Linking educational specifications and standards for dynamic modelling in ADAPTAPlan

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Abstract. ADAPTAPlan project provides dynamic assistance to support the author in developing instructional design tasks which are included in learning design templates generated in terms of user modelling, planning and machine learning techniques, and making a pervasive use of educational specifications (IMS family) and standards (IEEE-LOM, ISO PNP). In this paper we describe how these standards and specifications are linked to support the dynamic modelling. Three types of user characteristics are considered in order to generate adaptation: i) Felder learning styles, ii) the knowledge level based on Bloom's Taxonomy and iii) collaborative competency levels. The modelling is performed in ADA+, a multi-agent architecture that applies collaborative filtering, machine learning and fuzzy logic techniques on the learners' interactions to support the development of personalised learning paths and to generate dynamic recommendations to be provided during the course execution.

Keywords: Learning objects, Metadata, Learning design, Competences, IMS Global Learning Consortium, Knowledge representation, Educational standards, Educational specifications, Felder learning styles, Bloom Taxonomy, Multi-agent systems, Machine learning, Fuzzy logic, JADE agents, Weka.

1 Introduction

ADAPTAPlan project provides dynamic assistance to authors to support the authoring of instructional design tasks in terms of learning design templates generated with user modelling, planning and machine learning techniques and making a pervasive use of educational specifications and standards. The purpose is to reduce the design effort, which is proven as a major bottleneck in adaptive standard-based learning management systems that support the full life cycle of eLearning [1]. Current educational specifications assume an ideal design scenario where all required elements can be managed at design time. Nevertheless, diverse issues makes unaffordable to design in advance all possible situations: a) learners' performance, b) synchronization and termporization issues, c) evolving learners' needs and preferences, d) adaptation process sustainable over time, e) pedagogical requirements affected by runtime adaptations, f) dynamic modelling.

To cope with these issues, ADAPTAPlan approach relies on a pervasive use of educational specifications and asks the author to add semantic on those elements that the author has traditionally defined (e.g. materials, learners, competences, objectives, …) and exempts him/her from describing alternative learning routes for different types of learners according to their features [2]. In turn, a planning engine takes as input the information provided by the author and the user model dynamically built from the learner's interactions to generate a personalized Unit of Learning (UoL) described in terms of IMS Learning Design specification [3]. ADA+ multi-agent architecture is used to build the user model and provide the dynamic support to learners. It applies collaborative filtering, machine learning and fuzzy logic techniques on the learners' interactions to support the development of personalised learning paths and to generate dynamic recommendations to be provided during the course execution. Details are given elsewhere [4].

2 Educational Specifications and Standards

Specifications describe in a precise, complete and verifiable way the requirements, design and behaviour of a system [5]. If they pass a validation process, they become standards.

To support design time adaptations and improve accessibility, reusability and maintenance in the ADAPTAPlan project we are using in an intensive way the specifications generated by the IMS Global Learning Consortium. In particular, IMS Learner Information Profile (IMS-LIP) [6], IMS Access For All (IMS-AccLIP) [7], IMS Question and Test Interoperability (IMS-QTI) [8], IMS Learning Design (IMS-LD) [9], IMS Reusable Definition of Competency or Educational Objective (IMS–RDCEO) [10], IMS Content Packaging (IMS-CP) [11] and IMS Metadata (IMS-MD) [12]. The later is superseded by IEEE LOM standard [13]. Furthermore, ISO standard on Individualized Adaptability and Accessibility in e-Learning, Education and Training (Personal Needs and Preferences), which is derived from IMS Access For All, will be considered when it is publicly available[1]. Each of them focuses on specific functions in the design and execution of the learning process in the context of a virtual learning environment.

IMS-LIP provides the general framework to define the general user characteristic, such as identification, goals, certification and licenses, acquired competencies, interests, etc. It can be linked to other specifications like IMS-RDCEO, which define the user competences.

IMS-AccLIP is an extension of IMS-LIP that considers the users preference regarding accessibility. IMS-AccLIP modifies the <*accessibility*> element in IMS-

[1] http://jtc1sc36.org/doc/36N1139.pdf, 36N1140.pdf and 36N1141.pdf at the same base URL, visited 6th May 2007 (expected to be publicly available at the end of 2007).

LIP, by removing the <*disability*> element and by addition of the <*AccessForAll*> element in this label. This new element considers information about how the materials are displayed, how the learner interacts with the system and the learner's preference about the content.

IMS-QTI uses the ASI model (Assessment-Section-Item) to define reusable evaluations. These evaluations and its parts can be interchange between different kinds of systems.

IMS-LD formalizes the design of a learning process in a Unit of Learning (UoL). The specification defines three levels of detail. Level A offers the necessary vocabulary to express a general learning process. It considers the definition of different user roles in the process (e.g. teacher and learner), the creation of activities composed by scenarios or environments and the utilization of learning objects in these environments. The second level, level B, adds the possibility of defining conditions based in properties about the individual user or roles. Finally, the level C allows the definition of a notification mechanism between roles.

IMS-LD can be linked from the <*environment*> element to IMS-QTI specifications. The evaluations are considered resources in IMS-LD. Moreover, the properties in IMS-LD can refer to attributes of the IMS-LIP or IMS-AccLIP specifications. Thus, it facilitates personalisation at course level or assessment level.

IMS RDCEO is a minimalist but extensible-based XML data model to define competencies or learning objectives. With this model it is possible to achieve a clear definition of competencies. It does not adjust to any particular curricular model and depending of the author different characteristic elements of the competency can be considered. Each UoL in a LD refers to objectives that can be associated to an IMS-RDCEO competence definition.

Additional to the above specifications, we are also using IEEE LOM standard / IMS-MD specification to characterize the learning objects and IMS-CP specification to generate or import packages with different kind of resources, such as courses and evaluations.

3. User characteristics for Adaptation

Three user characteristics are considered in ADAPTAPlan project [3] in order to generate adaptation: 1) Felder Learning Styles [14], the Knowledge Level based on Bloom's Taxonomy [15] and the Collaborative Competency Levels [16].

In [4] we introduced how we are managing the learning styles in the project. We have defined clusters for each of the 4 Felder's dimensions (Input, Processing, Understanding and Perception) in order to clearly separate the preference of different students. Table 1 shows how the clusters are assigned for the Perception dimension.

Table 1. Clusters for Felder's Learning Styles (Perception dimension)

CLUSTER	VALUES	STYLE DESCRIPTION
Balanced	1s, 3s, -3i, -1i	Sensitive / Intuitive
Moderated	5s, 7s, -7i, -5i	Sensitive / Intuitive
Strong	9s, 11s, -9i, -11i	Sensitive / Intuitive

The user's knowledge model is based in the Bloom Taxonomy [15]. It considers six levels of knowledge (Knowledge, Understanding, Application, Analysis, Synthesis and Evaluation). The student acquires these levels through the learning process by the study of the learning objects for the subjects of the course and the performance of the associated activities. The knowledge is the main element of a competency (although not the only one) since it influences the adequate performance of a person in a specific context. For this reason, we relate the student knowledge with a level of a specific competency.

Finally, we consider the six Collaborative Competency Levels defined in [16] (see table 2). We decide to separate this type of competency because it defines important aspects in the collaborative and cooperative behavior of the student. We are interested in modelling these user characteristics in order to establishing their relation with the success of the learning process.

Table 2. Level for the Collaborative Competency Table

LEVEL	OBJETIVE	DESCRIPTION
1	Participative_Learner	Interacts frequently in the course
2	Non_Colaborative_ Learner	Behaves as if there are no collaboration facilities.
3	Comunicative_Learner	Shares information with other learners using the available communication tools.
4	With_iniciative_Learner	Starts the proposed activities without waiting for other student's contributions.
5	Insightful_Learner	Makes contributions and comments on activities from other learners that later receive high scores.
6	Useful_Learner	Makes comments and contributions that are considered by other learners.

These competency levels have to be promoted for each student. Monitoring their achievement by the system can facilitate the generation of recommendations to encourage collaboration when needed.

Now that we have defined the learners' characteristics used for the adaptation, it is necessary to establish the relationship between these characteristics and the attributes in each of specifications mentioned above, which we are using to model the learning process (see table 3).

Table 3. User characteristics vs. IMS-LIP and IMS-RDCEO Specifications.

USERS CHARACTERISTICS	LIP – RDCEO SPECIFICATIONS ELEMENTS	POSSIBILITIES
FELDER LEARNING STYLES	accessibility.preference.typename.tyvalue accessibility.preference.prefcode	- Learner_Style_Processing - Learner_Style_Understanding - Learner_Style_Perception - Learner_Style_Entry
COLLABORATION COMPETENCY LEVELS	IMS – RDCEO Rdceo.identifier Rdceo.statement.statementname Rdceo.statement.statementtoken	- Participative_Learner - Non_Colaborative_ Learner - Comunicative_Learner - With_iniciative_Learner - Insightful_Learner - Useful_Learner
KNOWLEDGE COMPETENCY LEVEL	IMS – LIP Lip.competency.contentype.referential.indexid Lip.competency.exrefrecord	- Novice_Level (Bloom Knowledge and Comprension Levels) - Mean_Level (Bloom Application Analysis and Synthesis Levels) - Expert_Level (Bloom Evaluation Level)

The learning styles are linked to the <*preference*> element in IMS-LIP, which "it can be used to describe the physical environment required, the input/output technology required and also the learning styles that best suit the individual" [6]. For each learner there are four instances of this element, one by each dimension of Felder theory. The attribute *prefcode* stores the value of the dimension (balanced, moderate or strong). The learning styles are obtained from Felder Test [14].

The definition of the competencies is performed using the IMS-RDCEO specification. For each competency, an identifier is defined. In the <*statement*> element, specifically in statementtoken, the level of the competency is established. These values are dynamically generated through the analysis of learner interactions with the learning objects and activities and the evaluations results. Each competency is also referred in the <*competency*> element present in IMS-LIP.

In the table 4 examples of these definitions are presented.

Table 4. Examples of elements definitions

USERS CHARACTERISTICS	LIP – RDCEO SPECIFICATIONS ELEMENTS
FELDER LEARNING STYLES	accessibility.preference.typename.tyvalue= Learner_Style_Processing accessibility.preference.prefcode=visual.strong
COMPETENCIES	rdceo.statement.statementname = collaborative competency rdceo.statement.statementtoken = Participative_Learner

4. Adaptation generation in ADAPTAPlan

Adaptation in ADAPTAPlan is two fold. On the one hand, it consists in the generation of personalized learning routes in IMS-LD adjusted to the users' characteristics. On the other hand, dynamic recommendations to learners are provided during the course execution. In this paper we focus on the first one.

The personalized learning routes are generated by the planning engine [3]. The system should identify the adequate learning objects, collaborative tasks and evaluations in order to present them to a particular learner. For these reason, it is necessary to define the following set of properties in the IMS-LD:

- Four global and personal properties to model Felder's learning style for each learner. These properties are related to the IMS-LIP attributes defined in Table 4.
- Six local and personal properties to model the different knowledge levels. These properties are related to a specific knowledge body and to the level of competency.
- Six global and personal properties to model collaborative competency level.

The values of these properties constitute the input for the planner to generate a learning route adjusted to the user preferences and their characteristics. However, this process is only possible if there is an explicit relationship between the users characteristics and the different kinds of resources and activities associated to the learning design [17,18]. If the resources are characterized with metadata, rules can be applied to assign the resources to the activities in the UoL. In particular, IEEE LOM is used to characterize the learning objects. In Table 5, we present the relationship between the different Felder's dimensions for the learning style and the metadata attributes of the learning objects. This information facilitates the automatic generation of environments in the UoL selecting the appropriate learning objects for each particular learner. An appropriate learning object is one which addresses at least one characteristics of the specific user.

In the case of the knowledge level, each IMS-QTI evaluation is related to a specific concept of the knowledge body and to a specific knowledge level through its associated metadata. Each learning object addresses a specific level of knowledge, too. In this way, the evaluation process updates the knowledge properties in the UoL. Depending on the values of these properties, the learning objects are selected.

The collaborative competency levels are obtained by monitoring the learners' behaviour and their interactions in the system. This task is done by ADA+ multi-agent systems.

Table 5. Relating Users Characteristics with specifications attributes

LIP	LOM Attributes
– Learner_Style_Processing (Sequential - Global) – Learner_Style_Perception (Intuitive - Sensitive) – Learner_Style_Understanding (Active - Reflective)	Learning Resource Type – Exercise (Active,Intuitive,Verbal, Sequential) – Simulation (Active,Sensitive,Visual) – Questionerie (Active, Verbal, Sequential) – Diagram (Visual, Global, Intuitive) – Figure (Visual, Global,Sensitive) – Graph (Visual, Global,Sensitive) – Index (Global,Verbal) – Slide (Verbal, Sequential) – Table (Global, Sensitive) – Narrative text (Verbal,Reflective,Intuitive) – Exam (Active,) – Experiment (Active,Sensitive) – Problem statemen (Active, Sensitive,Verbal) – Self assessment (Active, Sequential) – Lecture (Verbal,Reflective,Intuitive)
– Learner_Style_Entry (Visual - Verbal)	Format (are free defined). It can be: – Text (Reflective, Intuitive,Verbals, Sequential) – Multimedia (Sensitive, Visual) – Graphics (Sensitive, Visual, Global) – Movies (Sensitive, Visual) – Sound (Sensitive, Verbal,Sequential)
– Learner_Style_Understanding (Active - Reflective)	Interactivity Type – Active (Simulation, questionnaires, exercises, problems) – Expositive (Hypertext, video, graphics and audio) – Mixed
– Learner_Style_Perception (Intuitive - Sensitive)	Density of Semantic – Very Low (Intuitive) – Low (Intuitive) – Medium (Sensitive) – High (Sensitive) – Very High (Sensitive)
– Level of Knowledge	Difficulty – Very Easy (Knowledge Level) – Easy (Comprenssion Level) – Medium (Application Level) – Difficult (Analysis and Synthesis Level) – Very difficult (Evaluation Level)

Some rules to define what learning objects are presented to each learner are described in Table 6.

Table 6. Rules to assign learning objects to learner's features

USER FEATURES	RULES
FELDER LEARNING STYLE	IF accessibility.preference.typename.tyvalue = Learner_Style_Entry AND accessibility.preference.prefcode = A THEN lom.format = Graphics, Multimedia,Movies IF accessibility.preference.typename.tyvalue = Learner_Style_Processing AND accessibility.preference.prefcode = A THEN lom.learning.resource.type = exercise,simulatons
KNOWLEDGE LEVEL	IF locpers-property.title=" Knowledg_Varieble" and locpers-property.value > 80 THEN Rdceo.statement.statementtoken.value = Expert_Level IF locpers-property.title=" Knowledg_Varieble" and locpers-property.value < 30 THEN Rdceo.statement.statementtoken.value = Novate_Level Now, IF Rdceo.statement.statementtoken.value = Expert_Level THEN lom.dificultty = difficult,very_difficult IF Rdceo.statement.statementtoken.value = Novate_Level THEN lom.dificultty = easy,very_easy

5. Conclusions

Having in mind a general approach to provide design time and run time adaptations in open and standard-based virtual learning environments [1] in this paper we focused on design issues. More specifically, our approach supports current educational specifications (IMS family) and has been integrated in dotLRN LMS through a web services interface. In this way, interoperability and extensibility is guarantee.

In this paper we defined the user characteristics required to generate adaptations according to learning styles, knowledge level and collaborative competences. Furthermore, we described the mechanism to link together those features with learning objects and resources to be integrated in the final learning design specification.

Our approach supports different educational specifications and standards in order to generate different kinds of adaptations and is intended to lessen the workload of the authoring process directing authors' attention to those elements they are used to manage and control in learning scenarios, like the specification of learning activities, temporal restrictions, evaluations, and not so much on a thorough description of alternative learning routes for different types of learners according to their features, which in any case are strongly dependent on learners' interactions and their evolution over time.

To date we have been exploring the application of this approach to several courses. First, a course on How to teach through the Internet taught in the on-going education program at UNED from year 2000. Second, an Object Oriented Programming Course (OOPC) developed in the Shaboo Project [19]. Our initial experiences has shown that course authors are much more predisposed to provide this set of information via a web-based interface rather than defining the whole IMS-LD design.

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