Model of semantic interoperability between Learning Management Systems[1]

Modelo de interoperabilidad semántica entre Sistemas de Gestión de Aprendizaje[1]

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Abstract

Currently there is a wide variety of Learning Management Systems (LMS), serving all levels of education and academic areas. This diversity originates a problem of semantics in the knowledge making it dispersed and inaccurate because each LMS manages its own formats, architectures and specifications. This hinders the interoperability of information between different platforms affecting mainly students. The article describes the proposal of a semantic interoperability model to solve the information exchange needs characterized by the LMS, based on the existing solutions proposals in the field of e-learning specifications, Web services and Ontologies in general.

Keywords: Interoperability; Learning content; Learning management systems; Ontologies.

Introduction

To improve the scope of different types of population, education has been supported by technologies supported over the Internet called e-learning (Enríquez, 2004). E-learning has allowed education to be structured in face-to-face, semi-virtual and virtual modalities. All of them seek to carry out pedagogical practices that are often personalized to achieve the internalization and effective appropriation of the knowledge that make up the educational process (Facuando, 2005). These support technologies have evolved, and it have been classified into three major capabilities as: (i) Learning Management Systems (LMS), (ii) Learning Content Management Systems-(LCMS) and (iii) Intelligent Tutoring Systems (ITS) (Mikic-Fonte *et al.*, 2010). In general, in terms of technological functionality, LMS manages information for users, LCMS allows the generation, storage and transfer of information in various formats and especially in the form of Learning Objects (LO). ITS enables personalized

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accompaniment solutions and teaching route management. One of the biggest technological challenges of e-learning was in terms of Interoperability between LMS platforms and their repositories (Bueo de la Fuente, 2008; Lee, *et al.*, 2011; Baile, 2008); Defined interoperability at three levels: (i) technical, (ii) syntactic and (iii) semantic. In e-learning, technical interoperability allowed the interconnection in the communication of protocols and exchange of information between the computer equipment that support them. Syntactic interoperability makes possible to exchange information in a standardized common format. And finally, semantic interoperability allowed the exchange of information, using a common and shared vocabulary that avoids inaccuracies in the interpretation of the meaning of the contents that are shared. Thus, at this level belong the metadata, the models of representation of information, vocabularies and as an innovative strategy the ontologies (Berners *et al.,* 2001). The most common definition of ontology in computing is the formal and explicit specification of a shared conceptualization of a domain. It contains elements among classes, attributes, relations and logical axioms to understand the domain represented (Myroshnichenko and Murphy, 2009). The ontologies are represented in formal languages to make them compatible and processable by the machines, such as the Web Ontology Language (OWL) case that was recommended by the W3C for its creation (Santoso *et al.*, 2011). OWL provides machines with greater interpretability of XML (Extensible Markup Language), RDF (Resource Description Framework) and RDFS (RDF scheme), providing additional vocabulary along with a formal semantic (Web-Ontology Working Group , 2004). The present work proposes a model of interoperability based on ontologies between LMS, considering the technical and syntactic levels based on the use of standards for documentation of Learning Object Repositories (LOR) and relational representation models of LMS information, and from there proposes an ontological mechanism to share information based on the shared representation of knowledge.

Related works

Related works to this research are set out around the guidelines of:

• *Interoperability model (IM) in computing*

There are several frameworks to improve the interaction of systems and platforms. For example, Goodchild (1999) and Munk (2005) analyzed the need for information exchange between components, from system distribution and exploitation to technical, syntactic and semantic levels. Their approaches provide a solution to (i) Distributed data, (ii) Global information infrastructure and distributed computing, (iii) heterogeneous communication technology, and (iv) information exchange needs to achieve reach in a global system. These models are proposed as mechanisms external to the systems, the interoperability model (LCIM) (Tolk, 2004) was set out as levels interoperability model proposed as intermediate mechanism. The most relevant and research-related levels of this model are described: At level 0, the connection is not established at all. There is no interoperability between systems. The data are used within each system autonomously. In level 1, or technical level of connectivity allowed physical interconnection through bits. At level 2, or syntactic level, data were exchanged in standardized formats or compatible protocols. At level 3, or semantic level, data were exchanged with their context, that is to say, the information, could be exchanged with its unambiguous meaning given by common reference models.

• *Interoperabiity mechanisms focused on e-learning*

At the technical level, the following levels were found: (i) communication, (ii) transport, (iii) storage and (iv) representation of information, such as Z39.50 (Lynch, 1991), OAI- 2003) and SOAP (Box *et al*., 2000), among others. At the syntactic level frameworks work to exchange materials based on specifications of languages, XML-based messages and formats (Extensible Markup Language), and XML Schema Definition (XSD) schemes. Examples of these approaches are discussed in Hernández (2003), Najjar *et al*. (2003), Alvarez *et al*. (2006), Vélez *et al*. (2008), Gonzalez *et al.* (2009b) and Lluvia Morales *et al.* (IMS, 2014), IMS Learning Design (IMS, 2014), IMS (IMS) and IMS (IMS) - IMS LD («IMS LD», 2014), IMS QTI («IMS QTI», 2014), IMS reusable definition of competency - IMS RDCEO (IMS GLC-RDCEO, 2010) and IMS- Content Packaging («IMS CP», 2014), among others.

The proposals to advance the semantic exchange of content have transcended to the specifications, since the needs of the LMS go beyond exchanging contents, towards the possibility of managing them automatically with the highest precision and quality as possible. Efforts are concentrated on semantic mechanisms embedded in the LMS and external mechanisms. Among the internal mechanisms in the LMS, the scientific community has proposed the integration of semantic repositories in the platforms. These are used by ITS for personalization and reuse of content and teaching route management as in the case of Raju and Ahmed (2012), Torres *et al*. (2013) and Ochoa *et al.* (2014). Nevertheless most of the common LMS repositories are outside these frameworks and their adjustment involved a complex process of redesign, costs, and expert knowledge. On the other hand, in a generalized way and as an external semantic interoperability mechanism of LMS, frameworks have been proposed to share information from: i) Relational databases (RDB), the integration of data through Semantic Web approaches (Berners-Lee *et al*., 2001) is sought to access precisely the resources required in RDBs . To achieve this the W3C has recognized the need to perform representational transformations of RDB to OWL (Vavliakis *et al*., 2013). This is the case of Cuéllar *et al*. (2011a), Sequeda *et al*.(2011), Choi and Kim (2012), and ii) Learning Object Repositories (ROA). In the second case of ROA IS, several papers have been formulated that represent semantic repositories with formal representations OWL and from this they propose external mechanisms with algorithms of correspondence and equivalence between concepts to support searches, retrieval and classification of materials as in Case of Farhat *et al*. (2015), Archint and Arch-int (2013), Lee *et al*. (2007) and Lee *et al*. (2011). However, interoperability approaches in all cases do not consider interoperability requirements in relation to common ROAs and the various formats of materials.

Other contributions are multilevel. In the first place are service oriented architectures (SOA) for LMS platforms. These are based on the specifications of the Frameworks: IAF - IMS Framework IMS Framework (IMS, 2014) and OKI - The Open Knowledge Initiative - OKI (OKI, 2012). These architectures propose a distribution of components in layers interconnected through WEB services. This strategy is designed to allow interoperability between tools and be able to access, adapt and reuse services supported in the Semantic Web to achieve interoperability levels. Second are the CMI (Computer Management Instruction) specifications of AICC - Aviation Industry CBT Committee (AICC, 2014). It delivers semantic recommendations and guidelines for learning materials for file-based and WEB-supported environments. Nevertheless, both approaches were created after the implementations of the current LMS and its implementation in the current platforms requires its consolidation and the knowledge of an expert. This is the case of Fontenla *et al*. (2010) and Hardy *et al*. (2011); CAMPUS PROJECT, 2013.

Work approach

The proposal was based on the needs and interoperability capabilities of the LMS platforms and proposed a semantic interoperability model (MIS) based on levels through components as an external mechanism. In such a way that any LMS can be adjusted without significant modifications of the same.

The proposal took into account works related to interoperability based on specifications (syntax) (Arch-int and Arch-int, 2013; Lee *et al*., 2011), RDB to OWL transformation mechanisms (Choi and Kim, 2012; Sequeda *et al*., 2011) and from these additional components were proposed for the harmonization of knowledge from its transformation, formalization and semantic correspondence. The strategy was supported in domain and high level ontologies in total agreement with the guidelines of the Semantic Web. With respect to the work related to the semantic level where the present proposal was located, the general approaches of content integration described and stored in relational models and OA interoperability approaches were collected in a single model applicable to the majority of The LMS characterized.

Materials and methods

The methodological steps are presented: i) Characterize the interoperability levels of LMSs from their technical documentation; ii) Characterize LMS interoperability needs based on related scientific work according to identified core issues; and iii) From To propose the interoperability model to respond to identified needs and shortcomings. This stepwise methodology is shown in Figure 1.

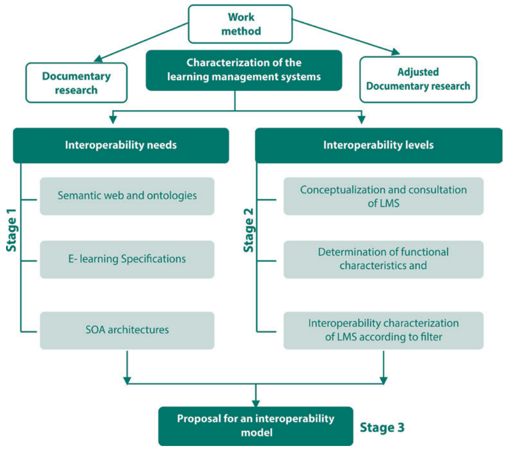


Figure 1. Methodological diagram of the research
Source: The authors

In order to address stage one (1) and two (2), the documentary research methodology (MID) (Serrano, 2002) was used because of the wide variety of documentation related to this work. Through the MID, the needs and levels of interoperability of the Learning Management Systems were determined. It was carried out in five research phases: (i) Preparation, (ii) Description, (iii) Thematic Core Interpretation, (iv) Global Theoretical Construction and (v) Extension and Publication.

Stage 1. LMS interoperability needs

The preparation and description stages of the research were focused on related researches on core topics on Interoperability based on e-learning specifications, service-oriented architectures, as well as ontologies and Semantic Web. From the application of the MID in its phases of Interpretation and global theoretical construction, the interoperability needs described in Table 1 were obtained.

Stage 2. Current platforms inter- operability levels

To characterize the interoperability levels of the LMS, the MID was applied adjusted to 5 phases. In the preparation phase, the following activities were carried out: i) LMS consultation, ii) LMS filter. In the description phase the activities of determining in the LMS were carried out: iii) the functional characteristics, (iv) technical, syntactic and semantic interoperability characteristics. In the phase of interpretation and global theoretical construction it was done the, (v) Characterization of the LMS by its data model; (vi) Analysis of the Accessibility of LMS data according to its repositories; and (vii) Analysis of comparison and contrast between LMS according to their technical and interoperability characteristics.In the detailed study of the preparation phase, several types of LMS were analyzed between: (i) Commercial LMS for Education, (ii) open source LMS for education and (iii) LMS for corporations. From this group of more than 500 LMS, the nine LMSs were selected for their use patterns according to the investigations of (Alvarez and Gutierrez, 2009; Thibault, 2011; Sanchis, 2013) with the criterion that they were open source and the information was accessible.

In the description phase, the thematic cores were identified and the characteristics of LMS related to interoperability were analyzed according to the needs and models identified as: i)Technical support of repositories management,(ii) the possibility of format migration, (iii) the feature of content neutrality, (iv) open interfaces for interoperability with others LMS, v) the management capacity of the LMS repositories, vi) the compatibility of repositories with e-learning standards, vii) the representation of the contents in repositories of learning objects (ROA), viii) data model and ix) semantic functionalities From this analysis, the functionalities of the platforms were detected, as well as the need for semantic interoperability as a challenge.

Among the dominant LMSs selected are: (i) Moodle («Moodle - Open-source learning platform | Moodle.org», 2015), (ii) dotLRN («.LRN Home», 2015), (iii) Sakai («Home | Sakai», 2014), (iv) Blackboard («Blackboard», 2015), v) Person Learning Studio («Pearson LearningStudio», 2015), vi) Atutor («Tutor LMS», 2014), vii) Bodington («Bodington», 2013), viii) Claroline («Consortium Claroline», 2015) y ix) Drupal («Drupal», 2015). The study found that open source LMSs are highly dominant systems in the educational community. From the evaluation of the functional characteristics of interoperability of these LMS platforms according to Table 2, the generalized concept of compliance of these characteristics was issued under the concept of Functionality solved (FS) and functionality to be solved (FPS). In the evaluation it was considered that the LMS complied with this functionality, when at least 80% of the LMS sample satisfied the evaluated characteristic. From the analysis made on the LMS sample, it was possible to conclude in a general way that LMS: i) They have technical support of protocols in their repositories for the exchange of information based on FTP, SMTP, HTTP, and so on. ii) Do not support migration of formats between platforms for which neither content neutrality. iii) All LMSs support OA according to e-learning specifications. iv) The contents are represented and documented in XML. v) The models of representation of the information of the LMS are mostly of relational type. vi) Most LMS reach levels of technical and / or syntactic interoperability, but none of them evidence aspects of semantic interoperability.

Results

Proposal for a solution- Semantic Interoperability Model –MIS

Based on the characterization that identified the needs and levels current of interoperability, the MIS was raised. The MIS proposal was based on layered architecture of data, representation and business (Moquillaza *et al.*,

2014) as shown in Figure 2.In the data layer are find the represented contents in RBD and ROA corresponding to level 0. Levels 1, 2 and 3 are provided by the MIS in their business logic layer.

The interface layer provides methods and functions of access to the lower levels.

Specifically the components in the model layers in their business logic consist of: i) Technical component of information management (CTGI). ii) Technical component of format conversion (CTCF). iii) Conceptual formalization component for systems with relational databases (CFCRDBS). iv) Conceptual formalization component for ROA (CFCROA). v) Ontological Mapper (MO), vi) Management interface (GI). vii) Information Models (MI).

Table 1. LMS interoperability needs

Core topics	Analysis units	Interoperability needs
E-learning specifications	(Hernández, 2003), (Alvarez, Espinoza, and Bucarey, 2006; J, R, A, and J.L, 2008; Gonzalez et al, 2009a; Morales and García-Gorrosieta, 2010; Najjar et al., 2003, (Velez et al., 2008).	Learning content: 1. Learning Object Recovery. 2. Transparent reusability of learning objects between LMS. 3. Durability of contents. 4. Effective search and retrieval of learning content. 5. Hardware and software contents independence. 6. Cross-platform content portability. 7. Mechanisms for effectively sharing information between LMS.
Service-oriented architecture	(Martínez and Farinango, 2011 y CAMPUS PROJECT, 2013)	**In Services and Tools** 8. Intermediate services of semantic interoperability. 9. Mechanisms for interoperability of tools between LMS.
Ontologies, Web	(González et al., Semántica 2010;Cuéllar et al., 2011b; Ming et al., 2011; Raju and Ahmed, 2012; Torres et al., 2013; Ochoa et al., 2014).	**Representation, transformation and correspondence of information** 10. Translation of RDB databases to application ontologies. 11. Integration of LMS relational databases. 12. Mechanisms of correspondence between ontology clases,supported by domain ontologies. 13. Inclusion of knowledge exchange reference frameworks between LMS in totally automatically way. 14. Semantic classification of OA from a local or remote knowledge base based on specific domains. 15. Proposals for external architectures to improve the quality and Access of OA in training. 16. Global learning systems proposals, service-oriented, flexible to the inclusion of new tools, reprogramming and adapting the parts of the interoperable system for third party content and tools.

Source: The authors

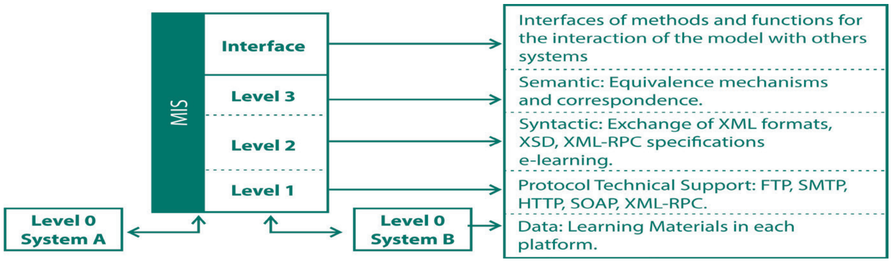


Figure 2. MIS Template
Source: The authors

Table 2. LMS characteristics.

LMS INTEROPERABILITY FUNCTIONALITIES	Moodle	DoLRN	Sakai	Angel/bb	Desire-2learn	Person Learning Studio	Atutor	Boding-ton.	Claroline	Drupal	CONCEPT GENERALIZED	
											FS	FPS
TECHNICAL SUPPORT	FTP, SMTP, HTTP,	FTP, SMTP, HTTP	FTP, SMTP, HTTP	FTP, SMTP, HTTP	FTP, SMTP, HTTP	FTP, SMTP, HTTP	SMTP, HTTP.	FTP, SMTP, HTTP	FTP CLIENTE, SMTP, HTTP,SOAP	FTP, SMTP, HTTP	X	
FORMAT MIGRATION	NO	NO	YES	NO	NO	NO	YES	NO	NO	NO		X
NEUTRALITY OF THE CONTENTS	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO		X
IOPEN INTERFACES WITH LMS OR OTHER ERP SISTEMS	NO	NO	NO	NO	NO	NO	OAUTH API	NO	NO	NO		X
MANAGEABLE REPOSITORY (I)	YES	YES	YES	UNDEFINED	UNDEFINED	UNDEFINED	YES	NO	YES	YES	X	
REPOSITORY COMPATIBILITY WITH STANDARDS	IMS-LD, IMS CP,IMS ENTERPRISE,IMS MD,IMS QTI Y SCORM	AICC,IMS CONTENT PACKAGING,IMS QTI, IMS ENTERPRISE Y SCORM	IMS CONTENT PACKAGING, IMS QTI YSCORM	SCORM 1.2 SCORM 1.3	IMS-LD, IMS CP,IMS ENTERPRISE,IMS MD,IMS QTI Y SCORM	AICC,IMS CONTENT PACKAGING, IMS QTI,IMS ENTERPRISE Y SCORM	IMS-LD, IMS CP,IMS ENTERPRISE,IMS MD,IMS QTI Y SCORM	NINGUNO	IMS CONTENT PACKAGING, IMS QTI Y SCORM	SCORM, IMS Y MARC	X	
CONTENT REPRESENTED IN XML (I) AND STORED IN XML (II)	XML	XML	XML Y RDF	XML	XML	XML	XML	NINGUNO	XML	XML/ RDF	X	
TYPE OF DATA MODEL	RELATIONAL	OBJECT ORIENTED	RELATIONAL	INDETERMINATE	RELATIONAL	INDETERMINATE	RELATIONAL	INDETERMINATE	INDETERMINATE	RELATIONAL	X	
SEMANTIC FUNCTIONALITIES	NONE	NONE	SEMÁNTIC WEB	NONE	NONE	NONE	NONE	NONE	NONE	NONE		X

Source: The authors

These components meet the interoperability requirements characterized in stage 1 and were not evidenced within the set of functionalities of the current LMS interoperability levels. The relationship of the interoperability requirements identified in the LMS in relation to the components of the model set forth in Figure 3 are given in Table 3. The layers and components of the model are described in detail below.

Data layer

In this layer the contents and specified data of e-learning are located. The data are represented in different schemas within the platforms instantiated under specific domains.

The data to be considered are the representation models of the information of learning materials and their context. This information took into account learning competencies, virtual spaces, learning objectives, teacher tools, assessments, etc. According to the characterization, this information was found as: i) Relational databases-Relational database (RDB). ii) Learning Object Database (LODB). In the case of RDBs, open source LMSs generally rely on relational data models. These are well documented and to some degree equivalent among all LMS. Such models are rich in contextual information of learning. This can be extracted for subsequent processes through query and interconnection protocols such as Open Data Base Connectivity (ODBC), Structured Query Language (SQL), etc., and mechanisms of transformation of semantic approaches (Do, 2006; Euzenat and Shvaiko, 2013). An example of the information schemas contained in the Moodle RDB and SCORM OA data models is presented in Table 4. In each of these schemes, although the data are represented in different formats through Of RDB and based on the SCORM e-learning specifications, equivalent information is stored in relation to the formative intention. However, platforms have no methods to match learning needs with available content. This is due to the difference in representation and absence of unification mechanisms.

To achieve this, the Business logic is proposed in the MIS, with its components described in detail below.

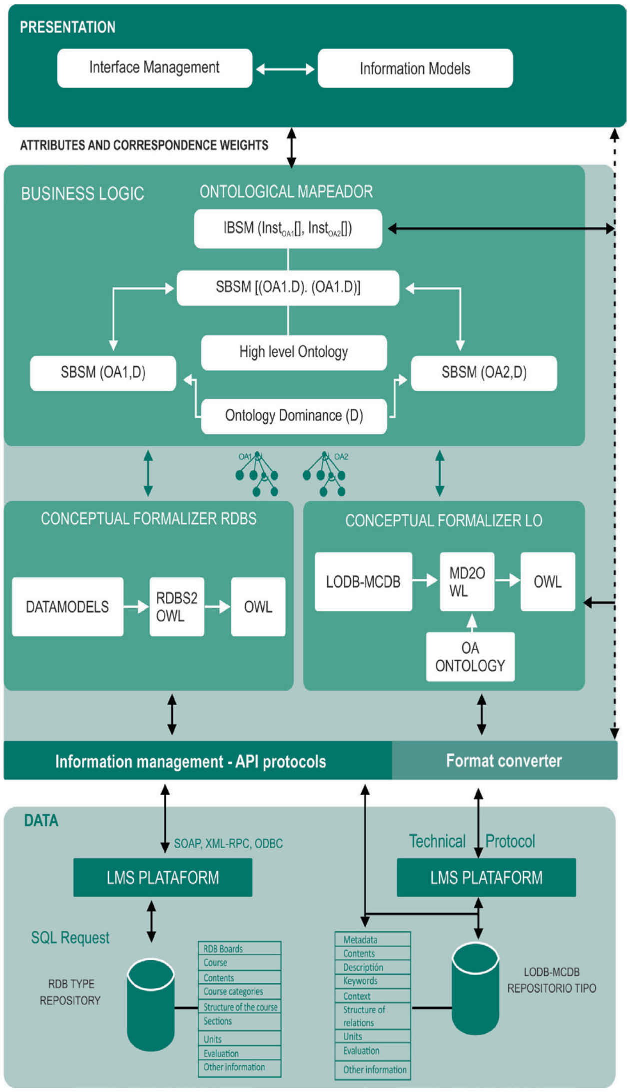


Figure 3. General model of semantic interoperability
Source: The authors

Table 3. Interoperability Needs vs Components of the MIS Mode.

Needs	Component
1	CTGI
2,5,6	GTGI – CTCF
3	CTCF
4,7,8	MIS
10,11	CFCRDBS
12,13	MO
15	MIS
9,14,16	IT IS NOT TRUE

Source: The authors

Business logic layer

The business logic layer is conceived as a semantic strategy for e-learning because it relies on domain ontologies as a common reference model for information matching. Each component of the mechanism is detailed below.

Table 4. Moodle and OA SCORM data schemas.

Course Resources RDB	Learning Objects Resource-SCORM
id	Identifier
name	Title
Description	Catalog
Module	Entry
Instance	Lenguaje
Section	Description
Path	Keywords
Time_modified	Location
file_type	Format

Source: The authors

• *Information management and conversión*

This component provides: information management and conversion methods as shown in Figure 5. It acts on information repositories, managing them through an application programming interface (API) of technical protocols including SOAP, FTP, HTTP, ODBC, etc., among others. Deliver the metadata and data model to the higher levels. To achieve this it supports captures of: i) Relational platform data model. ii) The manifests of OA. On the other hand, due to the interoperability needs 1,2,4,5 and 7 of stage 1, as a solution approach, a transformation component is proposed for transparent operation with different specifications and formats according on the compatibility of the platform («ASSEC», 2008).

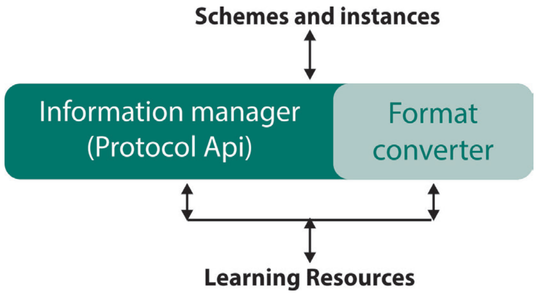


Figure 5. Information management and format conversion
Source: The authors

• Conceptual formalizer

This is a model base component. Its function is to extract information from the data layer and convert it to application ontologies to represent RDB and ROA through automatic transformers. To achieve this, two approaches are used: i) Direct mapping for RDB, where the SQL / METADATA schema of the database is transformed by rules with a semantic component to an Ontology and the relational data are exposed as instances of the generated Ontology. i) The other method applied to the formalization of ROA suppose the existence of a domain ontology that wraps the database in such a way that its content appears as instances of the Ontology. Following, the two (2) formalization mechanisms are detailed.

• RDBS conceptual formalizer

In the case of RDBs, currently work approaches about transformation are typified as: (i) Direct transformation of relational schemas to ontologies (Direct mapping). (ii) Transformation of entity-relation (ER) schemas to ontologies and (iii) Transformation of relational schemas in combination with additional domain semantics (Sequeda *et al*., 2011, Myroshnichenko and Murphy, 2009, Levshin, 2009). The focus of this component on the MIS model was worked on in the engineering research pyramid and as part of the work (Bravo and Suarez, 2013). This direct transformation takes into account the usual RDBS representation artifacts. Such as tables, primary keys, foreign keys, null and non-null attributes, data types, etc. In addition, other artifacts not considered in the investigations consulted as the relationships and types of inheritance are taken into account. Once the transformations of the data model were made to the resulting ontology, it was semantically enriched by the transformation of the new rules. To structure this component, the transformation schemes were characterized according to the following criteria: i) The resulting ontologies comply with the W3C standard. ii) Using the Direct Mapping approach. iii) Presentation of transformation rules used. About the research work the set of base rules were studied and the missing ones were created. The study considered 25 ground rules, redefined an ambiguous rule, and formulated 4 new inheritance rules. The service packet diagram is shown in Figure 6.

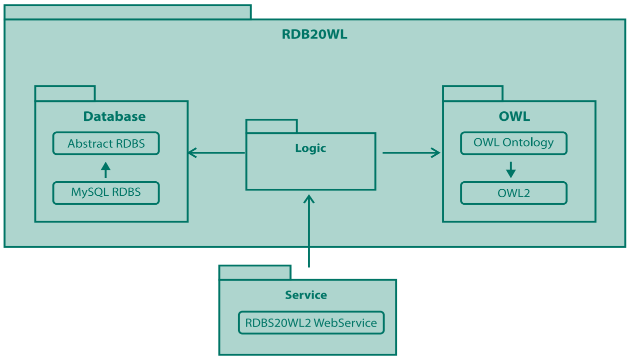


Figure 6. Service packet diagram.
Source: The authors

• Conceptual Formalizer of Learning Objects

Learning objects are supported in the e-learning specifications that describe their content through XML metadata. This language lacks semantic expressivity so that the same OA can be described syntactically through various schemas and instances. This lack of semantic description of the OA metadata presents limitations when it comes to reusing OA, so it is necessary to take them and transform them from the level of standard metadata to semantic metadata through strategies that evaluate its context in Specific domains (Al-Khalifa and Davis, 2006). These transformations have been addressed by the scientific community, and solution initiatives have been proposed based on existing ontologies to transform the OA metadata provided by the specifications into information with semantic representation of OA (Esteban-Gil *et al*., 2009; Malik , Santos *et al*., 2007). As a result, e-learning associations have proposed initiatives to represent their OA through ontological schemes that represent learning resources. As an example, a LOM representation ontology («LOM», 2002) is shown in Figure 7.

In the proposed model, to continue with the computational processing,the XML schemas were mapped to the ontology of learning objects through two processes: The first process mapped from XML notation to OWL, it was ensured: i) Class mapping: that is, map an XML node to an OWL concept and data type properties (map an XML node to an OWL datatype property). ii) Mapping object properties. It relates two mapped classes. This notation is defined in Table 5.

The second: the transformation of OWL instances. Process ensure that the class identifiers are unique.

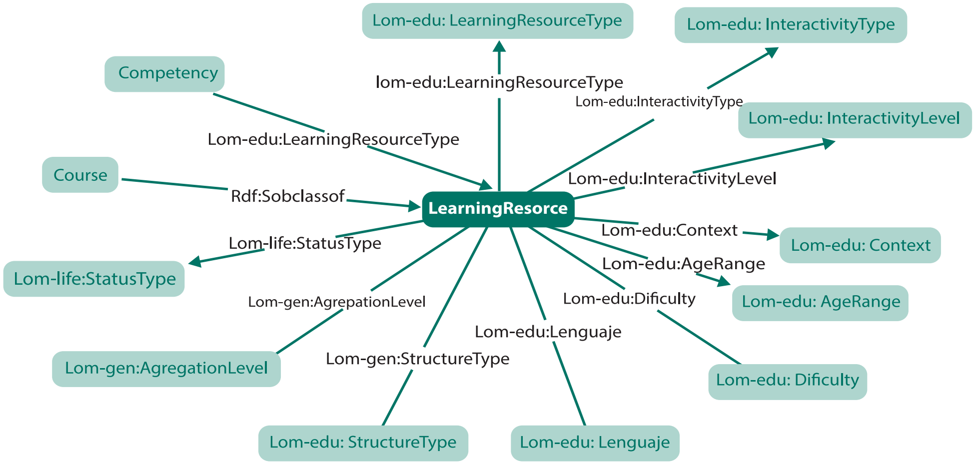


Figure 7. Partial view of ontology Courses and educational resources.
Source: (Santos et al., 2007).

Table 5. XML-OWL mapping notation

Mappi	WL Notation
Class	(OWL Class URI, Xpath expession) (OWL Class URI, Xpath expression, ID XPath expression)
Datatypes properties	(OWL Datatype Property URI, Domain Class Mapping, XPath Expression)
Objects properties	(OWL Object Property URI, Domain Class Mapping, Range Class Mapping)

Source: (Rodrigues, Rosa, y Cardoso, 2006)

The available tool is presented in ('JXML2OWL Project').

Ontological mapper

The integration mechanism of the LMS sought to integrate the LMS learning content data sources. This integration has already been worked extensively in other domains of computational sciences and described through strategies named in the scientific literature as scheme matching (Do and Rahm, 2002), ontology matching (Euzenat *et al.*, 2007), ontology aligment Euzenat *et al.*, 2004,), semantic correspondence (Do, 2006), etc. To refer to this integration technically in e-learning will be called as Scheme Matching (SM). The benefits of applying SM in e-learning were analyzed and the SM strategy selected was justified. The application of SM has several application approaches depending on aspects related to: i) Input information. ii) The correspondence process, and iii) The desired output information. Table 6 presents the characteristics of the stages of the correspondence process that are possible and applicable to achieve interoperability in e-learning.

Table 6. Operative characteristics of SM.

SM ASPECTS	
INPUT INFORMATION FOR SM	
INFORMATION	**TYPE OF INFORMATION**
DATA MODELS	Relacionales
	XML
	RDF
	OWL
DATA OF THE MODELS	Schemes (Tags, internal structure, types of attributes, relationships)
	Instances
	Schemes and instances
CORRESPONDENCE PROCESS	
TYPE OF PROCESSING	Intrinsic
	Semantic
	External
RESULTS	
Correspondence judgment	Gradual
	Conjunctual: Equivalence (=), Incompatibility (⊥),
	Subsumption (⊑)
	At the instance level
	At the outline level

Source: The authors

Specifically, in e-learning was determined the correspondence between two schemes that represent the content of educational resources of a RBD and a learning object, such as those shown in Figure 8.

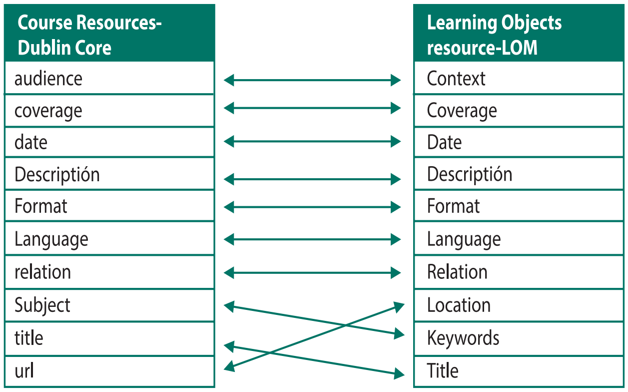


Figure 8. Example of RDB-OA correspondence schem
Source: The authors

In order to establish the correspondence strategy, we analyzed the contributions of the approaches of SM proposed by (Shvaiko and Euzenat, 2005, Do, 2006, Sun and Rose, 2003, Euzenat and Shvaiko, 2013). According to these investigations, to perform the SM process there are several approaches presented in figure 9 according to the characteristics of the input information (lower level), process (intermediate level) and output (upper level).

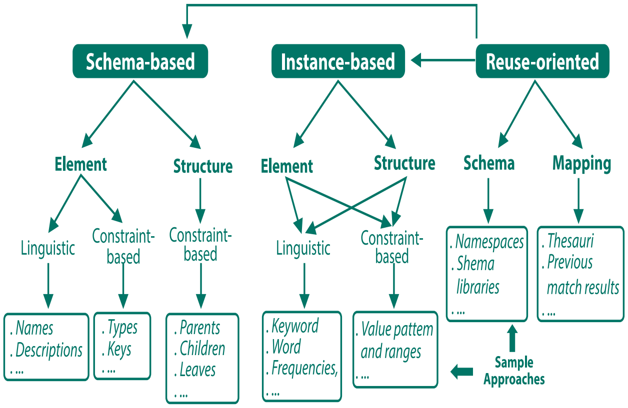


Figure 9. Scheme Matching Approaches
Source: (Do, 2006).

As a consequence of the above, the application of the strategies began with the reading of the base schemes and instances of the information to correspond. According to the characterization described in e-learning, these information schemes are the RDB or XML representation models that have been transformed into OWL. These input OWL schemes in the model are denoted as OWLA, OWLB and in joint with strategy E, they defined the appropriate correspondence configuration, which should execute two subprocesses of SM to mention: i) To establish correspondences between structures by ensuring the semantic consideration implicit in the platforms and resources, that would allow to establish the common vocabulary And shared between the two models by a specific domain ontology; And ii) To establish correspondence of its elements based on the instances of the corresponding structures. This strategy of correspondence in the MIS is presented in Figure 10. It should be noted that the strategy was formulated as a flexible system to various correspondence alternatives.

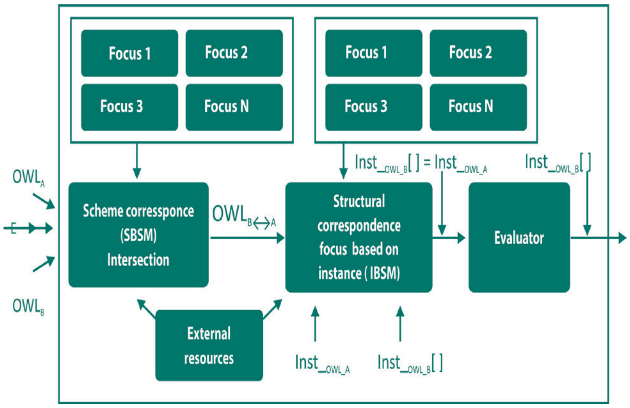


Figure 10. Correspondence strategy - Ontological Mapper
Source: The authors

Alternatives of correspondence approach based on schemas

The selection of schema-based correspondence approaches will ensure after this process that the target information structure corresponds to the source schema.

The schema-based SM approach has as input the native schemas transformed into OWL and its objective is to match partial or total structures between e-learning information schema.Examples of partial views of correspondence of schema in e-learning are shown between OA Dublin Core and OA LOM in Figure 11.

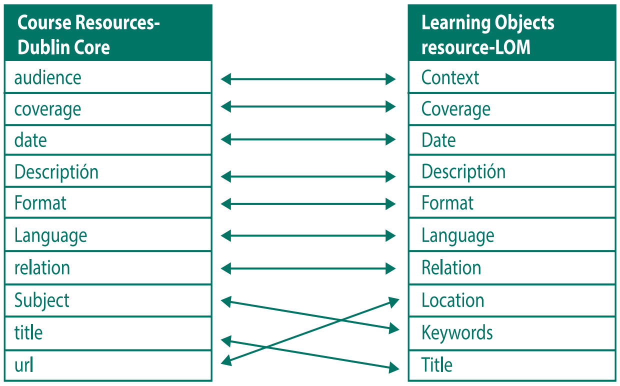


Figure 11. EExample of correspondence scheme OA Dublin Core- OA LOM
Source: The authors

Table 7 lists the approaches to establish correspondence at the level of e-learning structures according to the type of information, data, processing approach, process and some theoretical and algorithmic references that can be integrated into the MIS interoperability model. This proposal recommends that several approaches be used to complement the results, giving priority to correspondence of approach of semantic processing based on domain ontologies.

Table 7. Approaches to solution, correspondence at the structure level.

Approach of SM algorithms for correspondence at Structure Level and elements				
Type of information.	Datatype	Processing Approach	SM based on:	Algorithms and/or theoretical referent
Terminological	Strings	Linguistic - Syntactic	Strings-based	(Madhavan, Bernstein, Doan, y Halevy, 2005),(Madhavan, Bernstein, y Rahm, 2001),(Bilke y Naumann, 2005)
Terminological	Language objects: String interpretation	Linguistic-Semantic.	Languages-based	(Giunchiglia, Yatskevich, y Giunchiglia, 2005), (Clifton, Housman, y Rosenthal, 1998)
Terminological	Language objects: String interpretation	External - linguistic - Semantic	Linguistic Resources	(«SMATCH», s. f.), (Giunchiglia, Yatskevich, y Shvaiko, 2007), (Agrawal y Agrawal, 2014)
Structural	Structure of entities, attributes, data types, etc..	Syntactic - Syntactic	Based on schema constraints	(Bravo y Suarez, 2013),(Batini, Lenzerini, y Navathe, 1986),(Rodrigues *etal*., 2006).
Structural	Metadata and relationships of entity	External - Syntactic	Reuse of SM	<COMMA<. (Do y Rahm, 2002),(Sun y Rose, 2003)
Semantics	Structural models	External - Semantic	High level ontologies and domain ontologies	(Rodrigues *et al*., 2006)

Source: The authors

• *Correspondence approach alternatives based on instances*

Once two data structures as equivalent are determined, they may or may not be equivalent in their instances. Figure 12 shows the correspondence of two learning objects under the LOM and Dublin Core specification. In Figure 13, the case of null correspondence between two learning objects DC and LOM is presented.

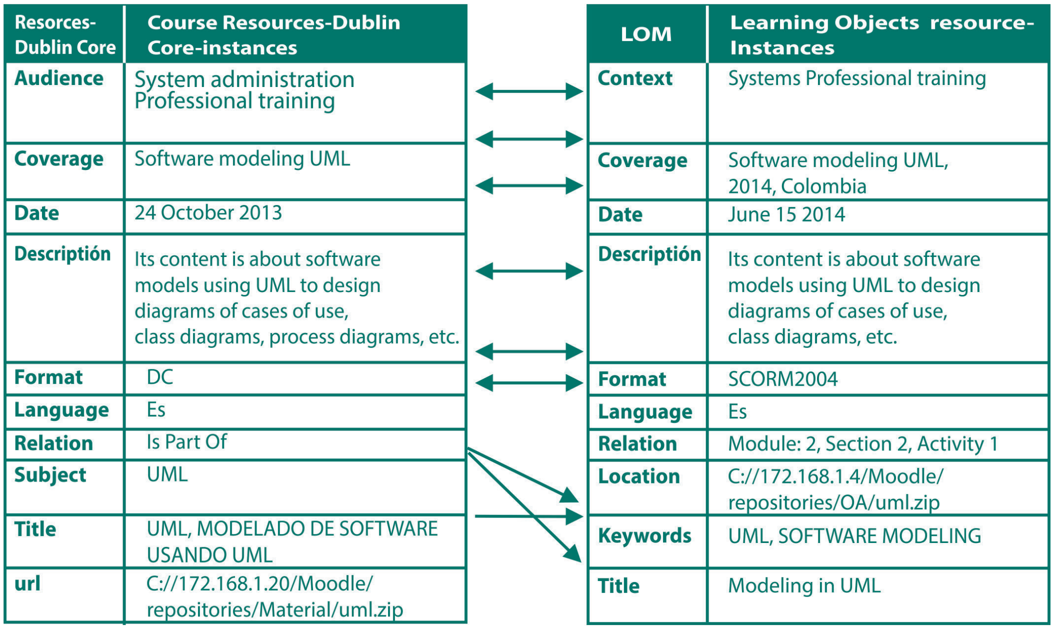
Approaches as a solution to instance correspondence consider as input information the names of columns, rows, schema attributes of XML and RDBS etc. The applicable approaches of instance correspondence are also the ones of correspondence based on schemas as linguistic-semantic, linguistic-syntactic, etc. However, there are correspondence approaches at the instance level. These approaches are based on the results of the textual analyzes of the instances of the elements in the scheme.

Statistical methods are often applied to make the hierarchical evaluation in relation to an ontology or application domain. From this evaluation, we obtain key words, on which we apply measures of repetition, closeness, etc. Some theoretical references and algorithmic are detailed in Table 8.

Domain and High Level Ontologies

According to the approaches discussed in the previous sections, the proposed interoperability mechanisms make use of domain ontologies in order to guarantee a common and shared vocabulary.

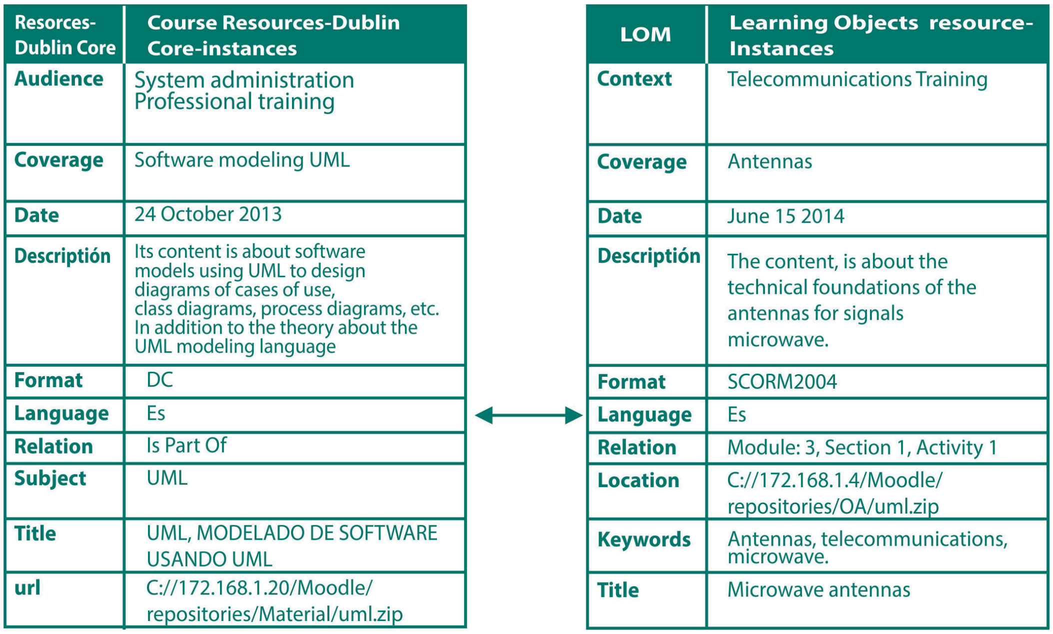
Nowadays, there are several domain ontologies in various contexts of computer science. A domain-specific ontology in e learning is described in Santos *et al*. (2007). Other high-level ontologies can also be used. According to comparative studies among several ontologies, DOLCE (Mascardi *et al*., 2007) is evidenced as a high-level ontology with a domain applicable to e learning.



Resorces-Dublin Core	Course Resources-Dublin Core-instances
Audience	System administration Professional training
Coverage	Software modeling UML
Date	24 October 2013
Descriptión	Its content is about software models using UML to design diagrams of cases of use, class diagrams, process diagrams, etc.
Format	DC
Language	Es
Relation	Is Part Of
Subject	UML
Title	UML, MODELADO DE SOFTWARE USANDO UML
url	C://172.168.1.20/Moodle/repositories/Material/uml.zip

LOM	Learning Objects resource-Instances
Context	Systems Professional training
Coverage	Software modeling UML, 2014, Colombia
Date	June 15 2014
Descriptión	Its content is about software models using UML to design diagrams of cases of use, class diagrams, etc.
Format	SCORM2004
Language	Es
Relation	Module: 2, Section 2, Activity 1
Location	C://172.168.1.4/Moodle/repositories/OA/uml.zip
Keywords	UML, SOFTWARE MODELING
Title	Modeling in UML

Figure 12. Example of OA instances mapping Dublin core-OA LOM
Source: The authors



Resorces-Dublin Core	Course Resources-Dublin Core-instances
Audience	System administration Professional training
Coverage	Software modeling UML
Date	24 October 2013
Descriptión	Its content is about software models using UML to design diagrams of cases of use, class diagrams, process diagrams, etc. In addition to the theory about the UML modeling language
Format	DC
Language	Es
Relation	Is Part Of
Subject	UML
Title	UML, MODELADO DE SOFTWARE USANDO UML
url	C://172.168.1.20/Moodle/repositories/Material/uml.zip

LOM	Learning Objects resource-Instances
Context	Telecommunications Training
Coverage	Antennas
Date	June 15 2014
Descriptión	The content, is about the technical foundations of the antennas for signals microwave.
Format	SCORM2004
Language	Es
Relation	Module: 3, Section 1, Activity 1
Location	C://172.168.1.4/Moodle/repositories/OA/uml.zip
Keywords	Antennas, telecommunications, microwave.
Title	Microwave antennas

Figure 13. Example OA Instance Mapping Scheme Dublin core- OA LOM
Source: The authors

Table 8. Approach at scheme instances level.

Approach of SM algorithms for correspondence at level of schema instances				
Informationtype	**Data type**	**Processing Approach**	**Algorithmic approach**	**Theoretical and algorithmic reference**
Semantic	Instances of the elements	Semantic- External	Ontologies, thesauri, schema constraints	(Ming Che Lee, Tsai, y Hsieh, 2011b), (Doan, Madhavan, Domingos, y Halevy, 2002)
Semantic	Instances of structures	Semantic- External	Ontologies, thesauri, schema constraints	(Qian, Li, Song, y Yue, 2009),(Wang, Wen, Lochovsky, y Ma, 2004)

Source: The authors

Presentation Layer

At this level are the components that support the interface of the model:

• *Management Interface*

It offers the methods and functions to access the components of the model. It can support searches of LMS clients, which in turn will support users. From this interface, through the component of Management of the information, the methods of access to the instances of relational databases and ROA are offered. To this end, previously there must be an interoperability agreement that allows integration to the model to share its educational resources. The input elements to the interface, to interact with the model are data schemas (according to information models), with the search addressing to the target schemas. The data schemas must describe the parameters according to the regulation of schemas of learning objects or ontologies. In the output elements of the interface, the users are supported in the presentation components inserted in the platforms that take the information models of the recovered elements and use them as input for the deployment of the contents.

• *Information Models*

They provide possible search schemas to interact from the presentation layer in the business logic layer. The templates allow to transform the input and output information of the model functions, to data appropriate for the user and the ontological mapper.

From the user are received instances of the elements and schemas with which it's going to interoperate to make the correspondence with the ontological mapper (Rodrigues *et al*., 2006). The user is given the data models with schemas and attributes, to access the resources matched according to instances and mechanisms of deployment on the platforms.

Validation-Instance of the MIS

To validate the proposed model, the qualitative evaluation methodologies between the interview and the focus group were reviewed. Due to the advantages of the degree of structure, the possibility of discovery of innovative information by experts and its general utility, the focus group methodology was selected (Malhotra, 2004). The stages developed in the focus group were: i) The planning of the protocol and preparation of the documents. (ii) Selection of participants. iii) Guidance of the session; and iv) Analysis of information and reporting (Kontio *et al*., 2008). In the preparation of the session, the materials that were delivered prior to the session were generated. The material prepared was composed of the participants' fiches, the summary and extended proposal of the MIS, the protocol and agenda, the component evaluation format and the MIS evaluation survey. The selection of the participants took into account two profiles: i) Professionals attached to the academy and with knowledge about e-learning. ii) Professionals with experience in e-learning and in software research and development. The selected participants are shown in Table 9.

In the conduction phase of the session the presentation of the MIS between LMS was performed. In this phase through an executive exhibition, each of the layers and components of the Model were described. Afterwards, each participant presented their detailed contributions with a constructive critical approach and, finally, each participant filled out the Component Evaluation Form and the General aspects Survey. From the evaluation of the components the quantitative evaluation of the qualitative evaluation of the MIS shown in Table 10 was obtained. In general, it was found that the MIS fulfilled most of the functions for which it was designed.

Table 9. Focus Group participants

Name	Participant	Institution
Mg. en Computing. Jimmy Andrés Campo Bravo	P1	Manager Oderlógica (Popayán)
Mg. en Computing. Carlos Alberto Ardila Albarracin	P2	Research Teacher universidad del Cauca
Systems engineer Diego Fernando Bolaños	P3	Virtual tutor leader, SENA- Centro Comercio y servicios. Integrator plataform Blackboard
Electronic and Telecomunications engineer Omar Albeiro Trejo	P4	Virtual tutor certified by the OEA, Blackboard.

Source: The authors

Table 10. MIS Focus Group Evaluatión

N°	ASPECTS THAT ARE SOLVED WITH THE MIS	OPTIONS		
		YES	NO	N S / NR
1	Solution to semantic problems.	100%		
2	Reuse of Learning Objects.	100%		
3	Search and effective retrieval of content	100%		
4	Independence of contents.	50%		50%
5	Heterogeneity and autonomy of LMS.	100%		
6	Semantic integration of LMS databases.	75%		25%
7	Semantic integration of ROA	75%		25%
8	Conceptual formalization of the data.	75%		25%
9	Ontological mapping of learning resource concepts.	100%		
10	Required methods and functions of the model.	75%	25%	
11	Ease of implementation.	75%		25%

Source: The authors

With the evaluation of the MIS, the participants generated: positive, negative and improve aspects and additional observations that led to the refinement of the MIS presented in section 4.

Design and implementation of the Web service

Taking into account the proposed model and the validation by experts in the focus group, the proposal of a Semantic Interoperability Web Service - SIS, based on Ontologies was proposed. The service was designed as one of many instances of the model. The Design of the proposed service, considered the use of:

- Relational databases.
- Learning Object Repositories.
- ODBC Database Management Driver.
- Learning Objects Repository Management Driver.
- E- learning specifications: SCORM, IEEE LOM and CP.
- Automatic Transformers for the generation of application ontologies.
- Application and Domain ontologies essential in the formalization process.
- Mechanism of correspondence between the different ontological representations.
- Web clients inserted in the LMS for Web service management.

Taking into account the above, a modeling of the Semantic Interoperability Service based on the 4 + 1 views architecture was proposed. In this modelling is describe: i) the use cases of the system. ii) The class diagram. iii) The sequence diagram. iv) The process view, and v) the deployment diagram. Below is show the deployment view of the architecture mentioned and the description of each of the components in Figure 14.

- LMS, represents any LMS, which can make use of the service to interoperate with other LMS.
- SERVER_INTERFACE, represents the service interface.
- LOM2OWLB, its function is to receive the OA metadata,

and then to transform them into a web ontology language. Likewise, it fulfills the management function of ROA.

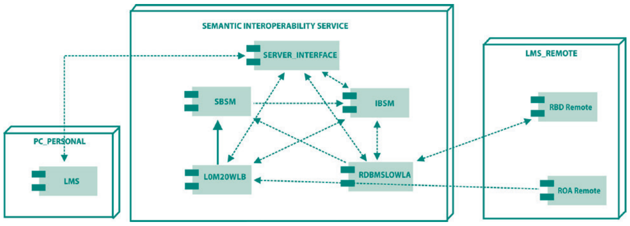


Figure 14. Distribution Diagram.
Source: The authors

- RDMBSLOWLA, is in charge of transforming information from representations of relational databases to web ontology language. Likewise, it fulfills the management function of RDB.

- SBSM, defines the schema-based correspondence strategy.

- IBSM, defines the correspondence of instance-based searches.

- Remote RDB, represents the models of relational databases with which the service interacts.

- Remote ROA, represents repositories of remotes learning objects.

Implementation of Semantic Interoperability Service

In figure 15 is show a basic scenario of interoperability for the implementation of the proposed service, specifically regarding OA interoperability; was considered, the interoperability of two LMS Moodle-Modle. Each of these LMS contains OA arranged in a file repository supported with the FTP protocol. For the implementation of this scenario were used the algorithms provided by the COMMA API and supported in the DOLCE2.0-Lite-v3 domain ontology. In the correspondence of instances, modified WORNET was used, to make inferences in different domains.

In the prototype, the user once logged into the LMS platform, can make use of the SIS Semantic Interoperability Service. For this it directs the service where the schemas and the search instances will be sent. Then, the user loads the interface where the Search parameters of the Learning Objects information will be entered, as well as the FTP repository address where the OA of the target LMS is stored as shown in Figure 16.

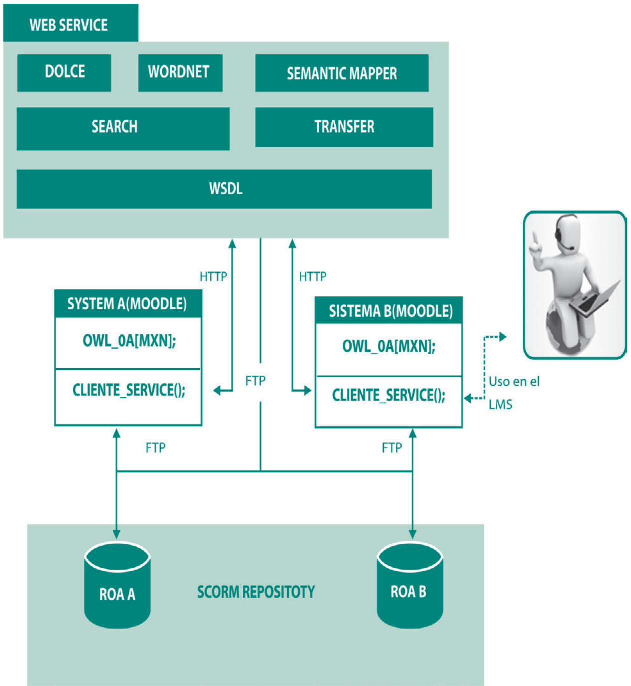
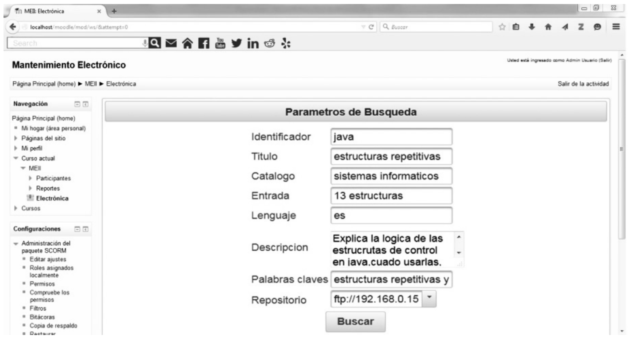


Figure 15. Interoperability scenario
Source: The authors



Mantenimiento Electrónico

Parametros de Busqueda

Identificador: java
Titulo: estructuras repetitivas
Catalogo: sistemas informaticos
Entrada: 13 estructuras
Lenguaje: es
Descripcion: Explica la logica de las estrucrutas de control en java.cuado usarlas.
Palabras claves: estructuras repetitivas y
Repositorio: ftp://192.168.0.15

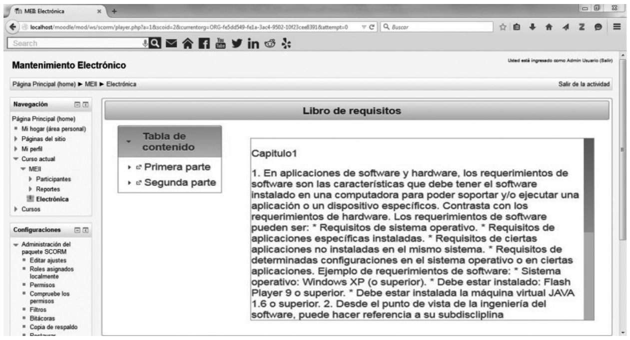
Figure 16. RUN SEARCH USE CASE
Source: The authors

When searching the resources in the target LMS, the resulting data is inferred and the resulting contents are displayed to the user. These are presented in hierarchical order according to the semantic distances between the schemas and instances sources and objectives. Learning objects can be visualized, using platform methods or retrieved on the local computer, as shown in Figure 17.

When visualizing the recovered, the user reuses the OA, enjoying the instruction, resources and pedagogical approach of the same, as shown in Figure 18.

Archivo	Correspondencia	Accion
Libro de requisitos	0.9	Ver Guardar
Tecnicas de requisitos	0.7	Ver Guardar
Documentacion de requisitos	0.7	Ver Guardar
Tipos de requerimientos	0.6	Ver Guardar
Clasificacion de requirimientos	0.5	Ver Guardar

Figure 17. Search Match
Source: The authors



Capitulo1

1. En aplicaciones de software y hardware, los requerimientos de software son las características que debe tener el software instalado en una computadora para poder soportar y/o ejecutar una aplicación o un dispositivo específicos. Contrasta con los requerimientos de hardware. Los requerimientos de software pueden ser: * Requisitos de sistema operativo. * Requisitos de aplicaciones específicas instaladas. * Requisitos de ciertas aplicaciones no instaladas en el mismo sistema. * Requisitos de determinadas configuraciones en el sistema operativo o en ciertas aplicaciones. Ejemplo de requerimientos de software: * Sistema operativo: Windows XP (o superior). * Debe estar instalado: Flash Player 9 o superior. * Debe estar instalada la máquina virtual JAVA 1.6 o superior. 2. Desde el punto de vista de la ingeniería del software, puede hacer referencia a su subdisciplina

Figure 18. View Information
Source: The authors

Conclusions

In relation to the methodologies used in the work were easy to be appropriated and applied, except for the MID, which due to the required rigor makes it spend too much time and its resulting artifacts are low publishable. It is therefore recommended to seek alternative methodologies to address similar problems.

As for the work on the characterization, it was found that in the LMS Learning Management Systems, content repositories, such as RDB or ROA, own the platform, which bring about that in practice, no evidence is found Semantic interoperability of content. This is because the proposed interoperability mechanisms are part of new lines of research and have not yet been extended to massive and widespread implementation in LMS. On the other hand, it was found that the LMS mostly have the mechanisms of technical and syntactic interoperability through base protocols and specifications However, since this is not sufficient to solve the learning needs, the researches advance coordinately towards the exchange of information at higher levels using semantic repositories, semantic interoperability between RDBs, frameworks based on ontologies, SOA architectures, etc. All these mechanisms aim to: (i) Improve the quality and variety of educational resources available in the market. (ii) Conserve resources invested in technology and development of educational resources through its reuse and (iii) Ensure transparency of resource use independent of hardware and software platforms. However, in the research carried out in this study, the measurement of these factors among different LMSs belonging to different educational communities was not found nor addressed, which would allow to qualify the comparative impact between all the approaches.

On the other hand, regarding the proposal of the model among the advantages considered, it is highlighted its structure by layers and components to facilitate the implementation of services and mechanisms for the exchange of content between LMS. In the same way, another of the advantages are the conceptual formalization components proposed for the unification of the formats of the materials with semantic nature of the data that in conjunction with the combined strategy of SM oriented to schemes and instances gives a clear view And simple guide to software development. As disadvantages of the model the dependence of the model with WEB contents was identified by the included formalization levels and data types considered. In the same sense, it was detected that much of the formalization, transformation and correspondence functionalities depend on the typologies of the databases of the current LMS whose nature, for the moment, is relational and limited for a number of users. In the event that in the future they evolve into non-relational systems, much of the MIS functions may become obsolete.

In relation to the model evaluation, it is recommended to use the focus group strategy in similar cases, not only to endorse proposals, but also to strengthen them in an agile and effective way.

Finally, as additional future work, we are working on tests and scenarios for the integration of RDB in the MIS and other approaches of application and implementation of the model in different educational institutions to improve contents and optimize economic resources.

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