A Pedagogy-driven Personalization Framework to Support Automatic Construction of Adaptive Learning Experiences

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ABSTRACT
In order to effectively exploit the wealth of content in Learning Object Repositories several issues should be addressed including the "closed corpus" problem as identified in the field of Adaptive Hypermedia as well as the "one size fits all" problem. Both are related to personalization. The creation of personalized learning experiences is considered as a necessity to cope with the overwhelming amount of available learning material. This paper presents a personalization framework that allows for the automatic creation of pedagogically-sound learning experiences taking into account the variety of the Learners and their individual needs. This framework defines a model for the representation of abstract training scenarios (Learning Designs) encoded in an instructional ontology. This ontology clearly separates pedagogy from content allowing this way the construction of real personalized learning experiences where learning objects are bound to the learning scenario at run-time taking into account information encoded in Learner Profiles.

Keywords
Personalization, Instructional Design.

1. INTRODUCTION
It becomes more and more apparent that "one size fits all" solutions are no longer enough to satisfy the Learners' educational needs. Different Learners have different learning styles, educational levels, previous knowledge, technical and other preferences and all these are parameters that affect the learning function outcome. Learners expect from systems a "personal trainer" and not a "classroom" behavior, where their personality and needs are known and taken into account. Moreover, the proliferation of the Internet and the wealth of content in Learning Object Repositories call for flexible solutions where content is not strictly bound with the learning plan but could be retrieved at run-time and ideally from many sources according to the Learner needs. This is called in Adaptive Hypermedia "open corpus". Several research areas are related with the above challenges: Adaptive Hypermedia Systems, Intelligent Tutoring Systems, and Semantic Web [1]. Although each area treats adaptivity of learning experiences from a different point of view, there is a convergence in the research community that pedagogy is important and should be represented in a consistent way. Moreover, the pedagogical model should be reusable and separated from content allowing appropriate learning resources according to the Learner profile to be bound to the training scenario at run-time.

In order to effectively support pedagogically-sound adaptive learning experiences, several issues need to be addressed:

1. Appropriate formulation and description of learning objects giving special attention to elements related with educational context (e.g. Learning Objectives).
2. Consistent representation of pedagogy separated from content according to a model that allows for the binding of appropriate learning objects to the learning scenarios at run-time.
3. Appropriate representation of Learner Profiles giving special attention to elements representing the learning

needs of Learners (e.g. learning goals, previous knowledge, learning style, educational level).

4. Specification of a personalization component that taking into account all the above constructs adaptive learning experiences that fit to the Learner's needs and preferences.

In this paper, we present a framework that addresses all the above issues exploiting existing eLearning standards. We use the IEEE LOM standard to describe learning objects and we make the necessary adaptation of this standard in order to be able to represent Learning Objectives in a structured way. Moreover, we propose a model for the representation of abstract training scenarios (Learning Designs) encoded in an instructional ontology. This model clearly separates content from pedagogy and defines reusable instructional units encapsulated in Learning Designs. This way the same Learning Designs can be applied in different instructional situations, by binding appropriate content to learning activities taking also into account the information represented in Learner Profiles. A Learner Profile usually includes information about demographic data, competencies, previous knowledge, interests, goals, technical and other preferences of the Learner. Here, we focus on the elements that should be present in order to support personalization in terms of the proposed framework. These elements could be mapped in appropriate elements of the IEEE Personal and Private Information (PAPI) and IMS Learner Information Package (LIP). Finally, we describe how the construction of adaptive learning experiences can be automated. The corresponding personalization component is able to select appropriate Learning Designs addressing the special instructional situations for each Learner and then create learning experiences by binding appropriate reusable learning objects according to the Learner Profile.

The structure of the rest of this paper is as follows: Section 2 presents a generic personalization architecture. Section 3 deals with aspects related with the formulation and description of learning objects. Section 4 presents a model for the representation of abstract training scenarios and a tool (Learning Designs Editor) that has been implemented for this purpose. Section 5 presents the important elements that should be included in a Learner Model to support the personalization framework presented in this paper. Section 6 presents the procedure of the construction of adaptive learning experiences by a personalization component. A review of the related literature is presented in Section 7 and the paper ends with some concluding remarks and future work.

2. OVERALL ARCHITECTURE

In the architecture depicted in Figure 1 one can see that in the proposed personalization framework personalized learning experiences are created in the form of SCORM packages using reusable learning objects residing at Learning Object Repositories in order to satisfy Learner needs and preferences expressed in Learner Profiles. To achieve this, the system consults Learning Designs (i.e. pedagogical templates) that describe how certain subjects should be taught.

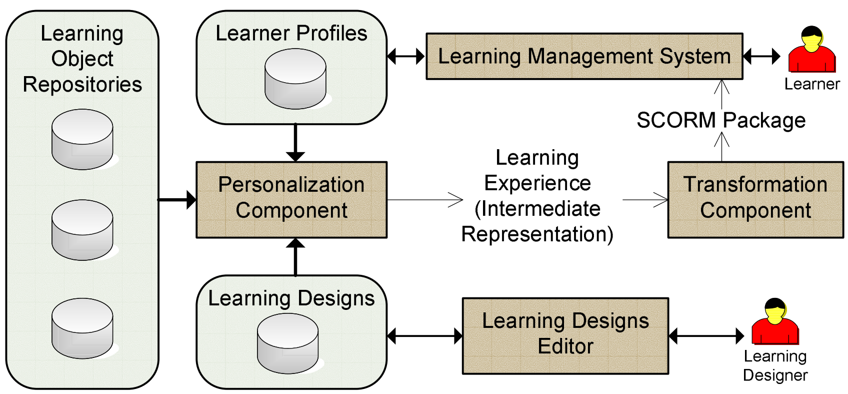

Figure 1. Overall architecture

The main component of this architecture is the Personalization Component, which takes into account the Learner Profile and tries to find an appropriate Learning Design that will be thereafter applied to the construction of a learning experience. Then, based on the selected Learning Design, which is essentially a hierarchy of activities, the component is able to bind specific learning objects to each activity using information from the Learner's Profile and builds an intermediate representation of the learning experience. Finally, a Transformation Component creates a SCORM package from this intermediate representation. A special tool, called Learning Designs Editor has been also implemented for the creation of Learning Designs.

In order to be able to retrieve learning objects from learning object repositories these should be described in a consistent way. Without being restrictive, it is proposed to use the LOM standard for the description of learning objects. If this framework is applied on top of digital libraries, we propose to use the approach that we presented in [2] in order to support multiple context views of digital objects.

It is assumed that a SCORM compliant Learning Management System (LMS) is used to deliver the constructed personalized learning experience (i.e. the corresponding SCORM package) to the Learner. This LMS is also able to track Learner's behavior and progress in order to keep the Learner Profile up to date.

3. FORMULATION AND DESCRIPTION OF LEARNING OBJECTS

Current developments in eLearning have promoted the concept of reusable learning objects. Traditionally, learning was organized in lessons and courses covering predefined objectives. In eLearning environments the material is broken into smaller independent pieces that can be used as they are or in combination with other material to form higher level objects covering the learning needs of the users on demand and at the right time.

One important issue related to the concept of reusable learning objects is their description with metadata. The most popular metadata model used is the IEEE Learning Object Metadata (LOM) standard. It is possible to represent some pedagogical properties that can be matched with corresponding properties of Learner Profiles in order to support an automated process for the construction of personalized learning experiences. However, one of the important aspects in personalization is the representation of Learning Objectives that capture the intended learning outcome of learning objects which is not directly addressed in LOM. Other elements of LOM, such as keywords or description are usually used to describe Learning Objectives. However, these simple text descriptions do not represent a formal way for defining learning objectives. Consequently, this approach presents a technical barrier because textual descriptions are not machine-readable and can not be exploited by personalization components.

To address the shortcoming described above we need to define a more formal and pedagogically-sound way of

Table 1. Bloom's Taxonomy descriptive verbs

Cognitive Category	**Learning Objectives Verbs**
Knowledge: Recall data or information.	defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states.
Comprehension: Understand the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.	comprehends, converts, defends, distinguishes, estimates, explains, extends, generalizes, gives examples, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates.
Application: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the class-room into novel situations in the work place.	applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses.
Analysis: Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences.	analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates.
Synthesis: Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.	categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes.
Evaluation: Make judgments about the value of ideas or materials.	appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarizes, supports.

```xml
<lom:classification>
<lom:purpose>
        <lom:value>educational objective</lom:value>
        <!-- Each educational objective is defined as verb from Bloom's Taxonomy)+ Topic (Ontology Concept/Individual) -->
</lom:purpose>
<lom:taxonPath>
        <lom:source>
            <lom:string language="en">http://somehost/bloomstaxonomy.owl</lom:string>
            <!-- The URL of the ontology containing the Bloom's Taxonomy Verbs-->
        </lom:source>
        <lom:taxon>
            <lom:entry>
                <lom:string language="en">explains</lom:string>
                <!-- The verb of the learning objective-->
            </lom:entry>
        </lom:taxon>
</lom:taxonPath>
<lom:taxonPath>
        <lom:source>
            <lom:string language="en">http://somehost/iconographyontology.owl</lom:string>
            <!-- The URL of the target ontology -->
        </lom:source>
        <lom:taxon>
            <lom:entry>
                <lom:string language="en">Iconographic Style</lom:string>
                <!-- The topic of the learning objective (a Concept of Iconography Ontology)-->
            </lom:entry>
        </lom:taxon>
</lom:taxonPath>
</lom:classification>
```

Figure 2. Use of classification element of LOM to represent Learning Objectives

expressing Learning Objectives, as well as their representations based on appropriate adaptation of existing LOM elements. We have chosen to use Bloom's Taxonomy of educational objectives [3] and to define Learning Objectives pairs consisting of a verb taken from a Bloom's taxonomy and a topic referencing a concept or individual of a domain ontology. The taxonomy of educational objectives [3] is comprised of six levels, namely: knowledge, comprehension, application, analysis, synthesis, and evaluation. Each level as shown in Table 1 has a corresponding set of descriptive verbs that can be used to form Learning Objectives.

In LOM, Learning Objectives can be expressed following the above approach using its classification element. The classification element describes where a learning object falls within a particular classification system. To define multiple classifications, there may be multiple instances of this category. Figure 2 shows how this element can be adapted in order to represent a specific Learning Objective.

4. LEARNING DESIGNS

Learning Designs are abstract training scenarios that are constructed according to an instructional ontology coded in OWL (Figure 3). This ontology has the important characteristic that learning objects are not bound to the training scenarios at design time, as in current eLearning standards and specifications (e.g. IMS Learning Design - IMS LD and SCORM). Whereas, pedagogy is separated and independent from content achieving this way reusability of Learning Designs or parts of them that can be used from the systems for the construction of "real" personalized learning experiences, where appropriate learning objects according to the Learner Profile are bound to the learning experience at run-time taking into account several parameters of the Learner Profile. This is possible, since the model gives the opportunity to specify in each Activity the learning objects' requirements, instead of binding the learning objects themselves, as IMS LD and SCORM impose. This ontology exploits some elements and ideas from IMS LD and LOM.

A *Training* is a collection of *TrainingMethods* that refer to the different ways the same subject can be taught depending on the *LearningStyle*, the *EducationalLevel* of the Learner and the preferred *Difficulty*. There are several categorizations of Learning Styles and Educational Levels, thus these elements are flexible so that being able to point to values of different taxonomies. A *TrainingMethod* consists of a hierarchy of reusable *ActivityStructures* built from reusable *Activities*. Each *Training*, *ActivityStructure* and *Activity* has a *LearningObjective*. Each *LearningObjective* is defined using the approach presented earlier. In particular it is composed of: (a) a *learningobjective_verb*, taken from a

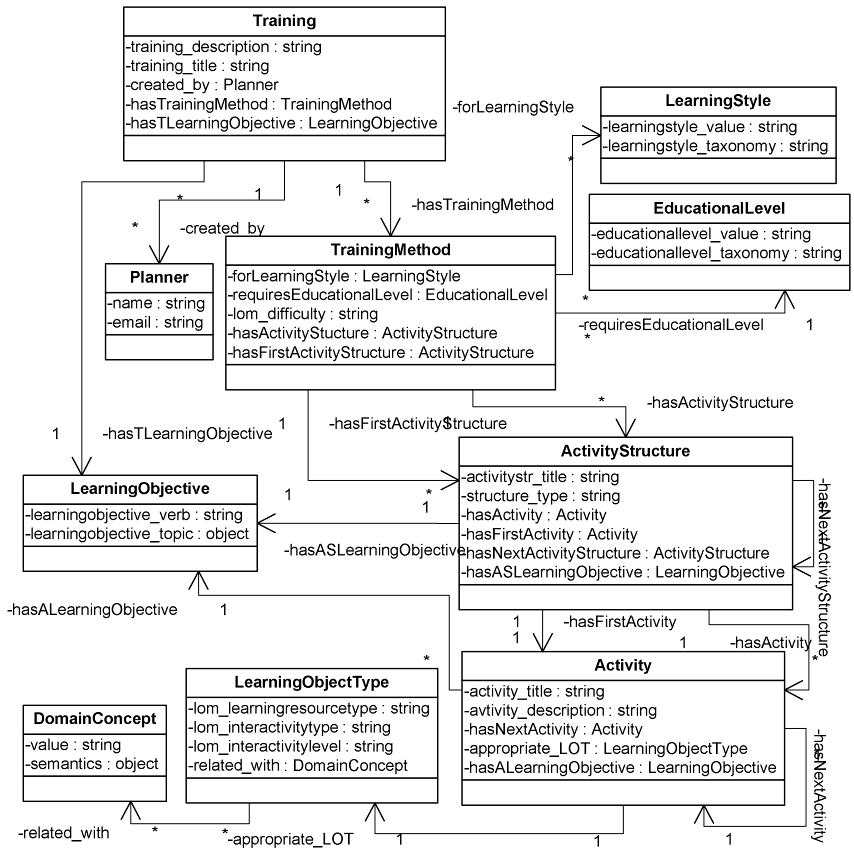

Figure 3. The instructional ontology

subset of Bloom's Taxonomy [3]) and (b) a *learningobjective_topic* that indicates the topic that the Learning Objective is about, referencing a concept or individual of a domain ontology. The *LearningObjectType* is used to describe the desired learning object characteristics without binding specific objects with *Activities* at design time. Via the *related_with* property we can further restrict the preferred learning objects according to their constituent parts (if they are semantically annotated) connecting them with *DomainConcepts* which refer to concepts or individuals from a domain ontology.

4.1 The Learning Designs Editor

The specification of Learning Designs is done using an editor that provides an intuitive GUI and is based on the above instructional ontology. The editor is able to create a Learning Design or open an existing one for further editing. Each Learning Design is presented in a hierarchical structure with its underlying Training Methods, Activity Structures and Activities in the form of a tree. Each tree node can be edited in a special form that contains all the corresponding properties. After editing a Learning Design the user can save it. At this point a set of well-formed rules are applied to check the structure of the Learning Design and find any inconsistencies that may be present and the user is informed about these inconsistencies so that he can handle them.

Figure 4 presents a screenshot of the Learning Designs Editor used to develop a Learning Design related to the teaching of Bulgarian Iconography. Four Training Methods are associated with this Learning Design forming alternative instructional paths for different combinations of learning style, educational level and difficulty. The screen shot also shows the editing form for a specific Activity inside the first Activity Structure of the first Training Method. The form contains fields for the editing of the title, the description, the Learning Objective and the Learning Object Type of the Activity.

5. LEARNER PROFILES

Our intention here is to focus on the elements that should be included in a Learner Model in order to support personalization within the framework presented in this paper. These elements could be mapped in appropriate elements of the IEEE Personal and Private Information (PAPI) and IMS Learner Information Package (LIP) using

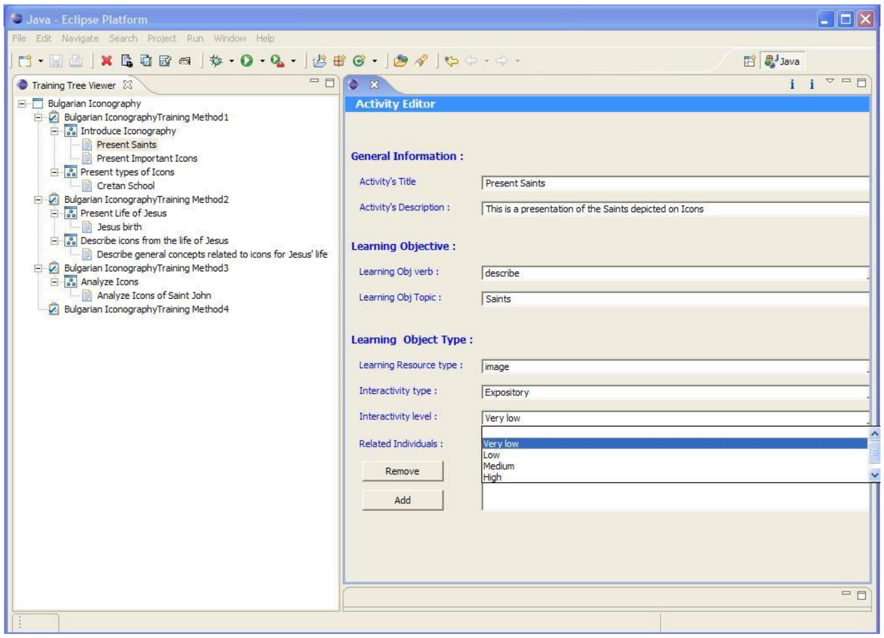

Figure 4. The Learning Designs Editor user interface

extensions. We focus on the Learner's goals and preferences and we illustrate those elements and their relations in a Learner Ontology (Figure 5).

A *LearnerGoal* is expressed in terms of *LearningObjectives* using the structure that was presented above in the instructional ontology. A Learner can have many *LearnerGoals*. A *LearnerGoal* has a *status* property (float in [0, 1]) indicating the satisfaction level of the goal

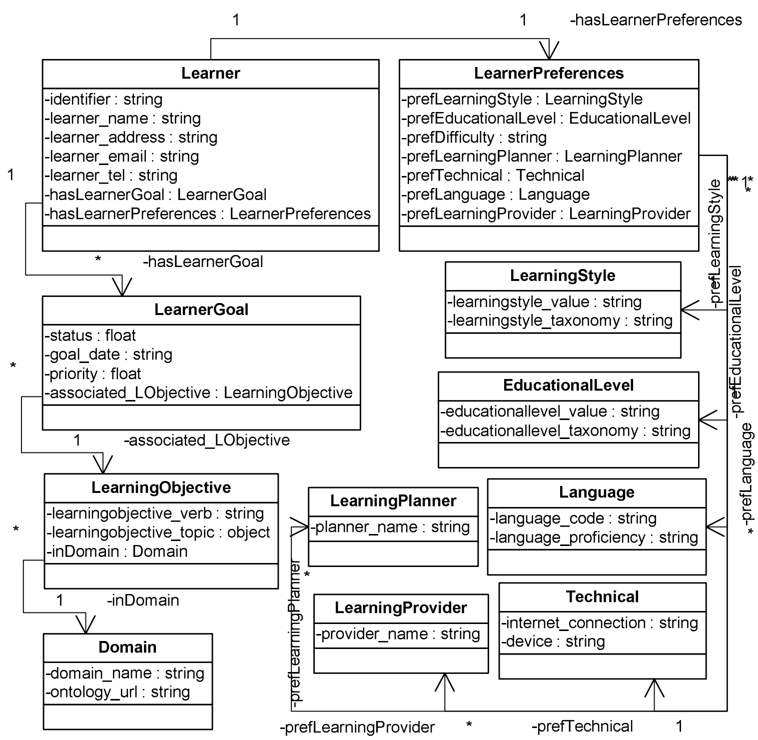

Figure 5. The Learner ontology

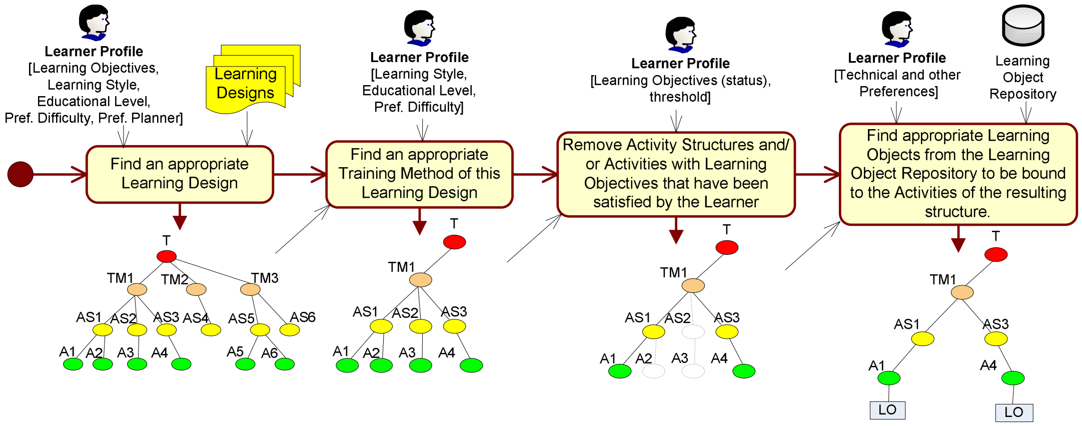

Figure 6. The procedure of generating adaptive learning experiences

(0 represents no satisfaction, 1 fully satisfied). Using this information one can also infer the previous knowledge of the Learner. The Learner can also define a priority for each *LearnerGoal*. The Learner can have several types of Preferences: *EducationalLevel* and *LearningStyle* matching with the corresponding elements of the instructional ontology, *Language*, *LearningProvider* (the author or organization making available the learning objects), *LearningPlanner* (the person that develops Learning Designs) and *Technical* preferences.

As it is described in the next section, these parameters affect both the construction of an appropriate learning path for a specific Learner according to existing Learning Designs and the selection of learning objects that are thereafter bound at run-time to the learning path to form the resulting learning experience.

6. THE PERSONALIZATION COMPONENT

The Personalization Component takes into account the knowledge provided by the Learning Designs and the Learner Profiles and constructs personalized learning experiences that are delivered next to eLearning applications in the form of SCORM packages. Specifically, the goal is to find an appropriate Learning Design that will be used thereafter to construct a learning experience adapted to the Learner's needs. As already mentioned, learning objects are bound to the learning scenario at run-time.

The procedure of constructing an adaptive learning experience is illustrated in Figure 6. In each step several parameters of the Learner Profile (given in brackets in Figure 6) are taken into account:

1. At the beginning, the component tries to find an appropriate Learning Design (Training in terms of the instructional ontology presented) taking into account the Learner's Learning Objectives, Learning Style, Educational Level, preferred Difficulty, and preferred Planner (optional).
2. When an appropriate Learning Design is found its structure is retrieved (Training(T), Activity Structures (AS), Activities(A)) and an appropriate Training Method of this Learning Design is selected, according to the Learner's Learning Style, Educational Level and preferred Difficulty.
3. The structure of this Training Method is further refined, by removing from it Activity Structures and Activities with Learning Objectives that have been satisfied by the Learner (the Learner can define a threshold value t, so that Learning Objectives with satisfaction value>t are considered as satisfied).
4. Finally, appropriate learning objects are retrieved and bound to each node (Activity) of this structure constructing the learning experience. Here, the Learning Object Type describing the characteristics of appropriate learning objects for each Activity is taken into account along with other learner's preferences (e.g. content provider, technical preferences). The resulted learning experience is transformed to SCORM (through a Transformation Component) and delivered to the Learner.

7. RELATED WORK

In [4] a similar approach is followed to represent pedagogy in order to support run-time resource binding. Our approach differs in that it takes into account the learning style, the educational level and learning goals of the Learners, supporting the representation of different learning paths (Training Methods) for training in a specific subject. In [5], although the need for supporting different training methods for the same subject is recognized, these methods are not connected as in our approach with the learning styles and educational levels of the Learners. Moreover, description of appropriate learning objects characteristics beyond semantics is not supported. An alternative approach is presented in [6] regarding automatic course sequencing. In this work learning paths are not constructed based on pedagogical models, but are extracted from a directed acyclic graph that is the result of merging the knowledge space (domain model) and the media space (learning objects and their relation) using minimum learning time as an optimization criteria. However, since this approach is highly based on the domain model that does not necessarily imply an instructional model, and also on the relations of learning objects and their aggregation level, there is a risk that the result of the sequencing process may be not always "pedagogically-right" adapted to the Learners' various learning styles.

8. CONCLUSION AND FUTURE WORK

We have presented a framework for supporting automatic construction of pedagogically-sound adaptive learning experiences using material in learning object repositories, taking into account the variety of learning needs of the Learners. Since pedagogy plays an important role to achieve this, a model for building abstract training scenarios (Learning Designs) has been also provided and an appropriate tool implemented, which guide the construction of pedagogically sound adaptive learning experiences and allow for the binding of appropriate learning resources at run-time according to the Learner Profiles. The framework has been initially implemented in a service-oriented architecture above an experimental digital library of audiovisual content [2]. Extensions are implemented and evaluation of the framework takes place within the LOGOS project.

9. ACKNOWLEDGMENTS

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