A Proposal to Define Adaptive Learning Designs

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Abstract. This paper outlines a framework to describe adaptive learning designs where definitions as the instructional design method, the type of tests, the learning style approach, and the adaptive rules are not prescribed. Standardized metadata based on IMS is used to guarantee the reusability and interoperability of the elements. The framework proposes, also, to adjust the learning design taking into account the student knowledge and the learning style of both the learner and the learning activities by means of adaptive rule definitions. These rules are defined using a set of elements (based on IMS LD) and they describe adaptive statements, techniques and students' stereotypes.

Keywords. Standards and metadata specifications, IMS specifications, Learning design, IMS LD, Adaptive Educational Hypermedia Systems

1. Introduction

Adaptive Educational Hypermedia (AEH) is a challenging and promising research area that may help to improve the learning of the students adjusting contents and navigation alternatives to their characteristics. However, to learn implies more than provide content and paths, but a process where learners gain knowledge and skills interacting with learning resources, activities, teachers, and other students. Instructional strategies have to be defined to detail this process.

Instructional strategies (or learning designs) consider learning goals, prerequisites, and the expected outcomes to indicate learning activities, sequences and learning materials.

We consider it is worthwhile to use learning designs as the key element to perform adaptivity in AEH, where the same learning goal can be reached by every student using different learning strategies tailored to her/his knowledge and learning styles, and also, to define those strategies as semantic elements –guided by a standardized metadata– in order to make it possible their exchangeability and reusability.

For these reasons, we are defining a framework to configure adaptive learning designs where the instructional design method, the type of tests, the learning style approach, and the adaptive rules are not prescribed, but open to be defined by teachers or instructional designers. This framework is within an ongoing research towards the definition of AEH based on learning technology specifications [2].

The rest of this paper is structured as follows. In section 2 we present the framework to describe adaptive learning designs and its components. In section 3 we depict a study case. In Section 4, we expose conclusions and describe further work.

2. The Adaptive Learning Design

Taking into account the Adaptive Web [5], it is important to use learning technology specifications to define learning designs. This will guarantee their interoperability, reusability, and exchangeability. Therefore, the definition of adaptive learning designs in the proposed framework follows the IMS LD specification [10]. Fig. 1 shows its conceptual structure.

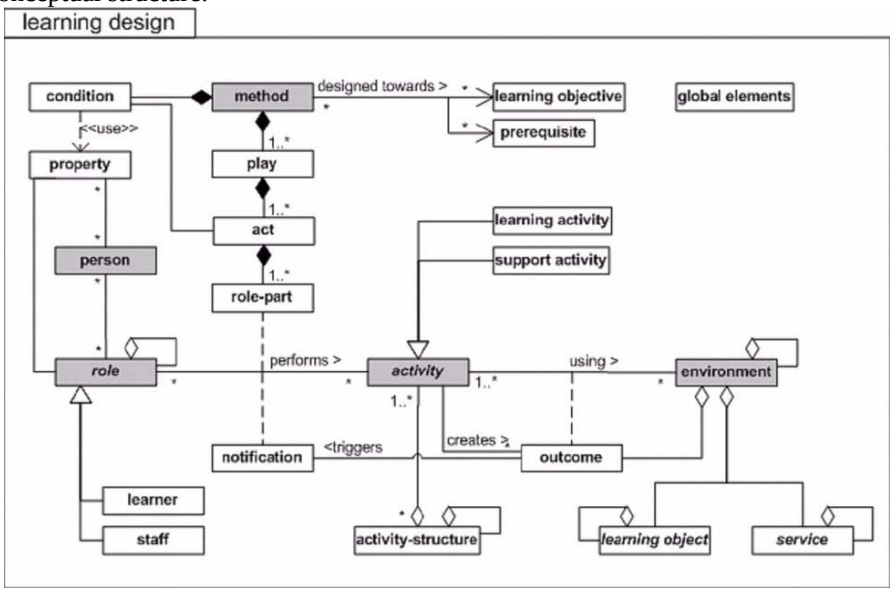

Fig. 1. Conceptual model of overall Learning Design [10]

From the wide range of learning technology standards that are currently under development [4], we have chosen IMS LD because it designs the learning process based on learning activities, it is open to any learning theory, it supports pedagogical diversity, it describes a pedagogical meta-model –based on EML [13]–, and it enables the possibility of integrating learning design to advanced e-learning applications [19]. Moreover, several elements of IMS LD (i.e. conditions, properties, when-condition-true, and so on) can be very helpful to adapt learning designs. IMS LD is divided into three levels of implementation and compliance: Level A contains the vocabulary to support pedagogical diversity. Level B adds attributes and conditions to level A (allowing personalization and a more elaborated interaction sequences based on students' portfolios). And Level C adds notifications to level B.

The framework to depict adaptive learning designs includes four definitions: (1) learning design, (2) tests, (3) learning styles, and (4) adaptive rules. In the rest of this section we will introduce them.

2.1 The Learning Design Definition

The learning design definition is ruled by the IMS LD (see Fig.1). Therefore, authors describe the pedagogical approach of the adaptive learning design defining its learning objectives, prerequisites, roles, outcomes (learning and support activities), environments (learning objects and services), and the method of instruction.

As effective instructional strategies are established first by the learning goals and the type of content to be taught and, then, by the learner style [14], the learning style of the activities will be considered to perform the adaptation.

Further, it is important to be able to define activities as learning elements that endorses one or more of the dimensions of a learning style approach (see Learning Style Definition below). The attempt is to open the scope and not state that just one learning style dimension can be covered in one learning activity or sequence. Consequently, the element *learning-style* will be added to the definition of learning activities to store what learning styles the activity endorses and in what percentage. Although this element is not considered in IMS LD, it will be added to the *learning-activity* and *support-activity* elements. We propose to create this new element to avoid storing values into standardized metadata elements characterized for other purposes.

2.2 Learning Style Definition

Learning styles try to establish indicators on how learners perceive, interpret, process and interact with learning environments. Considering these indicators it is possible to design learning materials or instructional designs suitable to the way each learner learns.

However, there has been much debate about learning styles and little consensus. As a result, many learning style approaches had been defined. Some well known examples are the Felder and Silverman Learning Style Model [6] and the Kolb's Experiential Learning Theory [12]. The former defines ten dimensions. Two are related to the way students receive the information (sensorial, intuition), and the other eight are related to the way the information is processed (visual, verbal; inductive, deductive; active, reflexive; sequential, global). This approach has been used in AEH systems as [15] and [17].

Kolb's Theory also takes into account the way the information is perceived (theorist and activist dimensions) and the way the information is processed (reflectors and pragmatist dimensions). Some personalized learning environments use Kolb's theory as [19] [16], or developed tests based on it, like [18].

Nevertheless, the framework does not prescribe any learning style. We argue that different learning style approaches should be used for different fields of knowledge and type of students. Therefore, authors can use the learning style approach they judge is the best for their content and context.

As a result, by means of the learning style definition the teacher specifies the learning styles approach that would be considered. For every learning style it is necessary to define its name, description and dimensions. With this information a learning object will created, it will be added to the framework, and will be available to

be (re)used in other learning designs. These objects will use the IMS group element {itemmodel} (see Table 1) to store the information.

Table 1. Main elements of the IMS {itemmodel} [10]

No.	Name	Explanation	Req	Mult	Type
0.1	Title	name of the resource, suitable for rendering in user-agents	O	0..1	string
0.2	Item	A node in a structure, referring to a resource	M	1..*	seq.
0.3	metadata	See above	O	0..1	seq.

Afterwards, authors will use the learning style definition to depict the learning style of the students, the learning style of the activities as well as to define the learning style test.

2.3 Test Definition

Within the definition of tests, authors describe the assessments to measure the knowledge and learning style of the students. There are four types of tests: learning style, initial knowledge, current knowledge, and final knowledge.

The objective of the learning style test is to identify the learning style of the student. This type of test should be in accordance with a learning style definition created before, which will provide the dimensions to measure the learning style of the student. This test is defined by its name, description, linked learning style definition, and a set of questions for each learning style dimension.

The objective of the initial knowledge test, current knowledge test, and final knowledge test is to measure the students' knowledge.

The initial knowledge test and the final knowledge test have to be linked to a unit of learning[1], while the current knowledge test has to be related to a learning activity or activity sequence (see Fig.1).

The results of these tests set the values of the learning style, initial knowledge, current knowledge, and final knowledge of each student. These values could be stored into the student model to use them in the definition of adaptive rules (initial-knowledge, current-knowledge, and final-knowledge elements of Table 2), and connect them with the learning style of the learning activities. Moreover, they can be included, at run time, in the <globpers-property>[2] element to represent the learning style of the learner.

[1] A unit of learning represents any delimited piece of education (course, module, lesson, etc.). It is modelled by including an IMS LD into a content package, preferably, IMS CP [9].

[2] Global Personal Property (portfolio-property): element used for personalization that has a different value for every user. Property operations can refer to it to operate on the value [10].

2.4 The Adaptive Rule Definition

While, in most cases, the definition of adaptivity is pre-defined by the designers of the adaptive learning environment, in the proposed framework the objective is to make use of authors' expertise in their knowledge field, and give them freedom to choose the characteristics and variables that are important to perform the adaptivity.

The goal is to provide authors with elements and functions that could be used to define rules that adjust the learning design to the students' characteristics and to the nature of the knowledge. The definition of adaptive rules includes the definition of (1) adaptive statements, (2) adaptive techniques, and (3) students' stereotypes [2].

2.4.1 Adaptive Statements Definition

Adaptive statements depict the conditions to execute an adaptive action. They are defined as (BNF notation):

<**adaptive-statement**> ::= IF <condition> THEN <action> (**1**)

<**condition**> ::= <element-set> [<unitary-op-set>] "(" <expression> ")"[<binary-op-set> <condition>] (**2**)

<**expression**> ::= [<spec-element> ","] [<value> | <binary-op-set> "," <value>]["," <relational-op-set> "," <value>] (**3**)

<**action**> ::= <action-set> "(" <expression> ")" [<binary-op-set> <action>] (**4**)

<**spec-element**> ::= specific-element-identified-by-its-id (learning-design-structure-set; student-set) (**5**)

<**value** > ::= [<data-set> |<integer> | <string> | <percentage>] (**6**)

Table 2. Collection of sets to describe Adaptive Statements

Name of the set	Sub-set	Elements
element-set	learning-design-structure	Prerequisite; Learning-objectives Learning-activities; Activity-sequence; Support-activity
	student-element-set	Student
data-set	learning-style-set	Learning-style
	student-data-set	Initial-knowledge; Current-knowledge; Final-knowledge
	attributes-data-set	Completed; Visited; Recommended; Sequence; Selection
	time-data-set	Time-unit-of-learning-started; Date-time-activity-started
logic-set	binary-op-set	And; Or
	unitary-op-set	Not
relational-set	relational-op-set	Greater-than; Less-than Equal; Greater-or-equal-than Less-or-equal-than
action-set		Show; Hide; Show-menu Hide-menu; Sort-ascending Sort-descending; Number-to-select

All the definitions contain “sets” (see Table 2) that group elements. For example, the <element-set> indicates authors can choose any element of that set (prerequisite, learning-objectives, learning-activities, activity-sequence, support-activity or student) to define an adaptive statement. These elements have been defined based on the IMS LD schema group {expression}[3]. Likewise, other IMS LD elements had been considered as, for instance, prerequisites, learning-objectives, or learning activities. Furthermore, actions like show-hide (included in the element <conditions>), and the sort and number-to-select actions (included as attributes in the element <activity-structure>) are also considered.

Two reasons motivated the way we defined the sets and their elements. Firstly, to take advantage of IMS LD possibilities, and be able to exchange and reuse the definition of adaptive rules within different learning designs. Secondly, to give authors a simple formalism to define adaptive statements.

2.4.2 Adaptive Techniques Definition

In the adaptive technique definition, authors configure the behaviour of the techniques that will be performed when the students are interacting with the learning design. For every adaptive technique, an adaptive statement can be defined. Their definition is based on the adaptive statement definition, thus the same collection of sets is used. The following formula defines the adaptive techniques description:

<**adaptive-technique**> ::= TECHNIQUE “<” <name-technique> “>” “=” <adaptive-statement> (**7**)

2.4.3 Students’ Stereotype Definition

The creation of students’ stereotypes allows authors to group students considering one or more characteristics or variables.

As in the adaptive techniques description, the definition of students’ stereotypes is based on the adaptive statement description but also in the IMS LD element *role-part* (see Fig. 1). We argue this element can be used to define student stereotypes, in such way that every *role-part* covers a set of learning activities related to a specific learning-style or to a learning-state (obtained from an adaptive statement).

The following formula defines the students’ stereotype description:

<**student-stereotype** > ::= STEREOTYPE “<” <name-stereotype> “>” “=” <adaptive-statement> (**8**)

3. Case of Study

In this section we exemplify how to define an adaptive learning design based on the proposed framework. This example is defined for illustrative proposes. We do not mean the author of the learning design has to use this “low-level” description; on the contrary, authoring tools have to be developed to provide an interface to create learning designs.

[3] It includes operators (calculation, logical), references (learning activity, activity structure, rol) and other elements to define conditions (IF-Then-Else) [10].

We take as a study case the vocational career of Chef, that has 2000 class hours, and it is divided into two modules. Each module has six courses. The second-module-course “Bakery and Confectionery” has six lessons. The dessert lesson is one of them. We will take it to describe how an adaptive learning design is depict using the proposed framework.

3.1 The Learning style definition

The learning style approach that will be used is Kolb’s Theory [12].

The learning style definition is not included in the IMS LD. Nevertheless, we use structures and elements of this specification to include this new element. Therefore, to define the <learning-style> element we create a new element based on the IMS group element {itemmodel} (see Table 1). By using this group is possible to establish the dimensions of a learning style. For instance, Fig.2 shows the learning style element of the Kolb’s theory and its four dimensions (Theorists, Pragmatists, Activists, and Reflectors).

```
<learning-style>
  <item identifierref="RES-ExpKolb" identifier="LSD_Kolb">
    <title>Kolb´s Learning Style</title>
    <item identifier="LSD_Kolb_Theorist"><title>Theorist</title></item>
    <item identifier="LSD_Kolb_Pragmatist"><title>Pragmatist</title></item>
    <item identifier="LSD_Kolb_Activist"><title>Activist</title></item>
    <item identifier="LSD_Kolb_Reflector"><title>Reflector</title></item>
  </item>
</learning-style>
```

Fig. 2. Definition of the learning-style element

3.2 The Learning design definition

The learning design definition includes the description of roles, prerequisites, learning objectives, learning activities and activity sequences.

Following the example, the information of the desserts lesson is defined as:

- Role: Student
- Learning objective: To be able to elaborate desserts. The resource “RES-ElabD” (type: webcontent) contains the learning objective.
- Prerequisites: The general introduction has to be completed. The resource “RES-GenIn” (type: webcontent) contains the prerequisite.
- Learning activities: (i) classification and description of desserts, (ii) techniques to elaborate simple desserts, (iii) Techniques to elaborate hot desserts, (iv) Techniques to elaborate cold desserts

Fig. 3 shows (to some extent) how the learning design “LD-Desserts” is described using IMS LD. The learning activity “classification and description of desserts” (LA-Class-Dess) is defined (using the element *learning-style*) considering the Kolb’s theory as 70% theorist, 10% pragmatist, 10% activist and 90% for reflectors. This

data is annotated using the attribute parameter. The learning style objects start with LSD (Learning Style Definition). This prefix is used to identify learning styles, as those defined in the official use of titles: LOB (learning-objectives), PRE (prerequisites), or LA (learning-activity).

```
<learning-design identifier="LD-Desserts">
  <title>Desserts - Lesson</title>
  <learning-objectives>
    <item identifier="LOB-dessert-lesson" identifierref="RES-Elaborate-
Desserts"/>
  </learning-objectives>
  <prerequisites>
    <item identifier="PRE-dessert-lesson" identifierref="RES-Introduction-
Elaborate-Desserts"/>
  </prerequisites>
  <components>
    <roles>
      <learner identifier="R-learner"/>
    </roles>
    <activities>
      <learning-activity identifier="LA-classification-desserts">
      <activity-description>
        <item identifier="I-classification-desserts"/>
      </activity-description>
      <learning-style>
        <item identifierref="RES-ExpKolb" identifier="LSD_Kolb">
        <item parameters="value,70%" identifier="LSD_Kolb_Theorist"/>
        <item parameters="value,10%" identifier="LSD_Kolb_Pragmatist"/>
        <item parameters="value,10%" identifier="LSD_Kolb_Activist"/>
        <item parameters="value,90%" identifier="LSD_Kolb_Reflector"/>
        </item>
      </learning-style>
    </learning-activity>
....
  </activities>
</components>
</learning-design>
```

Fig. 3. The definition of the learning activity “classification and description of desserts”.

3.3 The Test Definition

To exemplify the test definition, we can say that three types of tests will be defined: the learning style, the initial knowledge test, and the final knowledge test. The former could employ the CHAEA [1] instrument, which is designed to establish the learners’ learning style in the approach of the Kolb’s Theory. The others can be multiple-choice tests to measure the initial or final knowledge of the student.

3.4 The Adaptive Rule Definition

By means of the collection of sets (see Table 2), authors could create adaptive statements. For instance, an adaptive statement that establishes that if the learning style of the student and the learning style of the learning activity are –each one– greater or equal than 80% of the dimension “pragmatist” (Kolb’s theory), then it

would be necessary to show a menu that contains the prerequisites of the learning activity. We can define the following statement:

IF Student (learning-style, “pragmatist”, greater-or-equal-than, 80%) AND learning-activity (learning-style, “pragmatist”, greater-or-equal-than, 80%) THEN show-menu (prerequisites) (**9**)

Also, adaptive techniques as direct guidance and adaptive ordering can be defined. The aim of direct guidance is to suggest the “next best” node (learning activity) to visit [5]. It can be defined that when the student has an initial knowledge of 50% or less, then the prerequisites of the learning activities will be shown sequentially. This adaptive technique can be defined as:

TECHNIQUE <direct-guidance> = IF Student (initial-knowledge, less-than, 50%) THEN show-menu (prerequisites, sequence) (**10**)

Adaptive ordering is directed to sort all the links of a particular page taking into account the student model. The first link is more significant than the last one. This technique can be defined for the students that have a current knowledge less than the 50%, then the activity sequence will be sorted using the following rule:

TECHNIQUE <adaptive-ordering> = IF Student (initial-knowledge, less-than, 50%) THEN sort-ascending (activity-sequence) (**11**)

In addition, a student stereotype can be defined considering a student “Advanced” if her/his initial knowledge is greater or equal to 90%, as it is shown in the following rule:

STEREOTYPE <advanced> = IF Student (initial-knowledge, greater-or equal-than, 90%) (**12**)

All these definitions (learning design, test, learning style, adaptive rules) must be integrated into an IMS LD file that contains the learning design that will be presented to the students. This integration also includes “translating” the adaptation rules defined into the IMS LD element <method>. This translation will make possible that the defined rules can work in learning designs created by others and vice versa.

4. Conclusions and future work

In this paper we presented a framework to describe adaptive learning designs in such way that its description is open to define any learning style approach, tests, adaptation rules and learning instructional designs. Besides, the outlined framework describes a new approach to define adaptive rules. The aim is to describe adaptive learning designs with semantic meaning and make it possible their reusability and exchangeability.

We are extending the functionality of an application we developed for authoring hypermedia books, the Hypermedia Composer (HyCo [7] [8]), in order to utilize it as the learning design authoring tool [3]. Now, we are working on the definition of learning designs conform to IMS LD Level A. The next steps are to define the types of tests (true/false, multiple-choice, etc.) and analyze if they will be modeled with IMS QTI [11] as well as design how the adaptive rule definitions will be automatically modeled in the element <condition> of IMS LD. Moreover, we need to

define mechanisms (agents, patterns, templates, etc.,) to support authors in the authoring of adaptive learning designs.

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