomes> <outcome> <name> <value> <competence-id> </outcome> </outcomes>	This describes the outcomes of the assessment. Each outcome is linked with a competence.
<grants> <teacher></teacher> <learner></learner> </grants>	This describes the grants for each actor or user at the interfaces of TFA. It permits defining if a user can insert new items or areas of assessment, vote on items to include in the form, review or read results.
<items> <item> <id></id> <path></path> <weighting> <grade></grade> <item> </items>	This describes the set of items linked with a FTA test. The items are quality characteristics which are evaluated with a rubric score and a weighting.
<strengths> <comment> <teacher-id> <notes> </comment> </ strengths >	This describes the teacher's comments about strengths in the evaluated work.
<weaknesses> <comment> <teacher-id> <notes> </comment> </weaknesses>	This describes teacher's comments about weaknessess in the evaluated work.

TABLE V. ELEMENTS OF SELF ASSESSMET ITEM SCHEMA

<quality_characteristic> <title> <description> <competence_knowledge> <competence_context> </quality_characteristic >	This describes a quality characteristic that can be evaluated in a student's work. Each quality characteristic is linked with a competency. The description of the rubric score scale is saved within the item.

TABLE VI. ELEMENTS OF SELF ASSESSMET TEST SCHEMA

<task> <type></type> <name></name> <task-id></task-id> </task>	This describes general data on the task: type of task (individual or collaborative), name and task identifier.
<outcomes> <outcome> <name> <value> <competence-id> </outcome> </outcomes>	This describes the outcomes of the assessment. Each outcome is linked with a competency.
<grants> <teacher></teacher> <learner></learner> </grants>	This describes the grants for each actor or user at the interfaces. It permits defining if a user can insert new items or areas of assessment, vote on items to include in the form, review or read results.
<rating scale> <min-value> <max-value> <number categories> <rubric1-info></ rubric1-info> <rubric2-info></ rubric2-info> … <rubricN-info></ rubricN-info> </rating scale>	This describes the rubric score applied to assessment items. The rubric score is defined with a minimun value, a maximun value, the number of categories and their descriptions.
<items> <item> <id></id> <path></path> <weighting> <grade></grade> <item> </items>	This describes the set of items linked with the test. The items are quality characteristics evaluated with a rubric score and a weighting.
<strengths> <comment> </comment> </ strengths >	This describes students' own comments about strengths in the evaluated work.
<weaknesses> <comment> </comment> </weaknesses>	Ths describes students' own comments about weaknessess in the evaluated work.
<findings> <comment> </comment> </findings>	This describes students' own comments about findings in the evaluated work.

VI. CONCLUSIONS AND FUTURE WORK

Assessments play a significant role in the competence acquisition process and there is a clear need to run interoperable and adaptive competence assessment tests in LMSs. The traditional summative assessment of LMSs must be accompanied by other types of assessment. Metadata about assessed competencies must be defined and monitored throughout the e-learning process, and therefore the competency data model, learning design and assessment must work together.

In this paper a competency assessment data model is proposed as part of AEEA implementation. Three new types of model are proposed (schemas for formative peer assessment, formative teacher assessment and self assessment) as an extension of the IMS-QTI specification. Competency data are introduced in assessment items and test metadata. Other research is integrated to implement the author assessment package of AEEA.

Our work is now focused on the first package of AEEA implementation, in particular on developing assessment editor software tools, the integration of a competency data model with competency learning design and a CADM, and also on preparing assessment items in different repositories.

For the future, we plan to implement assessment software tools such as dotLRN and Moodle services and provide proof of the design-time architecture.

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