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Integration of Educational Specifications and Standards to Support Adaptive Learning Scenarios in ADAPTAPlan

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Abstract

ADAPTAPlan project provides dynamic assistance for reducing authors' effort in developing instructional design tasks using user modelling, planning and machine learning techniques and making a pervasive use of educational specifications and standards. In this paper we describe how these specifications are linked to support the dynamic modelling during the learning process. Three types of user characteristics are considered for generating adaptation, whose values are stored in the Learner Profile according to IMS-LIP: i) Felder learning styles, ii) the knowledge competency level per course objective based on Bloom's Taxonomy and iii) the collaborative competency level per course. Both competency levels are defined through IMS-RDCEO. The author creates the resources and adds a semantic description via learning object metadata (IMS-MD/IEEE-LOM), relating them to the generic competences. Moreover, IMS-QTI questionnaires are used to measure the improvement of the learners' knowledge. The paper also describes how to link together the user's characteristics with the resources metadata, so that they can be defined in terms of conditions in the learning routes (IMS-LD) during the instructional design.

1 Introduction

ADAPTAPlan approach intends to solve some of the difficulties found in developing and modelling standard-based adaptive scenarios, which were detected in aLFanet project (IST-2001-33288). In particular, ADAPTAPlan project (TIN2005-08945-C06-00) provides dynamic assistance for reducing authors' effort in developing instructional design tasks which are included in learning design templates generated in terms of user modelling, planning and machine learning techniques. 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 make unaffordable to design in advance all possible situations: a) learners' performance, b) synchronization and temporization issues, c) evolving learners' needs and preferences, d) adaptation process sustainable over time, e) pedagogical requirements affected by runtime adaptations and f) dynamic modelling.

To cope with these issues, ADAPTAPlan approach relies on a pervasive use of educational specifications (IMS family [2 – 9]) and standards (IEEE-LOM [10]) including users preferences and accessibility issues (Personal Needs and Preferences (ISO PnP) [11] and Digital Resource Description (DRD) [12]). At design time, the system 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 [13]. 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 [14].

In this paper we describe how these standards and specifications are linked to support the dynamic modelling during the learning process. Three types of user characteristics are considered in order to generate adaptation and its achievement is stored in the Learner Profile according to IMS-LIP [2]: i) Felder learning styles, ii) the knowledge competency level per course objective based on Bloom's Taxonomy and iii) the collaborative competency level per course. Both competency levels are defined through IMS-RDCEO [6]. Moreover, IMS-QTI [4] questionnaires are used to measure the improvement of the learners' knowledge. The paper also describes how to link together the user's characteristics with the learning object metadata descriptions (IMS-MD [8]/IEEE-LOM [10]), so that they can be defined in terms of conditions in the IMS-LD [5] during the instructional design. Representative examples of the characteristics to be considered in a Unit of Learning (UoL) of a course on Object Oriented Programming designed using this approach are included in the paper. These features show the viability of the proposal and validate the integration among the different specifications and standards covered.

The experiences from previous projects PlanG [15], Shaboo [16], Mas-shaad [17], SAMAP [18] and ALFANET [1] are the basis for this initial approach, which was previously described in [19] and within this paper is detailed and extended.

2 Educational Specifications and Standards

Specifications describe in a precise, complete and verifiable way the requirements, design and behaviour of a system [20]. 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) [2], IMS Access For All (IMS-AccLIP) [3], IMS Question and Test Interoperability (IMS-QTI) [4], IMS Learning Design (IMS-LD) [5], IMS Reusable Definition of Competency or Educational Objective (IMS–RDCEO) [6], IMS Content Packaging (IMS-CP) [7] and IMS Metadata (IMS-MD) [8]. The later is superseded by IEEE LOM standard [10]. Furthermore, ISO standard on Individualized Adaptability and Accessibility in e-Learning, Education and Training (ISO PnP [11] and DRD [12]), which is derived from IMS Access For All [9], will be considered when it is publicly available. 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 characteristics, 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-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 interchanged 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, including the learning paths. 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. A learning object could be classified to contribute for a competency, referring from the <*classification*> element to a competency model, and relating IEEE LOM with IMS-RDCEO.

3 User Characteristics for Adaptation

Three user characteristics that are considered in ADAPTAPlan project [21] to generate adaptation include: Felder Learning Styles [14], the Knowledge Level based on Bloom's Taxonomy [22] and the Collaborative Competency Level [23].

3.1 Learning Styles

A learning style is defined as characteristic strengths and preferences in the ways people take in and process information [24], and it determines the unique way of learning for each student.

Between the different Learning Style Models proposed within educational research, ADAPTAplan takes as reference the Felder's Model. In their Inventory of Learning Styles [24], Felder and Silverman, define several dimensions regarding how people process information, and each dimension has two possible values:

- Processing: Active/Reflective
- Perception: Sensory/Intuitive
- Input: Visual/Verbal
- Understanding: Sequential/Global

There is an additional dimension, the Organization with values Inductive/Deductive. It was removed from Felder Learning Styles Inventory for pedagogical reasons; it is not justified to continue using the traditional deductive instructional paradigm. Table 1 provides a description of each one of these styles.

Dimension	Style	Description
Processing	Active	Tend to do best when they can work hands on and actually conduct experiments or manipulate things manually
	Reflective	Prefer to think things through before they act
Perception	Sensory	Gravitate towards concrete facts and figures
	Intuitive	Prefer the conceptual and the theoretical to the concrete
Input	Visual	Prefer to see what they are learning through graphs, diagrams and pictures
	Verbal	Are most successful when information is heard or read through words
Understanding	Sequential	Prefer to have information laid out in a linear and orderly fashion.
	Global	Prefer to see the big picture first

Table 1. Behaviour of learners according to learning

Overall, for each dimension, everybody has a behaviour sometimes (e.g. active) and sometimes the contrary (reflective). But frequently there exist a preference (strong or moderate) for one category or the other. Most people are *visual* and *sequential* learners.

The rationale behind this is that to effective as a learner, a balance of the two values for each dimension is desirable and also to be able to function both ways. In any case, when a preference for one category is strong, the learning process could improve its effectiveness with an instruction adapted to this learning style.

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 (Processing, Perception, Input and Understanding) in order to clearly separate the preference of different students.

We obtain the students learning style by directly collecting data from the learner using the Index of Learning Styles questionnaire, developed by Felder and Soloman [25]. The objective of this questionnaire is to establish the dominant learning style of each student. The questionnaire is formed by 44 questions. For each of the four above dimensions there are 11 questions (unordered distributed into the form) about how everyone perceives her/himself, and her/his behaviour. Each question has two possible answers, each one defining a different value in the dimension. Figure 1 offers a scale representing the possible results of the questionnaire for each one of the dimensions. Taking into account the learner's answers in the context of one dimension, the learner could be situated on one extreme of the scale (when the learner has answered all questions on the same style, the result is 11a or 11b, being *a* and *b* the style of this dimension), or she/he could be on an intermediate zone (1a or 1b). As an example, a result 3a indicates that from the 11 questions, the learner has answered 7 of them a and the other 4 questions she/he answered b.

In order to facilitate the learning styles processing, the six different quantitative values possible for each style (11, 9, 7, 5, 3, 1) are grouped using three qualitative modifiers (strong, moderated, balanced), also named clusters.

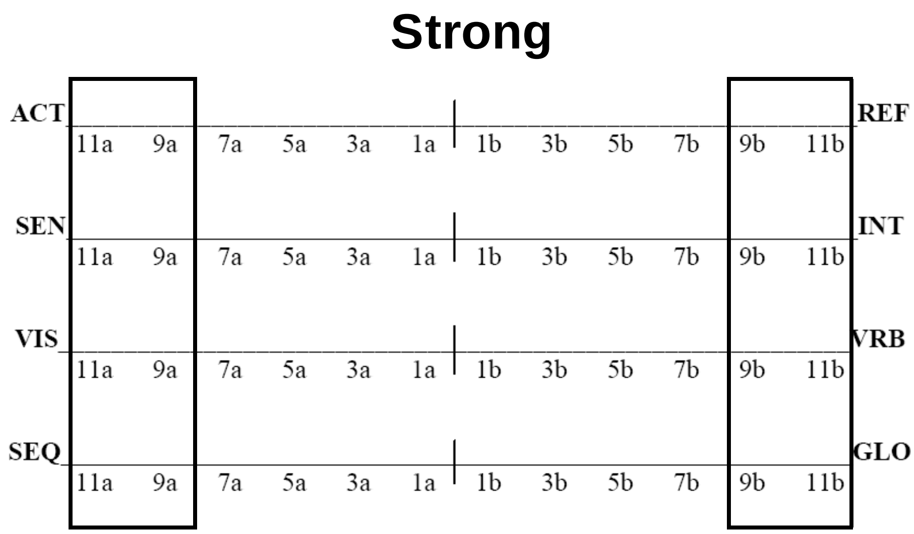

Figure 1. Strong Cluster in the four dimensions of Felder's Learning Styles

The *strong* cluster is the extreme possible values of this scale. This cluster will be the most relevant for adapting the instruction to this dominant style. As an example, table 2 shows how the clusters are assigned for the Perception dimension, where a and b have been substituted by sensitive (s) and intuitive (i) respectively.

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

Table 2. Clusters for Felder's Learning Styles (Perception dimension)

Thus, the learning style of a learner is described by four attributes (dimension in the table), each one taking one of the two possible style values, and within a cluster (strong moderated or balanced):

DIMENSION	STYLE	CLUSTER
Processing	Active / Reflective	Strong / Moderated / Balanced
Perception	Sensitive / Intuitive	
Input	Visual / Verbal	
Understanding	Sequential / Global	

Table 3. Description of a Learner with her/his Learning Styles

3.2. Knowledge Level

The user's knowledge model is based in the Bloom Taxonomy [22]. It considers six levels of knowledge (Knowledge, Understanding, Application, Analysis, Synthesis and Evaluation), in increasing order of competency. 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.

BLOOM OBJECTIVE	DESCRIPTION	LEVEL
Knowledge	Remembers a fact without a real understanding of the meaning	Novice
Understanding	Gets the meaning of the material	
Application	Can use the learned material in new and specific situations	Average
Analysis	Can divide a complex problem into different parts	
Synthesis	Can join different parts in order to create new entities	
Evaluation	Can judge values of a subject with a specific propose	Expert

Table 4. Levels of knowledge according to Bloom

The knowledge level is always associated to an objective within the course. It may be the global goal of the whole course, the partial goal of a chapter or section of the course, or at a lower level of granularity, the operational objective of an activity or task to be done during the course.

Whereas the learning style is something inherent to the learner, here, the knowledge level is the knowledge acquired by a learner regarding a competency or instructional objective.

This knowledge level could be dynamically acquired through the analysis of learner interactions with the learning objects and activities, and the evaluations results obtained from test, questionnaires or other evaluation tasks.

In this approach, the knowledge level of a learner within an objective is described by one attribute taking one of the possible values: novice, average or expert.

3.3. Collaborative Level

Finally, we consider the Collaborative Competency Level, as defined in [16] (see table 5). We separate this type of competency because it defines important aspects in the collaborative and cooperative behaviour of the student.

The collaboration competence of a learner in a course is computed taken into account the usage of the course services, such as forums, shared files, comments, etc. This competence, as the rest of the dynamic features in ADAPTAPlan, are learnt by a multi-agent system (ADA+) described elsewhere [21]. We are interested in modelling this user characteristic in order to establish its relation to the success of the learning process.

The definition of this collaborative competency follows the same idea as the Bloom knowledge level competency; it could take six levels, in a incremental manner. The learner shifts from *Non_Collaborative* to *Communicative*, as she/he progresses on collaborative tasks until the highest appreciated level (*Useful*) is achieved.

COLLABORATION VALUE	DESCRIPTION	LEVEL
Non_Collaborative_ Learner	Behaves as if there are no collaboration facilities.	Low
Communicative_Learner	Shares information with other learners using the available communication tools.	Medium
Participative_Learner	Interacts frequently in the course	
With_initiative_Learner	Starts the proposed activities without waiting for other student's contributions.	
Insightful_Learner	Makes contributions and comments on activities from other learners that later receive high scores.	High
Useful_Learner	Makes comments and contributions that are considered by other learners.	

Table 5. Level for the Collaborative Competency Table

These six collaboration values can also be grouped into three levels, i.e low, medium and high. The collaborative competency level has to be promoted for each student in the context of a course. Monitoring their achievement by the system can facilitate the generation of recommendations to encourage collaboration when needed.

3.4. Educational Specifications and Learners' Characteristics

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 one of the specifications mentioned above, which we are using to model the learning process (see table 6).

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" [2]. 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 (e.g. Sensitive / Intuitive) and the cluster (balanced, moderate or strong).

The definition of the competencies is performed using the IMS-RDCEO specification. The <*identifier*> element serves as the link with the IMS LIP record, which will store also the level of this competence acquired by the learner when playing the course. From design time, each learning objective of the course has one IMS-RDCEO definition. In the case of the knowledge competence, each <*statement*> element references to each one of the possible Bloom knowledge levels for this objective; the *statementtoken* determines how to pragmatically compute the achievement of the level, mainly by means of a IMS QTI test. In the collaboration level, the *statement* is not used since a lower granularity is not required. Moreover, the values are not obtained by IMS-QTI questionnaires, but from the analysis of the interactions.

USERS CHARACTERISTIC	EDUCATIONAL SPECIFICATIONS ELEMENTS	POSSIBILITIES
FELDER LEARNING STYLES	IMS – LIP Lip.accessibility.preference.typename.tyvalue Lip.accessibility.preference.prefcode	- Learner_Style_Processing - Learner_Style_Understanding - Learner_Style_Perception - Learner_Style_Input
KNOWLEDGE COMPETENCY LEVEL	IMS – RDCEO Rdceo.identifier Rdceo.title Rdceo.description Rdceo.definition.statement. statementid statementname statementtext statementtoken IMS – LIP Lip.competency.contentype.referential.indexid Lip.competency.exrefrecord Lip.competency.description	- Novice_Level (Bloom Knowledge and Understanding) - Average_Level (Bloom Application Analysis and Synthesis) - Expert_Level (Bloom Evaluation Level)
COLLABORATIVE COMPETENCY LEVEL		- Low_Collaboration_Level (Participative_Learner) - Medium_ Collaboration_Level (Non_Collaborative_ Learner, Communicative_Learner and With_initiative_Learner) - High_ Collaboration_Level (Insightful_Learner and Useful_Learner)

Table 6. User characteristics vs. IMS-LIP and IMS-RDCEO Specifications.

IMS-LIP	
lip.accessibility.preference typename.tyvalue= **Learner_Style_Processing** prefcode=**reflective.moderated** lip.accessibility.preference typename.tyvalue= **Learner_Style_Perception** prefcode=**sensitive.balanced** lip.accessibility.preference typename.tyvalue= **Learner_Style_Input** prefcode=**visual.strong** lip.accessibility.preference typename.tyvalue= **Learner_Style_Understanding** prefcode=**sequential.moderated**	Felder Learning Styles
lip.competency cotenttype.referential.indexid = lip65466 exrefrecord = rdceo54375.CourseA description = **Medium_ Collaboration_Level**	Collaborative Competency Level
lip.competency cotenttype.referential.indexid = lip85485 exrefrecord = rdceo434323.CourseA description = **Average_Level** lip.competency cotenttype.referential.indexid = lip85523 exrefrecord = rdceo434389.CourseA description = **Average_Level**	Knowledge Competency Level

Table 7 . Examples of IMS-LIP elements for a learner

When the learner interacts with the course resources, the system monitors his/her actions, and dynamically maintains a learner model based on this behaviour. Activities that include collaborative resources provide inputs to compute the collaborative level of the learner. In turn, activities with learning objects related to one learning objective provide information about the knowledge level of the learner in the context of that learning objective. But probably the most direct way to control the value of the knowledge level is when the learner passes a test were the outcome is graded.

When the learner completes a course session, the <*competency*> element of IMS-LIP learner profile is updated. This element does not provide the facility for directly qualifying the degree of achievement of a learner's competency. Instead it offers a *exrefrecord* item for "the description of the competency using an appropriate externally defined structure" [2], that we use for referring the IMS-RCDEO definition.

IMS-RCDEO	
rdceo.identifier = rdceo54375 rdceo.title = **Collaborative_Level** rdceo.description = "Social behaviour and interactions with peers"	Collaborative Competency Level
IMS-RCDEO	
rdceo.identifier = rdceo434323 rdceo.title = Java_Class_for_Figures rdceo.description = "Define a Java class to manage figures" rdceo.definition.statement. statementid = 123 statementname = **Bloom_Analysis** statementtext = Objective1 statementtoken = qti55435 rdceo.definition.statement. statementid = 124 statementname = **Bloom_Understanding** statementtext = Objective2 statementtoken = qti127883	Knowledge Competency Level
IMS-RCDEO	
rdceo.identifier = rdceo434389 rdceo.title = Patterns rdceo.description = "Have a light idea about OO patterns in java" rdceo.definition.statement. statementid = 128 statementname = **Bloom_Understanding** statementtext = Objective5 statementtoken = qti3554	Knowledge Competency Level

Table 8 . Examples of IMS-RDCEO elements definitions for three competences

The tables 7 and 8 offer examples of these definitions. Here, the learner profile of IMS-LIP defines four *lip.accessibility.preference* instances, one for each dimension of learning style. In particular, the learner has a strong visual style; with a moderated reflective processing and sequential understanding. Once these values are obtained they are supposed to be maintained during the course execution.

There are also three types of instances of *lip.competency*, one related to the collaborative level, and two to learning objectives describing the knowledge level. At the beginning of the course experience, none of them exist; as the learner interacts with the course, the system determines the competency levels and creates the *lip competency* instances. Across course sessions their values are changing, usually towards incremental values.

The codes referring *exrefrecord (rdceo54375.CourseA, rdceo434323.CourseA, rdceo434389.CourseA)* corresponds to IMS-RCDEO definitions, which were defined by the author during the course design.

4. Adaptation Generation in ADAPTAPlan

Adaptations in ADAPTAPlan are two fold: (1) generating personalized learning routes in IMS-LD adjusted to learners' characteristics, and (2) providing dynamic recommendations to learners during a course execution. In this paper we focus on the first one. The dynamic recommendations to learners are provided during the course execution by ADA+ multi-agent architecture. It applies collaborative filtering, machine learning and fuzzy logic techniques on the learners' interactions to build the user model, as it is described elsewhere [21].

The personalized learning routes are generated by the planning engine [14]. At design time, the system 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 [13]. 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 [14].

Figure 2 provides an overview of the information flow processed by the planning engine.

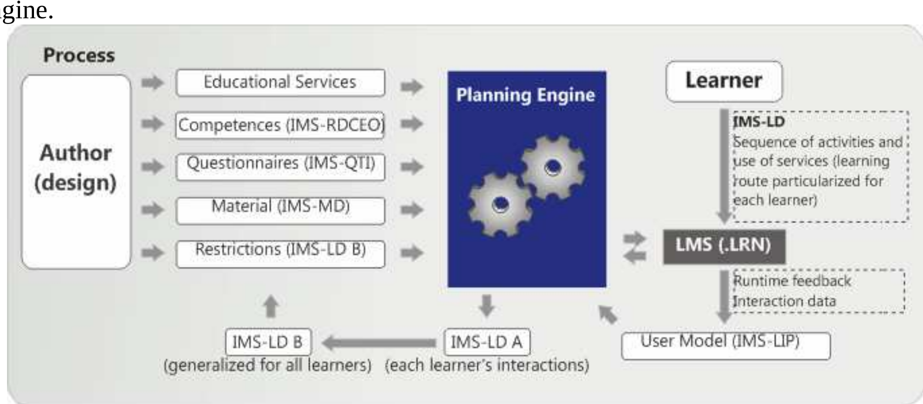

Figure 2. Planning Engine Process

When a learner enters into the system, the planning engine identifies from the repository of materials, the learning objects, collaborative tasks and evaluations, which are more appropriated to that particular learner, generating an adapted learning route defined in IMS-LD according to the user's characteristics described in section 3. This approach offers two advantages:

1. The resulting UoL could be executed in any LMS compliant with the IMS-LD specification.

2. The author does not need to work in a complex language, i.e. IMS LD which is not within her/his competence.

To illustrate the ADAPTAPlan approach first we describe what the planning engine requires from the design phase. Snapshots from the authoring tools used (IMS-LIP, IMS-LD, IMS-MD) are provided. Next we detail how the planning engine can obtain a personalised learning route. The examples that have been included are meant to illustrate the features to be considered in a Unit of Learning (UoL) of a course designed using this approach. The purpose here is to show the viability of the proposal and validate the integration among the different specifications and standards covered.

4.1 Design Phase: Author, Course and Goals

In order to provide an instruction adapted to learner needs and goals, we need first a common understanding of competencies, i.e., a generic Competence Model in the learning context that allows organizations to share a common language when referring to competencies, skills or learning objectives. This model could be defined by a taxonomy of competencies globally accepted, sometimes called Competence Map, or built from an existing taxonomy and extended until low levels of competences, like objectives, achieves, etc. The model could also be provided by an educational organization, describing the curricula of the different educational programs. A clear example of this type of models is the ECDL curricula [26].

ADAPTAPlan offers as well a reference for authoring the course resources. The design phase covers the following issues:

1. The educational organisation provides first the main goals and objectives of the course in terms of competencies defined in the generic model. Figure 3 presents a taxonomy that defines the name spaces of the course code CO000000, which corresponds to Object Oriented Programming Course. The taxonomy is very easy; it is formed by three categories: course, competence and objectives. If it's necessary, other subcategories could be defined at the lower level of objectives. For example, in this case the objectives have been divided in categories taken into account the Bloom Taxonomy although the scope of this particular course addresses only the novice level.

ADAPTAPlan		
Code of the course: CO000000		
Knowledge Competency (NC) Model easy problems using main elements and characteristics of the object oriented programming		
Novice (A) Knowledge and Understanding	Average (B) Application and Analysis	Expert (C) Synthesis and Evaluation
1. Define object oriented programming		
2. Recount the important facts or main characteristics in the evolution of OOP		

Figure 3. ADAPTAPlan Taxonomy

2. The author has freedom for detailing the generic competencies into more specific goals, until they reach the level of operational objectives. In this way the general purpose of a course can be broken down into smaller units. Figure 4 shows the specifications of the taxonomy using the IMS RDCEO schema. The taxonomy sets an order that can be used for codifying each competence. The goal identifier and the IMS-QTI identifier that evaluates that goal have been highlighted.

```
<?xml version="1.0" encoding="utf-8"?>
<rdceo xsi:schemaLocation="http://www.imsglobal.org/xsd/imsrdceo_rootv1p0.xsd
http://www.imsglobal.org/xsd/imsmd_rootv1p2p1.xsd
http://www.w3.org/XML/1998/namespace xml.xsd"
xmlns="http://www.imsglobal.org/xsd/imsrdceo_rootv1p0"
xmlns:xsi="http://www.w3.org/2001/SMLSchema-instance">
  <identifier>
    <catalog>URL</catalog>

    <entry>http://horeb.upbmonteria.edu.co:8000/ADAPTAPlan/COM-C0000000.pdf</entry>
  </identifier>
  <title>
    <langstring xml:lang="es">Object Oriented Programming - Novice</langstring>
  </title>
  <description>Model easy problems using main elements and characteristics of
  the object oriented programming</description>
  <definition>

    <model>http://horeb.upbmonteria.edu.co:8000/ADAPTAPlan/model_competence.html</mo
    del>
    <statement>
      <statement id="C0000000NCA1" name="Bloom A1">
      <statementext>
        <langstring><langstring xml:lang="en">Define object oriented
        programming</langstring>
      <statementtoken>E2007111112743</statementtoken>
    </statement>
```

Figure 4. IMS-RDCEO model

3. The author creates a repository of resources (theoretical lessons, examples, exercises, assessments, etc). Figure 5 shows the IMS-QTI that addressed the same goal of the figure 4.

```
<imsqti:questestinterop
xmlns:imsqti="http://www.imsglobal.org/xsd/ims_qtilitev1p2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.imsglobal.org/xsd/ims_qtilitev1p2
ims_qtilitev1p2.xsd">
  <imsqti:item ident="E2007111112743" title="[Questions]">
    <imsqti:presentation>
      <imsqti:material>
        <imsqti:mattext xml:lang="EN">The object oriented programming
        is:</imsqti:mattext>
      </imsqti:material>
      <imsqti:response_lid rcardinality="Single" ident="E2007111112743Resps"
      rtiming="No">
        <imsqti:render_choice shuffle="Yes">
          <imsqti:response_label rshuffle="Yes" ident="I2007111112030">
            <imsqti:material>
              <imsqti:mattext xml:lang="EN">Specifications of solutions in
              terms of object and relations</imsqti:mattext>
            </imsqti:material>
          </imsqti:response_label>
          <imsqti:response_label rshuffle="Yes" ident="K2007111112057">
```

Figure 5. IMS-QTI

4. The author characterises these resources (see step 3) using the IEEE LOM/IMS-MD, she/he describes the semantic information associated to them, and specifically, classifies the resources according to their learning objectives, as

references to the IMS RCDEO already defined in the step 2. This is the author's most relevant task. This classification implies setting the value of the element *classification.taxonpath.taxon.id* in MD/LOM standard to match the identifier of the competency or objective in the RDCEO specification. For example, in the figure 6 can be seen this attribute addressed to a specific objective in RDCEO. This way of classifying resources allows the automatic detection of pieces during the LD building phase.

```
  <classification>
    <purpose>
      <source>LOMv1.0</source>
      <value>educational objective</value>
    </purpose>
    <taxonPath>
      <source>
        <string>ADAPTAPlan</string>
      </source>
      <taxon>
        <id>C0000001NCA1</id>
        <entry>

          <string>http://horeb.upbmonteria.edu.co:8000/ADAPTAPlan/COM-C0000000.pdf</stri
          >
        </entry>
      </taxon>
    </taxonPath>
  </classification>
</lom>
```

Figure 6. IMS-MD

Moreover, the information of the learner is provided by her/his profile (IMS LIP). The previous experiences in other courses were stored on the *<competency>* element, as already mentioned. The interest in acquiring additional competencies is related to the *<goal>* element. In our scenario, when a learner is recruited for a course, the course goals are added to the *<goal>* element of the learner profile. Figure 7 shows the goals for a student enrolled in the course coded CO000000.

```
<?xml version="1.0" standalone="no"?>
<learnerinformation xmlns = "http://www.imsglobal.org/xsd/imslip_v1p0"
  xmlns:xsi = "http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation = "http://www.imsglobal.org/xsd/imslip_v1p0
  http://www.imsglobal.org/xsd/imslip_v1p0.xsd">
  <contentype>
    <referential>
      <sourcedid>
        <source>ADAPTAPlan</source>
        <id>LIP0002</id>
      </sourcedid>
    </referential>
  </contentype>
  <goal>
    <typename>
      <tysource sourcetype="imsdefault"/>
      <tyvalue>CO000000</tyvalue>
    </typename>
    <contentype>
      <referential>
        <indexid>CO000000NCA1</indexid>
      </referential>
    </contentype>
```

Figure 7. IMS-LIP

Finally all these specifications are integrated during the automatic process of construction of a Unit of Learning or more specifically an IMS-Learning Design. Figure 8 shows the manual build of a Unit of Learning using the authoring tool "Reload Learning Design Editor". Other authoring tools have been used at design time to define IMS-MD (Reload Learning Design Editor), IMS-QTI (QAed) and IMS-LIP (LIPEditor).

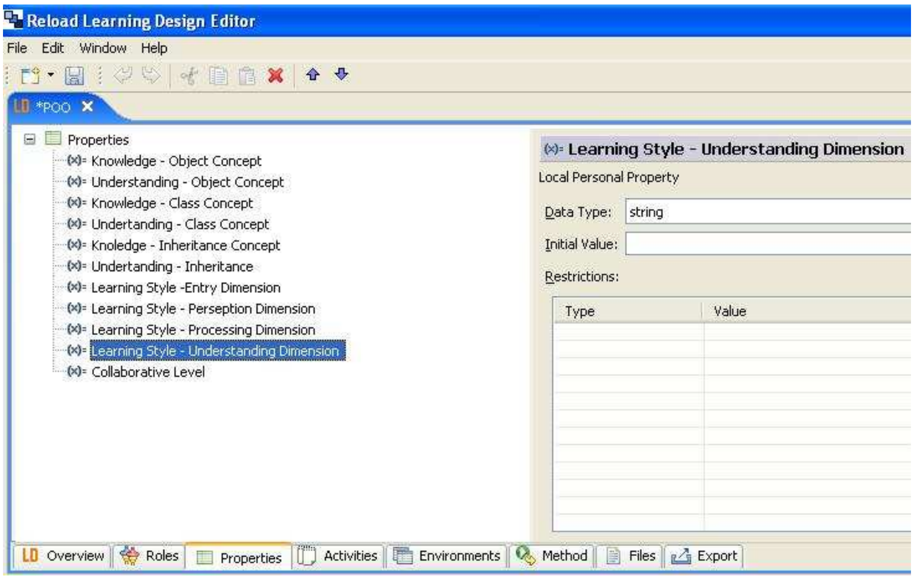

Figure 8. IMS-LD

4.2 Run-Time Phase: Obtaining the Learning Route

The starting point of ADAPTAPlan are the learner needs, described in the learner profile as goals to be achieved. The system performs an analysis taking also into account 1) the already available skills of the learner (competency in IMS-LIP) and 2) the repository of materials for a course, focusing on the existing learning objectives and competencies ready to be acquired. The matching process selects one or more *<goal>* elements of the learner profile, and the learner selects the goal to achieve. Then, the planner works on how to achieve this goal, generating the UoL for it.

The goal is defined as a reference to IMS-RDCEO from the Competency Model, and usually, it is refined into more specific sub-goals, as a hierarchy of learning objectives as defined by the author (see section 4.1). Additional restrictions amongst the goals can also exist (i.e. the work in an objective requires the previous achievement of another one). Taking all this information into account the planning engine constructs the activities structure, where a learning activity corresponds to a competency: activity structures when the goal is general (goal composed by sub-goals), and learning activities for operational learning objectives (leaf competency in the hierarchy).

For each learning activity, the planner filters the set of learning objects that match with its associated learning objective. Next, it selects from them, the ones that are better for the learner, according to the personal characteristics (see section 3).

To support this approach the following set of properties in the IMS-LD are defined:

- 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 7.
- One local and personal property per course objective to model the different knowledge levels. These properties are related to a specific knowledge body and to the level of competency.
- One local and personal property to model the collaborative competency level, in the context of the current course.

The values of these properties constitute the input for the planning engine to generate a learning route adjusted to the user preferences and her/his 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 [15, 27]. 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/IMS-MD is used to characterize the learning objects. In Table 9, 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 characteristic for a particular 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 user model. Depending on the values of these properties, the learning objects are selected.

LIP	LOM Attributes
Learner_Style_Processing (Active - Reflective) Learner_Style_Perception (Intuitive - Sensitive) Learner_Style_Input (Visual - Verbal) Learner_Style_Understanding (Sequential - Global)	Learning Resource Type – Exercise (Active, Intuitive, Verbal, Sequential) – Simulation (Active, Sensitive, Visual) – Questionnaire (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 statement (Active, Sensitive, Verbal) – Self assessment (Active, Sequential) – Lecture (Verbal, Reflective, Intuitive)
Learner_Style_Processing (Active - Reflective) Learner_Style_Perception (Intuitive - Sensitive) Learner_Style_Input (Visual - Verbal) Learner_Style_Understanding (Sequential - Global)	Format (are free defined). It can be: – Text (Reflective, Intuitive, Verbal, Sequential) – Multimedia (Sensitive, Visual) – Graphics (Sensitive, Visual, Global) – Movies (Sensitive, Visual) – Sound (Sensitive, Verbal, Sequential)
Learner_Style_ Processing (Active - Reflective)	Interactivity Type Active (strong active) – (Simulation, questionnaires, exercises, problems) Expositive (strong reflective) – (Hypertext, video, graphics and audio) Mixed (balanced)
Learner_Style_Perception (Intuitive - Sensitive)	Density of Semantic – Very Low (Intuitive) – Low (Intuitive) – Medium (Sensitive) – High (Sensitive) – Very High (Sensitive)
Level of Knowledge Novice Average Expert	Difficulty – Very Easy (Novice) – Easy (Novice) – Medium (Average) – Difficult (Expert) – Very difficult (Expert)

Table 9. Relating Users Characteristics with specifications attributes

Some of the rules for defining what learning objects are presented to each learner are described in Table 10.

USER FEATURES	RULES
FELDER LEARNING STYLE	IF accessibility.preference.typename.tyvalue = Learner_Style_Input AND accessibility.preference.prefcode = Visual.Strong THEN show LO with lom.learning.resource.type = Simulation | Diagram | Figure | Graph AND lom.format = Graphics | Multimedia | Movies
	IF accessibility.preference.typename.tyvalue = Learner_Style_Processing AND accessibility.preference.prefcode = Sequential.Strong THEN show LO with lom.learning.resource.type = Exercise |Questionnaire |Slides |Self assessment AND lom.format = Text | Sound
KNOWLEDGE LEVEL	(IMS-LD properties are obtained from the results of the IMS-QTIs associated to the competence) IF ld.locpers-property.title="Java_Class_for_Figure_KL" AND ld.locpers-property.value > 50 (from the QTI score) THEN lip.competency.description = Average_Level IF ld.locpers-property.title ="Java_Class_for_Figure_KL" AND ld.locpers-property.value < 30 (from the QTI score) THEN lip.competency.description = Novice_Level -- IF lip.competency.description = Average_Level THEN show LO lom.dificultty = Medium IF lip.competency.description = Novice_Level THEN show LO lom.dificultty = Easy | Very_Easy (lip.competency.description are IMS-LD properties that store the LIP value)
COMPETENCE LEVEL	(The IMS-LD properties are assigned by ADA+) ld.locpers-property.title := Collaborative_Level ld.locpers-property.value := Medium_Collaboration_Learner IF lip.competency.description = Communicative_Learner THEN show ENV with service = forum OR THEN hide ENV with service = forum

Table 10. Rules to assign learning objects to learner's features

The selection of the learning objects to include into one environment follows the following rules:

- According to the learning style, adaptation is driven by dominant users' preferences, the dimensions with "Strong" value in the cluster
- According to the knowledge level, the learning objects with a difficulty level appropriate to the knowledge level of the learner on the learning objective of the target activity are selected.

Regarding the collaborative competency level, there are no predefined rules to learn the competence level from questionnaires. It is obtained dynamically by monitoring the learners' behaviour and their interactions during the course. This task is done by ADA+ multi-agent system. While there are multiple knowledge competency levels, one for each course objective, there is only one collaborative competence level per course.

This competency is not used to select learning objects, but what services are offered and how they are configured. The author decides how to cope with it. Two different approaches can be followed by ADAPTAPlan:

- More services for low collaborative learners
- More services for high collaborative learners

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. Our approach focuses on reducing the workload of the teacher in the design task, asking her/him only for the main information that should be provided in order to generate the instructional design, such as objectives, resources characteristics and evaluation items.

In this paper we defined the user characteristics required to generate adaptations according to learning styles, knowledge level and collaborative competencies. Furthermore, we described the mechanism to link together those features with learning objects and resources to be integrated into 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 our approach supports current educational specifications (IMS family) and is being integrated in dotLRN open source learning management system [28] through a web services interface. In this way, interoperability and extensibility is guaranteed.

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" developed in the Shaboo Project [16]. The later has been selected to illustrate the approach in the paper. 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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