

Application of Learning Styles in a Model Based on Ontology: SIMBAD

Rojas Javier, Defude Bruno
Telecom SudParis, Evry, France

Javier.rojas.moreno@gmail.com, Bruno.Defude@it-sudparis.eu

Abstract

The developments of applications to strengthen the learning process through internet, known as e-learning, have involved the revision of different learning theories with the objective to determine its possible application in these environments. The learning objects have become in a fundamental element to develop educational contents for e-learning based environments. In this article we used the learning styles theory and its relationship with the learning objects to improve the quality of these objects. Extracting the metadata, using a tool described in this paper, can determine the learning styles in each learning object, then are selected the adequate objects per student depending on his/her preferred style. We applied this functionality in SIMBAD, a model created for the semantic web.

1 Introduction

In this article we applied the obtained results of the extraction of learning styles in learning objects described as per [1], in SIMBAD[2] that is ontology based model. This model has been developed with a high semantic richness. Our proposal intends to improve either the possibilities to adapt the contents to the student preferences and assist the authors in the selection and development of learning objects adapted to the student. The article starts defining the general concepts of the learning styles theory and learning objects technology, then is described the SIMBAD model and finally is shown a case of study where is demonstrated our proposal functionality.

2.1 Learning Objects

The e-learning technology has proposed various applications to support the learning process; one of them is learning objects technique. The IEEE Organization defined the learning objects in LOM, as “whatever entity, digital or not, that can be used in the learning, the education or the formation process” [3]. Other formal definitions are: "... digital resources, with a unique identification that can be used to support the learning..." [4], "...whatever digital resource that can be used or reused to support the learning..." [5].

2.2 Learning Styles:

The learning styles make reference to de individual differences between persons when they are immersed in a learning process, this theory defined in the 50s but started to be applied in the 70s. The learning styles are a combination of cognitive, emotional and physiologic characteristics. The Kolb model or Experiential Learning Model [6], is based on the idea that the experiences are a previous requirement to acquire physical abilities, reflexive observation, abstract conceptualization and active experimentation. The learning is a cycle where each person has specific preferences for some part of the process. Honey and Munford [7] identified four learning styles based on Kolb s experience. They started studying the LSI (Learning Style Inventory) and Kolb theory, to propose the four learning styles (activists, reflectors, theorist and

pragmatics) and the LSQ (Learning Style Questionnaire) test, this study was applied to a group of UK managers.

Honey & Alonso [8] took the Honey and Mumford experience and brought it back to the academic world. The CHAEA questionnaire is a result of the translation and adaptation of the LSQ of Honey and Mumford applied in Spanish Universities to 1371 students in different areas.

2.3 Learning styles metrics:

We have defined it in [9], this is a group of metrics that apply to reusability, complexity and pedagogic dimensions. In [1] we proposed to improve the learning objects quality using the learning styles, by presenting a group of indicators taken from Honey and Alonso theory. These groups of indicators have been evaluated by a team of learning styles experts. As a result we prepared a group of metrics to identify the indicators presence in each learning object. We also came out with a relationship between the learning objects and styles. Finally, we decided to evaluate the learning objects from their metadata. The metadata provides the information required to classify the learning objects. Given the fact that there are different metadata models, we choose to select the Learning Object Metadata (LOM) [10] model due to it has become in a standard applied to almost all learning objects environment.

Table 1. Learning Styles Metrics

Pedagogic Quality Metrics
M1: Number of persons who can take part
M2: Level of the people who takes part
M3: Number of theoretical concepts
M4: Number of practices concepts
M5: Number of videos
M6: Number of visual models and images
M7: Number of text content
M8: Number of sound contents
M9: Time by content
M10: Number of structure contents
M11: Number of linear contents
M12: Number of exercises or questions
M13: Number of complex content
M14: Number of simple content
M15: Number of new concepts

2.4 Metrics description and how to be obtained:

To obtain the metric it was developed an algorism to allow working on a flexible mode, this way we would apply the metrics into a different models and environments. It also allows to aggregate new functionalities from the historic data as well as to add the authors and teachers experience.

2.5 Definitions to conceptualize the metrics:

Definition 1: Component is defined as any unit that is part of a learning object. Considering the definition of learning objects given above, the components associated to this definition are: unit contents, concepts, files, e-medias, and whatever other element that could be used to support the learning process and has relevance from the point of view of the didactic strategy.

Example 1: The object C_{12} has inside the C_3 element that is a web page integrated by text and images, but should be accessed as a whole not in parts. That is why C_3 represents a component.

Example 2: The C_{12} has inside the C_6 element that is a chat reference, this reference is part of a designed strategy for the learning object, this way C_6 is considered a component.

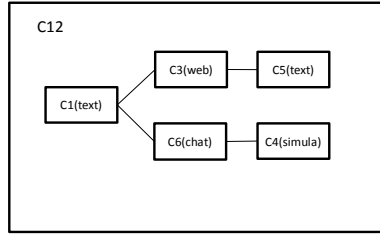


Figure 1. Content object

\mathbb{C} is set of all components.

C_i is unique ID of the component.

$Cx = \{C_1, C_2, \dots, C_i\}$ where Cx contain the components C_i .

Example 3: for the object C10 their components are $\{C_1, C_2, C_3, C_4, C_5, C_6\}$

Example 4: for the object C12 their components are $\{C_1, C_3, C_4, C_5, C_6\}$

Atomic component: A component is atomic when is composed for a unique element:

C_{atomic} if $\exists! C_i \in Cx$

Example 5: for the object C1 their component is $\{C_1\}$, therefore C1 is an atomic component.

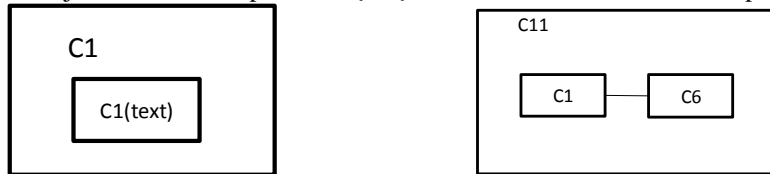


Figure 2. Atomic and composed components

Composed component: A content is composed when it contains two or more atomic elements.

$C_{compose}$ if $\exists C_i \in Cx$ and $|\{C_i\}| \geq 2$

Example 6: for the object C11 their components are $\{C_1, C_6\}$, therefore C11 is a composed component.

2.6 Components associated metadata:

Each component has defined characteristics through the LOM, they allow to define the functions to extract relevant information from the contents. In our case we use the following functions, where C_i is the identification of the component:

Table 2. Functions to extract learning object metadata

Function
RES(C_i)=get resource(C_i)
IUR(C_i)=get LOM.Educational.IntendedUseRole(C_i)
LRT(C_i)=get LOM.Educational.LearningResourceType(C_i)
FTE(C_i)=get LOM.Technical.Format(C_i)
TLT(C_i)=get LOM.Educational.TypicalLearningTime(C_i)
GES(C_i)=get LOM.General.Structure(C_i)
DIF(C_i)=get LOM.Educational.Difficulty(C_i)
PRE(C_i)=get Prerequisite(C_i)

2.7 Metrics and the way to obtain them:

Using the functions identified on the Table 2, we defined how to convert these data into the metrics defined in the Table 1. Following it is shown an example of the Metric 4 (Practice concepts number), where are defined the metric types, definition/relevant comments, rule to obtain the value and scale how to present it.

Metric	M4.- Number of practice concepts
Type	Attribute
Definition/ commentaries	Into metadata LOM LearningResourceType, the values associates are (simulation, diagram and experience).
Rule to obtain the value	$M4 = \{ \forall C_i \in C LRT(C_i) \in \{application, demonstration, annotation, conclusion, example\} \} $
Scale of preference	0 ● ————— ●

2.8 Presence or absence of value on the metrics:

As per Honey & Alonso [8], for the persons with *high* or *very high* preferences of a specific learning style they are learning strategies that ease or difficult the learning. They mentioned that, a reflexive student works better alone. In an opposite way, an active student the performance improves by working in groups. These two examples help to give value to the data that can be obtained from the metrics. We defined, from the opinion of the experts, the values associated to the metrics that are favorable, unfavorable and neutral per each learning style. Finally, from 15 metrics, the result was: 5 favorable (+), 5 neutral (O) y 5 unfavorable (-) per each learning style (see Table 3).

Table 3. Application levels of metrics.

Metrics	Pedagogic Quality Metrics	Activist	Reflexive	Theorist	Pragmatic
1	M1: Number of persons who can take part	+	-	O	O
2	M2: Level of the people who takes part	O	O	-	+
3	M3: Number of theoretical concepts	O	+	+	-
4	M4: Number of practices concepts	+	-	-	+
5	M5: Number of videos	-	O	O	+
6	M6: Number of visual models and images	O	+	+	O
7	M7: Number of text content	-	O	+	-
8	M8: Number of sound contents	-	+	O	O
9	M9: Time by content	-	+	O	-
10	M10: Number of structure contents	O	O	+	-
11	M11: Number of linear contents	O	-	-	+
12	M12: Number of exercises or questions	+	-	-	+
13	M13: Number of complex content	-	+	+	-
14	M14: Number of simple content	+	O	-	O
15	M15: Number of new concepts	+	-	O	O

3 SIMBAD model:

The SIMBAD model is divided in three parts (learner model, domain model and resources model) that have a complementary interrelation to offer an environment of great semantic richness, focus on the student. The Domain model contains concepts associated to the specific subject, the Learner model contains personal characteristics and the Resources model integrated by the learning objects. Following are shown each of these models with its components.

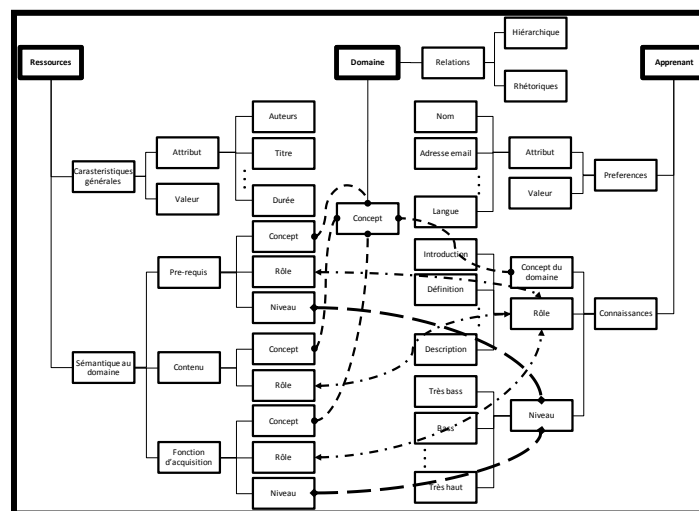


Figure 3. SIMBAD Model

3.1 Domain Model:

It is used to describe all the concepts included in the system. Following De Bra [11] the Domain model identifies the structure of the domain in terms of concepts and their relationships. In SIMBAD the concepts are described by a graph where the nodes are the concepts and the arcs are the semantic relationships between concepts. There are in use two types of relationships, hierarchical and rhetorical. The hierarchical relationships are established from the “father/son” concepts, this happens when a concept depends of other concept, this way it can only be explained from this other. In SIMBAD the domain graph is represented by ontology. The domain model will serve as a reference to semantically index learner with resource.

3.2 Learner Model:

The learner model storage the user characteristics to make the adaptation. It includes the knowledge of the user about the concepts of the domain model De Bra [11].

The preferences are considered by many e-learning systems in different ways, Brusilovsky [12] considers the preferences as the adaptation of the language or the presentation of the learning contents. The SIMBAD student model contains factual information of the users. The content of this model will change in a dynamic and automatic way to allow the student follows the courses and acquires new knowledge. The user model SIMBAD is represented by the tupla:

$\langle \text{learner}, \{\text{preference}\}, \{\text{knowledge}\} \rangle$

Where *Learner* corresponds al *userid*, the group *preference* are different aspects related to the student represented by the tupla $\langle \text{attribute}, \text{value} \rangle$, and *knowledge* is the group of values represented by the tupla $\langle \text{domain-concept}, \text{role}, \text{educational-state} \rangle$.

In order to add the learning styles to the user model, we use the preferences to indicate the levels of each learning style. Then, we have *attribute* that means each learning style and *value* the style level, for example: $\langle \text{reflexive}, \text{medium} \rangle$, $\langle \text{activist}, \text{high} \rangle$.

3.3 Resources Model:

They are the group of objects or resources selected and included in the system, from one repository of learning objects that can be related to de domain model in determined contexts. A domain is a group of concepts, while a context is a group of situations and learning contents. Each of the resources included in the system must have a complete semantic description in order to have them reachable and reusable; it means that must be described by a group of meta-data. In the fig. 4 are shown the components of the resource model.

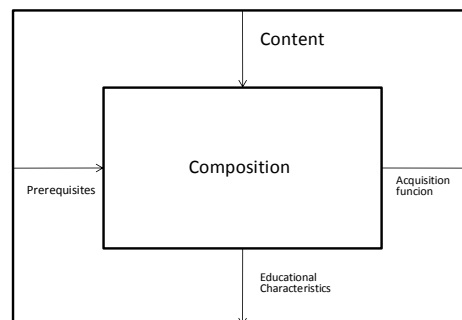


Figure 4: Resources description in SIMBAD

In SIMBAD one Educational Component is represented by the tuple:

$\langle Ci, Metadata, Composition \rangle$

Where Ci is the unique identifier of the component.

Metadata: includes the following items per each component: *Contents*, *Prerequisites*, *Acquisition Function* y *Other-Characteristics*.

Composition : a composed component is specified by a composition graph (an acyclic directed graph).

At the same time, each item is described as follows:

Contents : a component that can be related with at list of one domain concept, this relationship is defined by the tuple

$\langle domain-concept, role \rangle$

Where *domain-concept* is a piece part of the learning object and *role* describes the topic developed by a component in reference to the domain concept; $role \in \{application, definition, demonstration, description, experiment, history, introduction, summary, annotation, conclusion, explanation, example, exercise, hypothese\}$

Each component could perform one or more roles, the creator defines this Group of results in terms of the pedagogic goals.

Prerequisites : each component can require prerequisites, this means the previous contents required to get access to the current content. The prerequisites are represented by the tuple:

$\langle domain-concept, role, knowledge-level \rangle$

Where *role* is optional and *knowledge-level* is some of the following values $\{very\ low, low, medium, high, very\ high\}$

Acquisition Function : is a function $F(a)$ that represents the knowledge acquired by the student after using a component. In the other side it defines a mapping between educational levels used by this model and the educational levels used by teachers. The *Acquisition Function* takes two possible values: *success* or *FAIL*. Depending of the result it is incorporated or not this component to the user model.

Other Characteristics : is the Group of metadata used to describe non-functional properties of the component. For example author, title, format, copyrights, context, etc. They are represented by the tuple :

$\langle tag, value \rangle$

For the implementation of the learning styles in SIMBAD we extract the metrics M3, M4 y M12, from the *role* in *Contents*.

The value extraction functions are specified as follows:

Function
$RES(Ci)=get\ resource(Ci)$
$IUR(Ci)=get\ LOM.Educational.IntendedUseRole(Ci)$
$LRT(Ci)=get\ contents.role(Ci)$
$FTE(Ci)=get\ LOM.Technical.Format(Ci)$
$TLT(Ci)=get\ LOM.Educational.TypicalLearningTime(Ci)$
$GES(Ci)=get\ LOM.General.Structure(Ci)$
$DIF(Ci)=get\ LOM.Educational.Difficulty(Ci)$
$PRE(Ci)=get\ Prerequisite.domain-concept.knowledge-level(Ci)$

The metrics are converted in percentages to facilitate the locations in the values {high, medium, low}. The result value per each metric is incorporated to the model through the metadata “Other Characteristics”, being *tag* the metrics and *value* the calculated percentage per each one. For

example, the metric M7 obtains the value 78% can be aggregated to the following metadata: <M7, 78>

In the same way we will insert the level resulting value of each learning style obtained through the function *Niveau.Style* in “Other Characteristics”, being *tag* the learning styles and *value* the level obtained, for example:

<reflexive, high>
<active, less>

When each metric is expressed in common scale, this means in percentages, we can divide the scale in three equal parts to identify the metrics with high, medium and low level. The presence of a *high* in the analyzed metric is favorable for the style selected. In opposite, the presence of *low* in a metric is favorable for the style in which the indicator harms the learning.

3.4 Rules to determine the level of the metrics in the resources:

Rule 1: Rule to extract if the metric is favorable or not.

```
IF Mx is 'favourable' THEN prefer(Mx)='positive';
IF Mx is 'de-favourable' THEN prefer(Mx)='negative';
ELSE prefer(Mx)='neutre';
```

Rule 2: To determine the level high, medium or low of each metric.

```
IF 0%<Mx<33% THEN niveau(Mx)='Bass';
IF 33%<Mx<66% THEN niveau(Mx)='Medium';
ELSE niveau(Mx)='Haut';
```

Rule 3: To determine if the object satisfy the metric conditions.

```
IF niveau(Mx)='Bass' AND prefer(Mx)='negative' THEN application(Mx)=1;
IF niveau(Mx)='medium' AND prefer(Mx)='neutre' THEN application(Mx)=1;
IF niveau(Mx)='haut' AND prefer(Mx)='positive' THEN application(Mx)=1;
ELSE application(Mx) = 0
```

Rule 4: To obtain the total value of the accomplished metrics.

$$Total.Metrics = \sum_{i=1}^{10} application(Mx) | prefer(Mx) = 'negative' or prefer(Mx) = 'positive'$$

Rule 5: To obtain the level of each learning style for the selected object.

```
IF 0<Total.Metrics<3 THEN Niveau.Style='Bass';
IF 4<=Total.Metrics<=7 THEN Niveau.Style='Medium';
ELSE Niveau.Style='Haut';
```

3.5 Resources composition:

A composed resource is structured by the application of the resources composition operators. This creates a composition graph. In SIMBAD exists 5 operators, three simple (SEQ sequence, PAR parallel, ALT alternative), and two complex (AGG for resources aggregation and PROJ to define one resource as a projection of other).

3.6 Interaction modes:

In SIMBAD are defined three different selection types that corresponds to different pedagogic modes; course mode that represents the classic learning model, concept mode that represents an active mode for the student and the query mode that is similar to the concept mode but it is expressed in non semantic parts of the description model.

Each mode performs the customizing process to finally provide the student with a component as a result of the process. The customization is done in all the selection modes and is integrated in four parts; Composition Expansion, Prerequisites Filtering, Prerequisite Rewriting and Preferences Filtering.

Composition Expansion: The composition graph is transformed to obtain one Group of Delivering Graphs. Prerequisites Filtering: it is related to the student background and expressed in the prerequisites. In the user model are selected the adequate delivery graphs. Prerequisite Rewriting: if there is not a delivery graph that complies with the prerequisites of the student, it is performed a process of rewrite of the prerequisites until some adequate result appears. Preferences Filtering: when a group of adequate delivery graphs are found, they are filtered based in the student preferences.

We have expanded this last aspect by introducing the learning profile inside the preferences. It is clear that the preference of the learning styles, as per the description in this article, presents an integral vision of the learning process. Due to the above mentioned, to select the Delivery Graph (DG) we use the learning profile. There are 4 ways to customize with learning styles: selecting the DG s with total coincidence with the learning profile (all the styles in the same level), using the style with *high* preference (preferred style), considering the style with *low* preference that needs to improve (deficient style) or selecting the style that best fits with the student learning style (favorable strategy).

3.7 Concepts and rules for adaptation process:

Following are described the basic concepts and rules to make an adaptation process by using learning styles.

```

Variables:
:style: identificateur style
Function user-style-level:
user-style-level(:uid, :style)is {low, medium, high}
Function user-style:
user-style(:uid)= (user-style-level(:uid, "active"), user-style-level(:uid, "reflexive"),
user-style-level(:uid, "theoric"), user-style-level(:uid, "pragmatic")
Function content-style-level:
content-style-level(:coid :style) is {low, medium, high}
Function content-style:
content-style(:coid)= (content-style-level(:coid, "active"), content-style-level(:coid,
"reflexive"), content-style-level(:coid, "theoric"), content-style-level(:coid, "pragmatic")

```

Rule 6: To determine the preference contents per learning profile:

```

IF q-contain(:uq, :coid)
AND equal(user-style(:uid), content-style(:coid))
DO
    USE-CONTENT (:coid);

```

Rule 7: To determine the contents by preferred style:

```

IF q-contain(:uq, :coid)
AND equal(user-style-prefer(:uid), content-style-prefer(:coid))
DO
    USE-CONTENT (:coid);

```

Rule 8: To determine the contents by styles with low preference:

```

IF q-contain(:uq, :coid)
AND equal(user-style-low(:uid), content-style-prefer(:coid))
DO
    USE-CONTENT (:coid);

```


Rule 9: To determine the roles for the theoretic style:

```
IF q-contain(:uq, :concept)
AND equal(user-style-prefer(:uid), "theoretic")
DO
    USE-ROLES ("Description", "Definition", "Example", "Introduction", :concept);
```

Rule 10: To determine the roles for the pragmatic style:

```
IF q-contain(:uq, :concept)
AND equal(user-style-prefer(:uid), "pragmatic")
DO
    USE-ROLES ("application", "demonstration", "annotation", "example", :concept);
```

Rule 11: To determine the roles for the activist style:

```
IF q-contain(:uq, :concept)
AND equal(user-style-prefer(:uid), "active")
DO
    USE-ROLES ("application", "demonstration", "Experiment", "example", "exercise" :concept);
```

Rule 12: To determine the roles for the reflexive style:

```
IF q-contain(:uq, :concept)
AND equal(user-style-prefer(:uid), "reflexive")
DO
    USE-ROLES ("Description", "Definition", "history", "conclusion", :concept);
```

3.8 Case of study:

In the following case of study we can observe the rules defined previously, first of all we have the function user-style that obtains the learning profile of the students and then the function content-style obtains the styles profile of each learning object.

Function user-style:

```
user-style(Student-1)=("high", "medium", "medium", "high")
user-style(Student-2)= ("medium", "low", "low", "medium")
user-style(Student-3)=("medium", "medium", "medium", "medium")
user-style(Student-4)= ("medium", "high", "high", "low")
user-style(Student-5)= ("medium", "medium", "medium", "medium")
user-style(Student-6)= ("low", "medium", "high", "medium")
user-style(Student-7)= ("high", "low", "high", "medium")
user-style(Student-8)= ("high", "medium", "low", "medium")
user-style(Student-9)= ("medium", "low", "medium", "low")
user-style(Student-10)= ("low", "medium", "medium", "high")
```

Function content-style:

```
content-style(object-1)= ("low", "medium", "high", "low")
content-style(object-2)= ("low", "medium", "high", "low")
content-style(object-3)= ("medium", "low", "medium", "low")
content-style(object-4)= ("low", "low", "medium", "low")
content-style(object-5)= ("medium", "low", "medium", "low")
content-style(object-6)= ("low", "low", "medium", "low")
```

For the student 9, the objects 3 and 5, are in correspondence with their learning profile, this means:

```
user-style(Student-9)= content-style(object-3)
("medium", "low", "medium", "low") = ("medium", "low", "medium", "low")
```

For the student 6, the objects 1 and 2, are adequate for the preferred style, this means the theoretic.

```
(user-style-prefer(student-6)= content-style-prefer(object-1))
("high") = ("high")
```

For the students 2 and 8, the objects 1 and 2, are adequate to strengthen its low style, this means the theoretic style.

```
(user-style-prefer(student-6)= content-style-prefer(object-1))  
("low") = ("high")
```

4. Conclusions

The application of the learning styles in learning objects is a powerful way to improve the contents quality, by presenting the adequate objects for the student's preferences.

We have applied the metrics of the learning styles in the selection, indexation and reutilization of learning objects.

The tool developed to extract the metrics can be used in different environments, being a source of assistance to the contents authors in the design and selection of the objects. In the other hand it contributes with the students by adapting the environment to the learning styles preference.

The application of our proposed tool in SIMBAD model allows completing the pedagogic dimension associated to didactic strategies that is a coherent mode to extend the model by adding the student's individual differences.

In future studies we will be able to refine the metrics group and the validation scales from the data mining to allow quantify in a direct mode the preferences and learning styles. This would be obtained from the student's navigation data taken from their interaction with a variety of domains.

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