Learning Objects Adaptation in Virtual Courses Using Software Agents

Julian Moreno
Universidad Nacional
Colombia
jmoreno1@unal.edu.co

Demetrio A. Ovalle
Universidad Nacional
Colombia
dovalle@unal.edu.co

Jovani A. Jiménez
Universidad Nacional
Colombia
jajimen1@unal.edu.co

ABSTRACT

The aim of this paper is to present a model for educational digital content adaptation for an Intelligent Tutoring System using a Multi-Agent approach. Such model handles several types of Learning Objects which are described trough metadata standards and it uses them in the implementation of active learning strategies based on learning styles and other characteristics of the student profile.

RESUMEN

El objetivo de este artículo es presentar un modelo para la adaptación de contenido educativo digital en un Sistema Tutorial Inteligente usando una aproximación Multi-Agente. Dicho modelo contempla diversos tipos de Objetos de Aprendizaje, los cuales son descritos por medio de estándares de metadados y son usados en la implementación de estrategias de enseñanza activas basadas en los estilos de aprendizaje y otras características del perfil del estudiante.

KEYWORDS

E-learning, Intelligent Tutoring Systems, Learning Objects, Learning Styles, Metadata, Multi-Agent Systems.

INTRODUCCIÓN

In the e-learning field, the Learning Objects (LOs) have emerged as an interesting option to create, save and retrieve educational digital contents, becoming very useful for students and teachers who can access big resources repositories making the learning/teaching process easier. Such features have promoted LOs, which have been used in order to design, using also pedagogical theories and approaches, more robust tools, reducing the gap between classical and virtual education.

More specifically, Intelligent Tutoring Systems – ITS whose basis are supported by Artificial Intelligence techniques, are nowadays one of the most interesting approaches to create virtual courses and they uses LOs in order to improve them. According to Siemer and Angelides [12] an ITS has a defined architecture (see Figure 1) and allows to simulate the human teaching process adapting the kind and content of the instructions to the specific students needs deciding when new concepts must be introduced and when going over previous ones if they have not been assimilated. In order to perform these tasks an ITS considers the knowledge to be taught (domain model), the way to teach it (teaching model), and the relevant information of the student who is learning (student model).

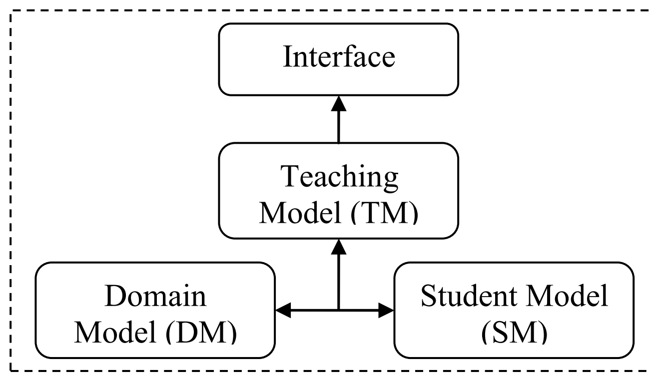

Figura 1. ***Typical ITS structure***

The rest of this document is organized as follows: In the next section some background about ITS and its relation with LOs is presented. Next a brief review of related works is described followed by the description of the proposed model. Finally some conclusions and an outlook are discussed.

BACKGROUND

In this section a brief description of Intelligent Tutoring Systems and Learning Objects is presented.

Intelligent Tutoring Systems - ITS

According to the revision of literature, an ITS must accomplish the next functions:

- Having knowledge about the contents to be studied as well as the way to teach them.
- Being adaptive. It must adapt the contents to the needs and learning speed of the student.
- Being reactive. It must be able to reorganize the teaching plan if the student's evolution requires it.
- Being robust. It must have a large set of didactical tools and a selection mechanism for them.

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- Being evaluative. It must evaluate the though contents using exercises to verify the student's knowledge level.
- Being motivator. It must encourage the students using messages: congratulations when the evolution is adequate and warnings otherwise.

From these functions the adaptability is the one in which we focused because it allows simulating the attitudes of a good teacher when he/she adjust the classes according to the specific requirements of the students. In the field of computed assisted teaching/learning process, there are several adaptation techniques [1, 8]:

1. Curriculum sequence: Provides adjustment and individualization in the topics sequence and learning tasks that students must accomplish.
2. Interactive support to problems solution: Provides help on each step of the problem solving process when students face them.
3. Adaptive collaborative support: Its goal is using the information of each student regarding their group work profiles and interests in order to arrange well balanced study groups.
4. Adaptive presentation: Its goal is adapting the content of each part of the course (generally using a hypermedia page) to students' needs, knowledge level, learning styles or any other information saved in the student module.
5. Navigation adaptive support: Provides orientation in the content navigation in the sense that changes the appearance of the links [3].
6.

All of these techniques require a deep knowledge of each student and must feedback such knowledge in the student module in order to monitor and assist their progress. Besides, all of them represent a significant change with regard to traditional virtual courses as we know them (which are in most of cases just on-line contents): In a ITS the presentation of the course (usually web pages) is not static, rather it is generated dynamically and in a personalized way.

From these techniques the work presented in this paper focus mainly on 3, although the research project from which this work is a part, also considers 1 and 4.

Learning Objects

Within educational technological revolution of the last decades, the term Learning Object – LO appeared around 1992 inspired in the Lego game and its use has increased from there since different groups and researchers have worked on e-learning and the ways to improve it and make it more flexible. According to the IEEE a LO may be considered as a digital entity with instructional design features that may be used, re used or referenced during computer supported learning process with the aim of generate knowledge, skills and competences according to students' needs.

To separate LOs from the rest of resources that are offered trough Internet, they must have several characteristics:

- Interoperability: is the capacity of working under different platforms (i.e. operative systems)
- Usability: the same LO may be used in different courses
- Scalability: several Los may be integrated in larger and more complex structures
- Accessibility: students and teachers must be able of access the LO freely and during the time they need
- Durability: refers to the validity of the information that LOs contain. In other words LOs must not be obsolete.
- Self content: LOs must have information about themselves

This last characteristic is the one that allows the adaptation in the ITS because among such information, there are some data that may be associated with the learning style of the students. More specifically such information is known as the LO´s metadata and they allow, among other features, making more efficient searches, as well as compile and group LOs according several criteria [7].

There are some organizations like the IEEE, the IMS Global Learning Consortium and the Dublin Core Metadata Initiative that develop standards for those metadata. One the most known standards is the Learning Object Metadata - LOM that is usually encoded in XML. All these standards have a set of attributes to describe LOs like type of object, author, terms of distribution, format, pedagogical attributes, etc. Some of these may be used for the adaptation in ITS, however most of them are too generic and are not associated with learning profiles.

RELATED WORKS

Several ITS and other approaches have been implemented with the aim of making better virtual courses considering content adaptation. Some of these efforts have considered brain researches and the way humans learn in order to generate a raise in the learning level of the students. On example of this is the development of a design strategy of didactical tools that are based in the student's thinking style [10] which is measured with the Ned Hermman's integral thinking model [6]. To choose a didactical strategy, this approach uses specifically the Ned Hermman's colors theory to classify students in one of the four proposed colors and then they are classified by their learning style. Later, based on such classifications a strategy that is adapted to the student's characteristics is proposed.

Other work is the one of Peña et al. [9] who present a Multi-Agent System – MAS for adaptive intelligent tutoring that considers learning styles entitled MAS-PLANG. In this approach, the adaptation techniques look for the personalized selection of the didactical contents, the navigation tools and the navigation strategies. For student modeling, several Artificial Intelligence techniques like case based reasoning and fuzzy logic are used.

Other interesting application that integrates MAS and ITS with the goal of facilitating the creation and administration of virtual courses is presented by Salcedo et al. [11] and entitled Mistral. One important issue about this approach is the ability of making a diagnosis about the stugdent´s knowledge level, learning style and profile, in order to choose the best learning strategy and evaluation mechanism for that student.

Cataldi et al. [2] propose a structure for ITS that integrates the more significant issues of the MAS. Such structure considers the incorporation of software agents in the student and teaching modules also using the Perkins theory about the learning styles and the Gardner´s multiple intelligences model. This approach focuses in the student model, which is very complete, and in the implementation of several specific agents (interface, profile analyzer, evaluator, etc.) in order to adapt the learning process.

PROPOSED MODEL

This section presents the proposed adaptation model explaining first how the student's learning styles may be measured, then how a course may be modeled, later what kind of LOs may be considered, and finally what is the architecture of a MAS that supports all the considered features of the presented ITS.

Learning styles determination

According to what we have discussed so far, an ITS should adapt the educational contents to each student using their profiles and more specifically their learning styles which are saved inside the student model.

The learning style may be defined as the set of psychological characteristics and cognitive features that usually emerge when a person must deal a learning experience. Each person uses several styles, but most of the times one of them is predominant. These styles may be measured trough several tests like the Felder's test [4, 5] whose analysis reflects different dimensions of a person's learning and, in some way, the features that describe his/her personality. Peña et al [9] who were cited in the related works section also uses this test in order to obtain the predominant learning style of the students. Table 1 presents the dichotomycal dimensions in which a student may be more strongly classified and they came from the answers given by Felder and Silverman to the next questions:

¿What kind of information the student rather perceive?
¿How is the cognitive information more easily preceived?
¿With what kind of information's organization does the student feel more comfortable when he/she is working?
¿How does the student prefer processing the information?
¿How does the student progress during learning?

Once these dimensions is determined as the predominant (or a couple if a strong tendency is not evident) the ITS must present the contents of a course in an adequate format so the student may achieve a better comprehension. Peña et al. also presents several mappings between these dimensions and several features of the educational contents as shown on Table 2 and 3.

	Dichotomy	
Dimensions	Active	Reflexive
	Sensitive	Intuitive
	Visual	Verbal
	Inductive	Deductive
	Sequential	Global

Table 1. ***Learning styles classification***

	1	2	3	4	5	6	7
Global	X			X	X	X	X
Sequential	X	X	X	X	X	X	X
Verbal	X				X	X	X
Visual	X	X	X	X		X	
Active	X		X			X	X
Reflexive	X	X	X	X	X	X	X
Sensitive			X	X			X
Intuitive	X	X	X	X	X	X	X

Table 2. ***LO interactive type vs. learning style***

Where:

1. Examples
2. Animations
3. Simulations
4. Interactive graphs
5. Glossaries
6. Self evaluation exercises
7. Open answer exercises

	8	9	10	11	12	13
Global			X	X		
Sequential	X	X		X	X	X
Verbal	X				X	X
Visual		X	X	X		
Active						X
Reflexive		X	X	X		X
Sensitive		X	X	X	X	X
Intuitive	X	X	X	X	X	X

Table 3. ***LO format vs. learning style***

Where:

8. Textual slides
9. Multimedia slides
10. Graphic clips
11. Video clips
12. Audio clips
13. Flat text

In the model presented on this paper we use a table similar to those tables and we make use of the metadata of the LOs to determine their features. For instance, a LO about a Gauss Bell in a Statistics course, like the one presented on Figure 2 and whose metadata (part of it) is presented above it, may be a flash file were students may select with the mouse the position on the curve and the LO shows them the corresponding accumulated probability. In this case this LO may be classified according to table 2 on column 4 and therefore it may be useful for students with all dimensions except for the ones who are Verbal or Active.

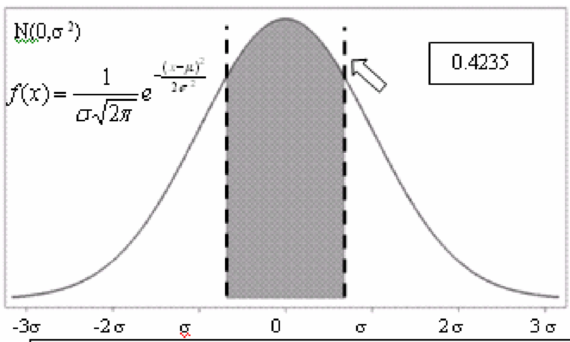


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Figura 2. ***Learning Object example: Gauss Bell***

Courses modeling

As it was mentioned before, the domain model in a ITS has the information about the course's contents and contains the knowledge that will be transmitted to students. The structure of such model must be organized in a hierarchical way from big components that make up the main parts of the course (units, chapters, etc.) to less complex components (sections, modules, etc.) until the more atomic parts that are precisely the LOs. The structure that we adopt for the ITS considers the course as the root of the hierarchy, and it is composed by Learning Basic Units – LBUs, that have one or several Topics. Such Topics have associated Instructional Goals – IGs which may be achieved through the development of one or several Activities which have associated one or several LOs (see Figure 3).

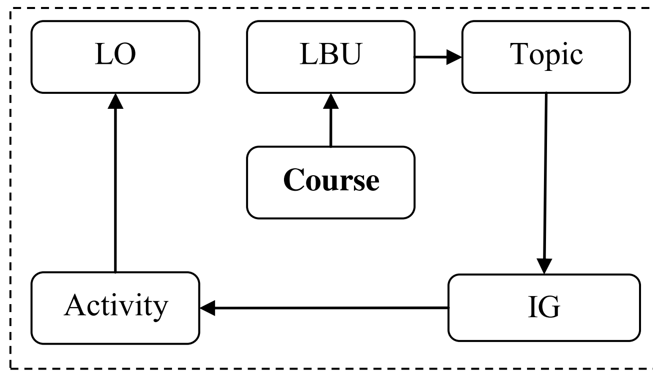

Figura 3. ***Domain model structure***

Based on this structure the ITS must adapt the instructional plan for each LBU and therefore all its components until the Activities level using the available LOs according, as we said before; to the learning styles of the student. In other words the ITS must contrast the information of the domain model (metadata of the LOs) and the student model (learning styles classification), using the teaching model in order to guide the learning process in an adapted way.

Learning Objects types and formats

As we discussed previously, the idea of the ITS that is presented in this paper is that it contains a set of LOs to present the contents of the courses in an adapted way, according to each student style. In order to do that, the ITS must have a LOs repository where several objects have the same content but with different format. Such formats include text files (pdf, doc, txt, rtf, etc.), video files (wmv, avi, mpg, etc.), audio files (mp3, wav, etc.), slides, (ppt, pdf, etc.), animations (swf, exe, gif, etc.), among others, and all of them must have the metadata that indicates somehow the learning styles that better suite them.

The LOs that were used in this work considered all those formats and are classified in four different learning modes (whatever the format is): Instruction, Practice, Collaboration and Assessment.

- Instruction: This kind of objects presents clear explanations about the theory, principles and concepts that a LBU contemplates. These objects may be presented in the form of lessons, lectures, workshops, etc. To encourage students' interactivity and to involve them effectively in the learning process, this kind of objects may also include anticipation questions and simple exercises. A pretty simple example of a part of this kind of objects using two different formats and styles is presented on Figure 4. The first one is presented as text more suited for a sequential and verbal student, and the second one is presented as a graphic more suited for a global and visual student. This example was taken from a basic programming course and both objects are associated with the IG: "Learning nested conditionals".

a. verbal/sequential

```
BEGIN
   Read X
   If X > 0
      Write "The number is positive"
   Else
      If X < 0
         Write "The number is negative"
      Else
         Write "The number is zero"
      End If
   End If
END
```

b. global/visual

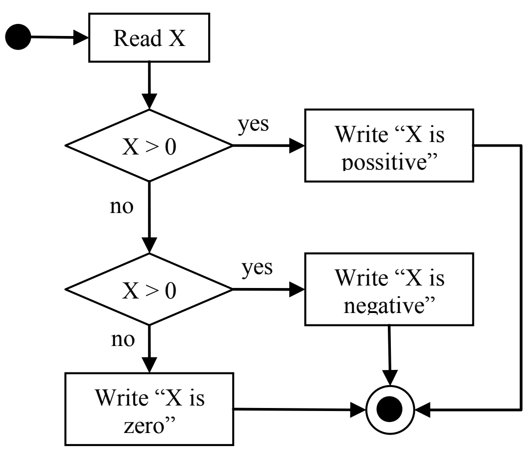

Figura 4. ***Learning Objects example***

- Practice: In this mode, students have the possibility of applying the recently acquired knowledge and their skills in complex exercises that, as far as possible, emulates real problems. These objects may be presented in the form of simulations, laboratories, role games, research problems, study cases, etc.
- Collaboration: The idea of this mode is that students may learn in a better way if they are able to interact with their classmates and teachers exchanging ideas, discussing and reinforcing concepts, etc. These objects may be presented in the form of group works and other collaborative strategies that may be supported by chats, forums, e-mails, etc.
- Assessment: Here is where the students are tested in order to verify their learning process before they pass to another course component (IG, Topic or LBU) or graduate of a whole course. These objects may be presented in the form of tests (evaluated by the IST itself or by the teacher), self evaluations, certification exams, etc.

Proposed architecture

When ITS first appeared, they were implemented using classical programming paradigms and later they were evolving to Object Oriented and Web based applications. As a contribution from Artificial Intelligence, the Multi-Agent Systems – MAS have emerged as a possible approach, and they have presented promising results in pedagogical applications [2]. The distributed nature of this approach facilitates the implementation of ITS because each module and actor may be modeled trough a software agent with specific tasks. In the proposal that is presented in this paper we used the structure that is shown in Figure 1 and considered two agents: Teacher and Student, which have their corresponding human counterparts. We also propose the next agents in order to distribute the ITS' tasks: Retrieval Agent, Filter Agent, Planner Agent, and Assessment Agent (see Figure 5).

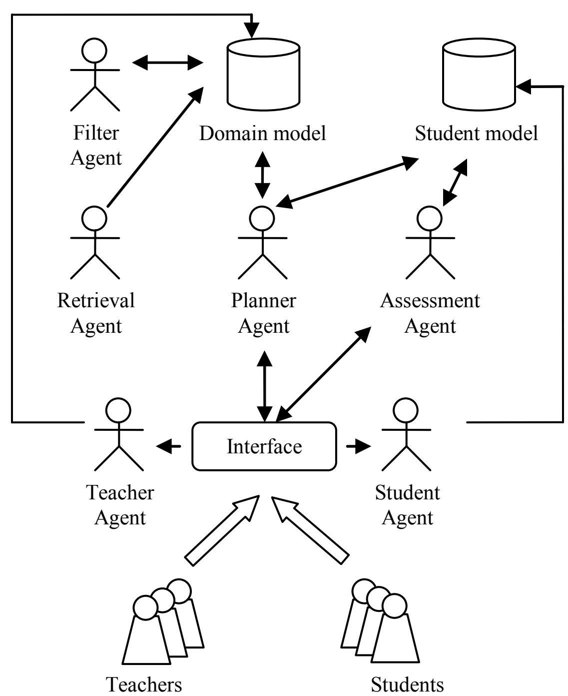

Figura 5. ***System's architecture***

From these four agents we only focused in this paper the Planner Agent, because it guides students in their learning process as similar as possible to a human teacher. In other words it is in charge of the curriculum sequence and the contents adaptive presentation that were discussed on the Background section. The other three agents do pretty much what their names say: Retrieval Agent "navigates" the Internet and local repositories looking for interesting LOs that may be used in the courses, Filter Agent selects and cleans the retrieved LOs and their corresponding metadata in order to incorporate them to the system, and finally Assessment Agent monitors the results of the assessments that were presented to the students by the Planner Agent in order to determine a grade (qualitative or quantitative) that feedbacks the planning process.

To perform the curriculum sequence the Planner Agent uses a hierarchical structure that associates the different course components. In this proposal we used a prerequisite approach at IG level, like the one presented on Figure 6, where each one of them has zero or more prerequisites, represented with arrows. In this way, when a IG is approved (measured using one or more assessment object), the IGs that have it as prerequisite are marked as active so the students could take them.

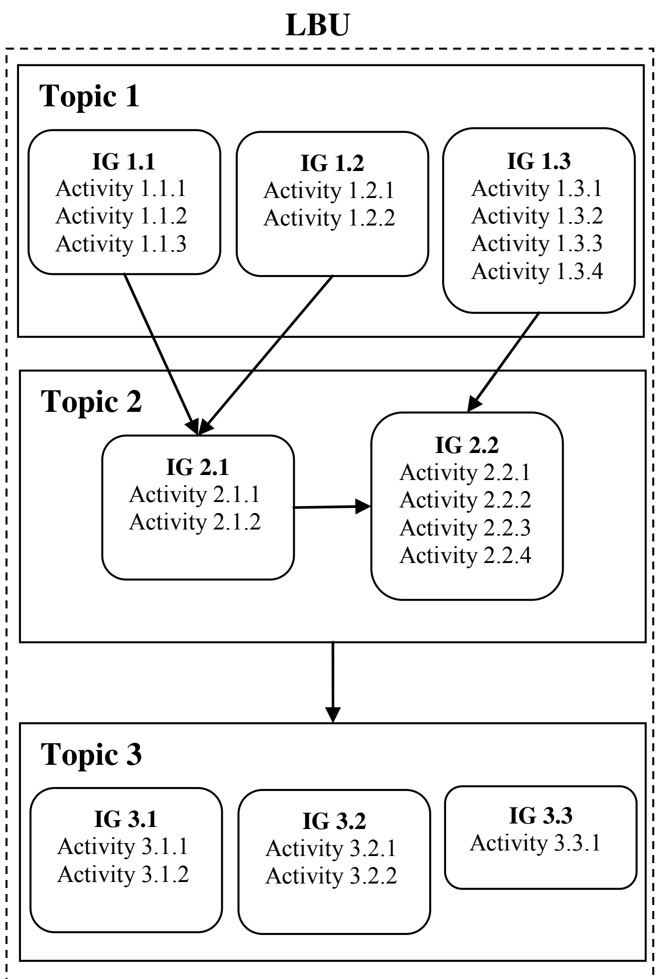

Figura 3. ***Prerequisite scheme example***

In the simple example a simple Course with only one LBU and three Topics is modeled. As shown on Figure 6 the IG 2.1 from the Topic 2 has as prerequisites the IG 1.1 and IG 1.2 from Topic 1, meanwhile the IG 2.2 has as prerequisites the IG 1.2 from Topic 1 and IG 2.1 from Topic 2. Between Topic 2 and three the arrow is not at IG level but Topic level, this is just an abbreviation and means that all IG from Topic 3 has as prerequisites all the IG from Topic 2.

Once the Planner Agent determines which IG it must present to a student the question is how does it must present it. If for a specific IG there is an Activity that has just one LOs the ITS, in the absence of any other option, must present it to each student. However, if there are several LOs that cover the same content, which one must be selected for a specific student? To solve this question the Planner Agent uses the student information and more specifically its learning style that is saved in the student module after it presented the Felder test described earlier (other psychological/pedagogical tests may also be used). The Planner Agent contrast this information with the metadata of each available LO and with the mapping between LOs features and learning styles that is presented in Tables 2 and 3. After this comparison the Planner Agent selects the LO that maps more criteria. If there is a tie between several LOs one of them is selected randomly.

For instance, consider a student whose Felder's Test classified him mainly as Reflexive and Verbal, and consider the metadata presented on Table 4 for 3 different LOs that cover a specific IG that is active for that student:

	LO 1	LO 2	LO 3
Title	While Instruction	While	While Cycle
Description	Describes how a WHILE works	Presents the structure of the while instruction with some examples	Examples of algorithms that uses while cycles
Format	ppt	rtf	swf
…			
Learning resource type	Slide	Narrative text	Simulation
…			

Table 4. ***Metadata example in LOM standard***

According to Table 3 LO1 (if classified as Textual slide) gets 1 point: Verbal but not Reflexive, LO2 (if classified as Flat text) gets 2 points: Verbal and Reflexive, and LO3 (if classified as Graphic clip) gets 1 points: Reflexive but not Verbal. In this way, LO2 would be selected for that specific student.

CONCLUSIONS AND FUTURE WORK

Most virtual educational applications that can be found in schools and even universities are quite simple and they limit to on-line content with no supervision or adaptation features. Such applications, even if they may have a lot of multimedia resources, use a linear and passive scheme where the lack of a personalized process is the main disadvantage.

In this sense, the proposed model in this paper is a valuable contribution because it enriches the scope of the Intelligent

Tutoring Systems – ITS, reducing the current gap between classical and virtual learning processes. In order to do that such model uses a Multi-Agent System - MAS architecture where one of the agents, the Planner agent, uses the information of the students and the metadata of the available Learning Objects – LOs to adapt the content to the student needs and preferences. To obtain the student's information, more specifically its learning styles the proposed model uses the Felder's test and the LOM standard for the LOs metadata.

As first task of the future work we are aware that a validation of the proposed model using some pilot tests is needed. In order to do that we expect to implement a whole basic engineering course (probably programming fundamentals) and present the obtained result in a further publication.

As future improvements of the model we propose including other LO metadata that may be useful for the adaptation to students' specific needs. For instance LOM standard includes other features like: Typical age range, Difficulty, Typical learning time, Keyword, etc. that could be contrasted to students' information. We also propose the study of other psychological tests that could give information about the students' profiles and the analysis of other ways of mapping the LOs with the learning styles. Finally as it was demonstrated with the instance in the last section, other LO standards (besides LOM) should be analyzed in order to discriminate the LOs in a more accurate way, making a more clear differentiation between the LO interaction type (what LOM calls *Learning Resource Type*) and its format or type of presentation.

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