Recommending Learning Materials according to Ontology-based Learning Styles

Joselaine Valaski, Andreia Malucelli, and Sheila Reinehr

Abstract-- **Personalized online systems have been developed to make learning more effective. One of the ways to achieve this personalization is to recommend the use of learning materials according to learning styles. However, information on learning materials and learning styles must be formalized to make automatic processing by the computer possible. The objective of this work is to propose an ontology that allows the recommendation of learning materials according to learning styles. The experiments presented here have proved that the use of ontology to meet the established objective is viable.**

***Index Terms* -- Learning Material, Learning Style, Ontology.**

I. INTRODUCTION

The availability of learning materials for sharing and reusing helps to reduce costs with material preparation, saves time and prevents duplication of efforts [1]. Therefore, to result in a more effective learning, personalized online learning materials have been developed to meet the individual needs of each learner [2].

One of the ways to offer personalization in an online learning system is by recommending specific learning activities and materials [3]. This personalization can be based on the learner's previous knowledge, objectives and preferences [4]. In this approach, learning materials can be recommended according to learning styles, since different people learn specific information in different ways [5]. Some learners feel more comfortable with theories and abstractions; others, however, prefer learning through visual presentations rather than oral explanations [6].

The existing information on learning materials and learning styles help an online learning system to make personalized recommendations. However, this information must be formally represented to be automatically processed by computers. The formalism adopted may offer a specific vocabulary, which would facilitate the automatic processing by the computers, and inference mechanisms for the discovery of new knowledge.

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Some representation standards for learning materials information [7]-[9], as well as for personal information [10]-[11], have been proposed. However, information on learning styles is not considered by these standards [1], [12]-[13]. In addition, the type of formalism adopted by these patterns offers only a common vocabulary without any inference mechanisms.

One way to represent this knowledge formally and be able to use an inference mechanism is by using ontology. Ontology is a formal specification of shared conceptualization [14]. It can describe a hierarchy of concepts connected by subsumption relationships, a concept more aligned with taxonomies; or a structure where axioms are added to express relationships among concepts and to limit their intentional interpretations [15]. Axioms make ontology more expressive by allowing the use of inference mechanisms.

In this context, the objective of this work is to propose ontology for recommending learning materials taking into consideration learning styles. The proposal is based on existing standards, but it also includes classes and properties.

The other sections in this article are organized as follows: Section 2 presents the theoretical background on learning styles and online learning systems representation patterns; Section 3 describes related works; Section 4 introduces the proposed ontology; Section 5 describes the experiment and discusses results; and, finally, Section 6 concludes the article.

II. LITERATURE REVIEW

A. Learning Styles

Material adaptation and personalization can be based on the learner's previous knowledge, objectives and preferences [3], being the learning style one of the ways to identify the learner's preferences.

Learning style refers to the differences that individuals have in understanding an instruction or studying, making learning more effective [5]. Kolb [16] defines learning style as individual learning differences based on learners' preferences by using different phases of the learning cycle.

Some learning style identification models have been developed such as the Kolb model and the Felder and Silverman model. In the Kolb model [16], two scales show how people get information (Concrete Experience - CE or Abstract Conceptualization - AC) and how they process this information (Active Experimentation - AE and Reflective Observation – RO). Based on these two scales, four learning styles were identified: diverging (CE/RO), assimilating (AC/RO), converging (AC/AE) and accommodating (CE/AE). The individual can be fitted in only one of the 4 available styles. In the Felder and Silverman model [17] five learning dimensions are defined: Perception (Sensory/Intuitive), Input (Visual/Auditory), Organization (Inductive/Deductive), Processing (Active/Reflective) and Understanding (Sequential/Global). In this model, one style is identified for each one of the five dimensions, i.e., for the Input dimension, the dominant style can be the Verbal whereas for the Processing dimension, the dominant style can be the Active.

For personalization to occur in an online learning system, learning materials, as well as personal information, must be formally represented.

B. Learning Objects Representation Patterns

To develop personalized learning programs and increase flexibility of learning contents it is recommended that these contents be organized into learning objects [18]. The IEEE [8] defines learning objects as any digital or non-digital identity that can be used, reused or referenced during technology-supported teachings. Some of the main patterns used to represent this information are discussed in this subsection.

The Dublin Core Metadata Element Set (DCES) is a vocabulary with 15 main properties used for resource description [7]. It was created by the Dublin Core Metadata Initiative (DCMI), an organization dedicated to the development of metadata standards to facilitate cataloguing, search and reuse of resources. The origin of the "core" concept is found in the broad and generic use of the terms defined by the DCES.

The Learning Object Metadata (LOM) IEEE is a standard defined by IEEE for e-learning environments. The LOM IEEE pattern presents a structure that describes learning objects through categories of descriptors. Each category has a specific purpose such as describe the general attributes of an object and educational objectives. In the educational category, there are descriptors for each learning resource type such as exercises, simulations, questionnaire, etc. [8].

The Sharable Content Object Reference Model (SCORM) is an extension of the DCES and LOM IEEE standards developed by the Advanced Distributed Learning (ADL) that has undertaken standardization initiatives in the learning area [9]. It is one of the most consistent standards and has as its main characteristic the possibility to represent the sequence of learning objects presentation [19].

Besides patterns for learning objects representation, there are also patterns for personal information representation. Some of these patterns are the FOAF (Friend of a Friend) and the IMS Learning Information Package (LIP). The main objective of the FOAF standard is to interconnect people and information on them via the Web [10]. The Instruction Management System (IMS) LIP is one specification to provide learner or content developer information interoperability with different systems. The main structure of the IMS and LIP is based on activities, competences, objectives, interests, qualifications etc.

However, these patterns do not take into consideration learning style representations in their specifications. The learning style representation is important to help personalize learning materials recommendations.

III. RELATED WORKS

A systematic review was carried out to identify ontology developed to represent learning styles which could be reused. The key words, learning style and ontology were fed into the IEEE, ACM Digital Library, ScienceDirect and SpringerLink electronic bases, from January to March 2011 and 310 articles were found. The abstracts were read, with the exception of the articles that did not deal directly with ontology and learning styles subjects. Later on, the whole article was read, excluding those that did not present ontology for learning styles representation. The 9 remaining articles were read and classified according to the learning style model on which ontology was based.

A. Ontology based on the Felder and Silverman's Model

In [12], ontology to describe learning objects is proposed, using some elements of the IEEE LOM standard. Four dimensions of the Felder and Silverman model are represented as Learning Style Attributes.

In [20], an environment is proposed to recommend users indicated as partners in a collaborative learning environment. To represent learning styles, the LOCO (Learning Object Context Ontology) ontology is used to represent learning styles, which has the LearningStyle and the LearningStyleCategory as its main classes. The LearningStyle class represents the learning style of a person and the LearningStyleCategory categorizes the dimensions of the Felder and Silverman model. The LearningStyleModel allows the representation of categories and learning styles of different models.

Gasparini [21] proposes ontology to represent leaning materials, aggregating knowledge level, reading level and learning style, to be used in the learning environment AdaptWeb. The LearningMaterial and LearningStyle classes are proposed, as well as the Visual and Verbal subclasses of the LearningStyle class. The objective of ontology is to facilitate the recommendation of materials more adequate to the learner's profile. Only the Visual/Verbal dimensions of the Felder and Silverman model are considered.

Huang and Duan [22] propose a customized semantic learning environment. Through inference mechanisms, the characteristics of the objects are compared with the learner's personalized parameters and contents are recommended for them. As for learning styles, the main ontology classes proposed are Learner and LearningStyle. Each dimension of the Felder and Silverman model are represented as attributes of the LearningStyle class. Thus the learning styles represented are restricted to the Felder and Silverman model.

B. Ontology based on the Kolb Model

Wang and Chen [23] propose an ontology-based knowledge integration framework. It is an ontology of a domain using the IMS LOM standard, and ontology for the student model using the IMS LIP model is proposed. Learning styles are represented in the ontology by four classes, which are named after the four learning styles defined in the Kolb Model.

Yang and Wu [24] introduce an adaptative environment where learning objects are recommended according to the users' profile and are represented by the Dublin Core standard. There is no formal representation of the ontology regarding learning styles, however, it was possible to identify, through the proposed architecture, a structure that suggested the four scales of the Kolb Model as classes that are related to one Learner Class. Only learning styles of the Kolb Model are represented.

In work [13], an adaptive environment is proposed based on agents, where the learning style is one of the criteria used to provide the adaptation. The SCORM standard is used to represent learning objects, and a learning style ontology is also proposed. Learning styles are represented by the Learner, LearningStyle and LearningStyleCategory classes. The learning style model is not considered, being limited to the learning styles representation of a single model.

C. *Ontologies based on other Models*

In [25] an ontology is proposed to provide learning materials personalization. The standard for the IMS LIP representation was used and the learning styles proposed by La Garanderie. As for learning styles, the Learner and LearningStyle are proposed. Each learning style is represented in the form of attributes of the LearnigStyle class. Only the learning styles of this model are considered.

Mahtar and Zin [26] approach the representation of the math area knowledge using the Open Mathematical Document (OMDoc) metadata. The representation of the learning objects follows the Dublin Core standard and the ontology for learning styles proposed as an extension of the OMDoc metadata. The main classes related to the learning styles are the LearningStyle, LearningStyleModel and ModalityPerception. The LearningStyleModel class suggests the option to use different learning styles and the ModalityPerception class categorizes the perception modalities by the Visual, Verbal, Auditory and Tactilekinesthetic subclasses.

D. *Discussion*

The LearningStyle class is represented in six of the nine works, stressing the relevance of the class. Two forms of relationships with the LearningStyle class were identified; in [12] and [21] the relationship takes place among learning materials whereas in other works this relationship takes with one person. The second relationship can be considered more adequate since learning style is a characteristic of the person and not of the learning material.

In addition, it is possible to identify two approaches to learning styles scales and dimensions. The first approach, in [12]-[13] and [22], suggests the creation of LearningStyle attributes while the second approach, [20]-[21], [23]-[24] and [26], recommends the creation of specific subclasses for the representation of learning styles scales or dimensions. The work [26] does not discuss this issue in detail.

Besides the proposal of subclasses proposal for learning styles scales and dimensions, work [20] proposes the LearningStyleCategory which allows the relationship between a Learning Style class and the subclasses for learning styles scales and dimensions. The LearningStyleTheory class is also a proposal and it makes the representation of several learning styles of different learning models possible. Work [20] was considered the most complete in regards to learning style representation. However, it does not cover learning materials representation and the connection of this information with learning style to recommend content taking into consideration the person's learning style.

IV. Ontology for Recommending Learning Materials (ORLM)

The ORML, Fig. 1, was developed to help recommending learning materials according to learning styles. The ORLM was constructed using the Protégé ontology editor [27], and its representation was based on three main concepts: learning material, personal information and learning styles. To indicate the origin of reused elements of existing standards, or added elements, four prefixes are adopted. Prefix "dc" identifies elements used from the Dublin Core standard, prefix "foaf" indicates elements used from the FOAF standard, prefix "user-model" indicates elements used from proposal [20], and the prefix "orlm" indicates elements added to complete the final objective of the oncology proposal. Representations of these concepts are detailed next:

A. *Learning materials representation*

To represent learning materials, elements were added as well as other from already established standards. The orlm:LearningMaterial and orlm:TypeMaterial classes are examples of added elements and the dc:creator, dc:format, dc:type and dc:title properties are examples of objects used from the Dublin Core. The Dublin Core was adopted for being a popular standard used in learning environments and for providing the minimum vocabulary to describe learning material information. The orlm:LearningMaterial class was added to include instances of learning materials and is associated to the reused properties of the Dublin Core. The orlm:TypeMaterial class was added to include types of materials such as video, audio, text, etc. , and is associated with the dc:type property. The addition of the orlm:TypeMaterial class was fundamental to establish the association between types of materials and learning styles and thus recommend the most adequate materials.

B. *Personal information representation*

The FOAF standard was used to represent personal information since it provides the minimum vocabulary for representing this information. The foaf:Person class and the foaf:firstName and foaf:lastName properties are some of the examples of the vocabulary used, based on the FOAF standard. To complement the personal information representation the user-model:hasLearningStyle property proposed by [20] was used, which was associated with the foaf:Person class.

C. Learning styles representation

To represent learning styles, the structure proposed by [20] was adopted since it presented a more complete representation among the analyzed works. The following classes were used: user-model:LearningStyle, user-model:LearningStyleCategory and user-model:LearningStyleTheory. The subclasses used were: user-model:Active_Reflective, user-model:Inductive_Deductive, user-model:Sensing:Intuitive, user-model:Sequencial_Global and user-model:Visual-Verbal. These subclasses represent the dimensions of the Felder and Silverman model. The following properties were also used: user-model:basedOnTheory and user-model:hasCategory. The user-model:basedOnTheory property is used to represent to which learning style theory model a determined learning style category it belongs.
To complement the learning styles representation, the orlm:LS_CE_AC and orlm:LS_AE_RO subclasses were added to represent the scales of the Kolb model. The addition of these subclasses was done since in [20] only subclasses for the Felder and Silverman model are proposed. Thus, as the user-model:LearningStyleTheory class allows the representation of other learning models and the Kolb Model, according to the revision described in Section 3, is also a model applied to learning styles, its representation scales were also included.

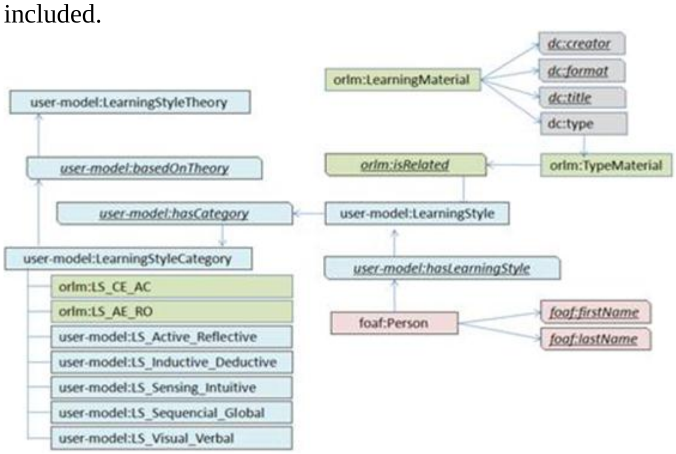

Fig. 1. Ontology for Recommending Learning Material (ORLM).

V. Experiments and Discussion

To evaluate the application of ORLM, an application scenario was created. The objective was to indicate, among the available materials, those that were more adequate to the learner, according to his or her learning style. The simulation was carried out in the Protégé , following four steps: (1) insert instances of people with specific learning styles, such as Andreia who has a Verbal learning style according to the Felder and Silverman Model, Andressa who has a Visual learning style according to the Felder and Silverman model and Joselaine who has the Visual learning style according to the Felder and Silverman model and an Assimilating learning style according to the Kolb model; (2) insert instances of types of materials and associate them with the learning styles available , such as Text type associated to the Verbal style, Image type associated with the Visual style and the Linear type associated with the Assimilating style; (3) insert instances of learning materials with their respective characteristics, as, for example, material001 with Linear and Text characteristics, material002 with Image and Linear characteristics and material 003 with Text characteristics; (4) carry out developed queries using the SPARQL [28] within the Protégé.

The query presented in Fig. 2 is an example of the queries that can be developed using the proposed structure. The objective of this query was to find among the available materials which ones were being recommended according to the learning style of each individual.

```
select distinct ?firstName ?theoryModel ?learningStyle ?material ?type
where {  ?y foaf:firstName ?firstName.
         ?y user-model:hasLearningStyle ?learningStyle.
         ?type orlm:isRelated ?learningStyle.
         ?material dc:type ?type.
         ?learningStyle user-model:hasCategory ?learningStyleCategory.
         ?learningStyleCategory user-model:baseadOnTheory ?theoryModel.}
order by ?firstName ?type
```

Fig. 2. SPARQL Query.

In Fig. 3, it is possible to visualize the results of the Fig. 2 query. The ontology considered all learning styles available, including the styles of different models. For each learning style, the correspondence with the characteristics of the learning material was verified before recommending it.

firstName	material	theoryName	learningStyle	type
Andreia	orlm:material001	orlm:Felder	orlm:Verbal	orlm:Text
Andreia	orlm:material003	orlm:Felder	orlm:Verbal	orlm:Text
Andreia	orlm:material004	orlm:Felder	orlm:Verbal	orlm:Audio
Andressa	orlm:material002	orlm:Felder	orlm:Visual	orlm:Image
Andressa	orlm:material005	orlm:Felder	orlm:Visual	orlm:Figure
Andressa	orlm:material006	orlm:Felder	orlm:Visual	orlm:Image
Everson	orlm:material006	orlm:Kolb	orlm:Accomodating	orlm:noLinear
Joselaine	orlm:material001	orlm:Kolb	orlm:Assimilating	orlm:Linear
Joselaine	orlm:material002	orlm:Felder	orlm:Visual	orlm:Image
Joselaine	orlm:material002	orlm:Kolb	orlm:Assimilating	orlm:Linear
Joselaine	orlm:material005	orlm:Felder	orlm:Visual	orlm:Figure
Joselaine	orlm:material006	orlm:Felder	orlm:Visual	orlm:Image
João	orlm:material001	orlm:Kolb	orlm:Diverging	orlm:Linear
João	orlm:material002	orlm:Kolb	orlm:Diverging	orlm:Linear
Kelly	orlm:material001	orlm:Felder	orlm:Visual_Verbal	orlm:Text
Kelly	orlm:material002	orlm:Felder	orlm:Visual_Verbal	orlm:Image
Kelly	orlm:material003	orlm:Felder	orlm:Visual_Verbal	orlm:Text
Kelly	orlm:material004	orlm:Felder	orlm:Visual_Verbal	orlm:Audio
Kelly	orlm:material005	orlm:Felder	orlm:Visual_Verbal	orlm:Figure
Kelly	orlm:material006	orlm:Felder	orlm:Visual_Verbal	orlm:Image

Fig. 3. SPARQL query results.

The simulations showed that it is possible to use the ORLM to help material recommendation according to learning styles, and different objectives can be achieved according to the query formulation.

Some objectives that can be reached through the structure presented are: find materials, considering only one determined learning model, find materials, considering only one category of a determined learning style model, or yet, find materials, considering a specific learning style.

Through ontology it is also possible to find similarities between different learning model scales whenever the same learning material characteristic point out to styles from different models.

The ontology proposed can also be used for other purposes which are not materials recommendation exactly. In this case, learning styles structure can be used and applied to other domains with other objectives.

VI. Conclusion

The objective of this work was to present the ORLM ontology to recommend learning materials taking into consideration learning styles. The proposal was based on already established Standards such as FOAF and Dublin Core and fragments of ontology for the learning styles found in a systematic revision. A simulation was carried out and the results showed that it is possible to use the ORLM to recommend materials according to learning styles.

The possibility of representing learning styles of different models offers flexibility in selecting which style is more adequate to the type of recommendation or customization being applied to a learning environment.

The proposed ontology is being improved to include axioms that allow greater expressivity to classes, and the integration of the proposed ontology with a learning environment directed to software development teams. In this environment, Software Engineering ontology must also be used to classify learning materials by content.

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