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PMIIDAS: Integration of Open Educational Resources Based on Semantic Technologies

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Abstract. This article presents a prototype called PMIIDAS. The prototype focuses on the creation of open educational resources based on pedagogical and institutional guidelines, their representation using semantic indexing, and the storage and retrieval thereof by Semantic Web technologies. The use of this prototype can have benefits such as the reuse of open educational resources, which are distributed in institutional repositories or educational platforms by applying a semantic approach, search and retrieval of relevant information can be done through the use of ontologies and user profiles; as well as the exchange of educational resources among educational institutions.

Keywords. Applications, education, open educational, semantic web, ontology.

1 Introduction

By the Budapest open access initiatives [1], Bethesda [2] and Berlin [3] worldwide have motivated the creation of technological platforms such as the Institutional Repositories (IR), which are implemented in a wide variety of universities and research centers in order to be able to disseminate, share and transfer scientific and academic production, which is embodied in different educational resources. IRs can be considered as institutional memories preserving and increasing knowledge embodied in educational resources [4].

An IR can be understood as an information system that collects, preserves, disseminates and gives access to the scientific and intellectual production of an educational or scientific institution. In addition to having mechanisms to store, preserve and recover educational resources [5] [6]. These educational resources are described through metadata, which conforms to the standard OAI-PMH (Open Archives Initiative Protocol for Metadata Harvesting) [7], which is implemented as a protocol for interoperability in different IRs such as DSpace [8] E-Prints [9], Opus [10], etc.

On the other hand, the educational resources contained in the IRs when adopting open access policies become open educational resources. The United Nations Organization for Education, Science and Culture [11] defines an Open Educational Resource (OER) as any teaching, learning or research material which is in the public domain or which has been published under an intellectual property license that allows its use, adaptation and free distribution.

The opening of resources refers not only to free access to query them, to enrich them or to generate new resources from the original resources, but also to an open structure (semantic indexing) in a processable format (RDF, Resource Description Framework) [12]. Semantic Web technologies are made up of ontologies, descriptions of resources (semantic indexes) and languages for managing and representing of knowledge. The use of these technologies makes it possible to dynamically and actively reach the user by stimulating the use of applications and achieving a shorter time in the search for open educational resources [13].

This article presents the Prototype PMIIDAS, which is the acronym for Integrating Memory of Documentary Information Sources for Educational Institutions Based on Semantic Web Technologies; such tool can be defined as an organizational memory for educational purposes. The knowledge possessed by people (professors, learners and officers) and by educational resources (which are heterogeneous in content, format and type) is materialized explicitly and persistently in this tool in order to contribute to their reuse and decision making among members of the educational institution [12].

This prototype can be seen as a proposal to concentrate OERs within an educational institution, but also as an integration tool for different educational platforms. This prototype focuses on the creation of OERs based on institutional and educational guidelines, their representation using semantic indexing, and the storage and retrieval thereof by Semantic Web technologies.

The rest of the article is structured as follows: 1) Section II presents a review of the works related to education based on semantic Web technologies, as well as the institutional repositories that have emerged; 2) Section III discusses the methodology and the different stages, as well as the different activities that were used in the proposed work; 3) Section IV shows the process used for prototype design; 4) Section V shows the different tests on the queries made to the ontologies and the tests carried out on the prototype; and finally 5) Section VI shows the conclusion.

2 Related Work

In this section we present the description of some works that have been carried out in education and that use the semantic approach; as well as institutional repositories.

One of the main works in education based on the semantic approach is the ELENA project [14], which is a European Community project whose primary objective is to allow the creation of a “Smart Learning Space” by standards, educational mediators and semantic Web technologies as key factors in the integration of e-learning educational resources.

The article titled "A computational model for developing semantic web-based educational systems" [15] presents a computational model for the development of Web-based Semantic Educational Prototypes, focusing on adaptive learning.

The Didactalia project [16] proposes a personal learning environment including semantic and social tools, having a space in which the user collects show and share learning contents.

Procomún [17] is an intelligent, social and distributed Web, which is part of an educational environment under the building. Such tool can connect with educational communities in existing spaces by the Linked Open Data Cloud [18] using its semantic properties.

The work of Medina et al. [19] proposes a strategy to produce and consume linked open data from the OAI-PMH protocol, which is compatible with repositories.

As for the institutional repositories, we highlight the educational work called the Mexican Network of Institutional Repositories (REMERI by the acronym in Spanish), which emerged in 2012 with the purpose of integrating, spreading, preserving and giving visibility to the scientific, educational and documentary production of Mexico [20]. It is also the national network representing Mexico in the Federated Network of Institutional Repositories of Scientific Publications or LA REFERENCIA project where nine Latin American countries (Argentina, Brazil, Costa Rica, Chile, Colombia, Ecuador, El Salvador, Mexico and Peru) participate [21].

Also, the proposed law to create the national repository was approved during 2014 in Mexico. This proposed law is governed by the National Council on Science and Technology (CONACyT by the acronym in Spanish) and aims to make available the scientific and educational resources produced in Mexico with public funds [22].

In general, educational work based on semantic approach has examined proposals to exploit the Semantic Web approach from different perspectives. However, it is worth noting that there is little work developed in the establishment of educational guidelines to guide the process of creating OERs in the area of exercises, practices, thematic presentations, among others; since mainly OERs focus on the dissemination of theses, books and chapters of books, articles, etc., leaving aside teaching materials [23], and such materials represent the knowledge and experience that Professors have within the Institutions. On the other hand, an educational ontology that models education in the Mexican context has not been created. Besides, the data to describe OERs only include bibliographic metadata based mainly on the Dublin Core standard [24], without taking advantage of the content data and links to the resource itself.

3 Applied Methodology

The research presented is composed of two stages, these are: a) detection of needs by the study of use and preferences of Information and Communication Technologies (ICT) in the educational field, and b) building of the Prototype PMIIDAS.

3.1 Detection of Needs

At this stage, a study was carried out on the use of Information and Communication Technologies (ICT) to Professors and Learners of two higher education institutions. This study was applied to the curricula of Degree in Computing and the Degree in Electronics Engineering; as well as the Postgraduate in Information Science and Technology (master's and doctorate) attached to the Universidad Autónoma Metropolitana, Iztapalapa (UAM-I). Also, such study was applied on the Military Computing and Military Communications and Electronics Engineering of the Military School of Engineers (EMI by the acronym in Spanish).

From the analysis made to the study, user profiles, educational resources frequently used by Professors, educational resources of interest, and subjects requiring open educational resources could be determined. Using the information gathered from the study, we can propose the building of the prototype according to the needs expressed by the professors and learners of the two institutions.

3.2 Building of the Prototype MIIDAS

At this stage, different activities to be performed were established to develop the prototype, these are: a) Definition of the guidelines for generating educational resources; b) Building of the domain ontologies; c) Design of the prototype architecture, and d) Implementation of the prototype.

The following describes in detail each of the activities.

Definition of the guidelines for generating educational resources. In order to establish the guidelines for educational resources, the resources of greatest interest identified in the needs detection stage performed in both institutions were taken into account, which are: exercises, practices and thematic presentations.

Table 1. Common criteria for exercises, practices and thematic presentations (Source: own research).

Common criteria	Description
Educational Institution	Corresponds to the name of the educational institution to which the resource's author is attached.
Facilitator's Name	Name of the person who serves as the course instructor.
Name of Study Program	Name of the degree, engineering or postgraduate to which the resource impacts
Suggested Period of Use	Year, semester, quarter or quarter to which the resource can be applied.
Learning Unit	Name of the subject or subject for which the resource is designed.
Unit of Competence	Refers to one of the topics that are part of the Learning Unit.
Element of Competence	It is aimed at achieving the objective of the ongoing unit of competence.

Once the resources of greatest interest were identified, the educational approaches used by both educational institutions were explored, which was the competency-based approach. This approach is characterized by the identification of knowledge, expertise, skills, attitudes and values required to carry out a task [25].

The guidelines were worked together with specialists in pedagogy and didactics, by criteria that obey the competence approach. The common structure criteria among the three educational resources are presented in table 1.

It is important to point out that guidelines within institutions can help to standardize the educational resources created within the institution, as well as guiding new professors who are incorporated to generate their educational resources.

Building of the domain ontologies. Ontologies are a fundamental part of the Semantic Web Approach and therefore also for the Prototype PMIIDAS, since they provide a formal and standard representation of knowledge through a common vocabulary, favoring the exchange of such knowledge and its reuse among applications.

From the analysis carried out in the needs detection stage, 6 ontologies could be identified for the Prototype PMIIDAS. These are: user profile, domain (Computer, Electronic and Military), educational and digital educational resources. These ontologies have as main objective to establish a useful conceptual vocabulary for the project, as well as represent the concepts and relations inherent in the knowledge domain, thus constituting a knowledge model that allows us to make inferences about the data.

Methodology 101 [26] was adopted for building the ontologies. Such methodology was proposed by Stanford University and consists of 7 phases, which are: 1) Determine the domain and scope of the ontology; 2) Reuse existing ontologies; 3) List important terms for the ontology; 4) Define classes and their hierarchy; 5) Define the properties of the classes: slots, 6) Define the facets of the slots; and 7) Create instances or individuals. Table 2 shows the competence questions and the process to be performed for the user profile ontology.

Table 2. Competence questions and process to be performed for the user profile ontology (Source: own research).

Competence questions	Process to be performed
What professional activities do the professors and learners do?	
What skills do the professors and learners have?	
In what subjects are the professors specialized?	Adaptation of the user profile
What are the learners advised by professors?	ontology proposed in [20] and
Who are the learners of a particular professor?	the person ontology [11].
What are the learners with a particular English reading domain and interest in Semantic Web research?	

Table 3 and 4 show the competency questions and the process to be performed for the ontology of digital educational resources and the educational ontology, respectively.

The subjects requiring educational resources identified in the stage of needs detection were taken up again in order to determine the subjects and competency questions of the ontologies for computing and electronics. Table 5 shows the subject names identified by institution and user.

Table 3. Competence questions and process to be performed for the ontology of educational resources (Source: own research).

Competence questions	Process to be performed
What kind of educational resources are favorable for the active learning?	Adaptation of the ontology proposed in [11].
What kind of educational resources are suggested for the subject of Database?	
What are the educational resources that have pdf extension?	
What are the English language resources for Electronics?	

Table 4. Competence questions and process to be performed for educational ontology (Source: own research).

Competence questions	Process to be performed
What kind of educational approach do UAMI and EMI use?	The building of the ontology with a support of domain experts.
What are the teaching strategies established in the UAMI and the EMI?	
What educational resources can be used to support specific teaching strategies?	
What teaching strategies can help achieve the analysis?	
What are the assessment tools used by EMI?	

Table 5. Subjects requiring educational resources for UAM-I and EMI learners and professors (Source: own research).

User	UAM-I	EMI
	Subject	
Learners	Introduction to Programming Programming Fundamentals Data Structures and Algorithms	Electronics Programming Digital Systems Microcontrollers
Professors	Introduction to Programming Computer Networks Digital Communications Databases	Programming Electronics Microcontrollers Object-Oriented Software Development

Based on the identified subjects and the content analysis of each one, the competence questions are proposed for domain ontology for Computing and Electronics. Table 6 shows some of the competency questions and the activity to be performed.

In general, all the ontologies of the Prototype PMIIDAS have a total of 1,162 concepts distributed as follows: 22 concepts of user profile ontology; 30 concepts of the ontology for digital educational resources; 22 concepts of the Educational Ontology; and 804 concepts of the different domain ontologies distributed as follows: 662 concepts of computing; 142 concepts of Electronics; and 284 concepts of military ontology.

All the ontologies were developed with the ontology editor Protégé. On the other hand, it is important to point out that all ontologies have been validated by experts in each of the domains, as well as by the reasoner Pellet in order to verify the possible inconsistencies that could be found in them.

Table 6. Competence questions and process to be performed for ontologies for Computing, Electronics and Military (Source: own research).

Ontology	Competence question	Process to be performed
Computing	Is the star topology a network topology? Is the integer a primitive data type? Is analysis one of the stages in creating software?	Adaptation of the Ontology proposed in [4]
Electronics	What are the families of integrated circuits? What are the types of diodes? What are the parts of a transistor?	Adaptation of the Ontology proposed in [4]
Military	What is a council of war? What are the sub-values promoted by the Military Education System? What is a duty in the military field?	Building of the Ontology with the support of military personnel

Table 7. Use cases, description, user, and priority for the Prototype PMIIDAS (Source: own research).

User Case	Description	User	Priority
UC1-Login	Allows to log in to the prototype	Professor, learner and assessment committee	Half
UC2-Register user	Records the data of a new user	Professor, learner and assessment committee	Half
UC3-Generate OER	Creates OERs in digital form - exercise and practice type	Professor	High
UC4-Modify OER	Modify, delete and visualize the generated OERs	Professor	High
UC5-Load OER	Allows to load the OER into the IR, creating its semantic indexing	Professor	High
UC6-Recovering OER	Query and/or search for an OER	Professor, learner and assessment committee	High
UC7-Query guidelines	Shows the guidelines for the creation and use of OERs; as well as the prototype.	Professor, learner and assessment committee	Low

Prototype Design: Modeling is a central part of all the activities that lead to the production of good software. To carry out the requirements and architecture design activities for the Prototype PMIIDAS was based on the software architecture [27], where we used mainly the diagrams of 1) use cases and 2) architecture. The use of each is detailed below.

Use Case Diagram: These diagrams define the activities that the different users (professor, learner and assessment committee) will have in the prototype. The use cases, their description, the types of users, and the priority of each of them are showed in table 7.

Architecture Diagram: The type of architecture chosen for the creation of the Prototype PMIIDAS is a Web architecture due to the study carried out at EMI and UAM-I which considers the following reasons:

Users targeted by the prototype prefer to use web applications to query educational resources. In addition, they frequently use the computer for reviewing such resources.

Applications developed using a web architecture are lighter because they do not consume client resources, since the presentation, business and data layers are controlled by the server.

Fig. 1 shows the Architecture diagram of the Prototype PMIIDAS and different components thereof and the table 8 shows the description of the components of the Prototype PMIIDAS.

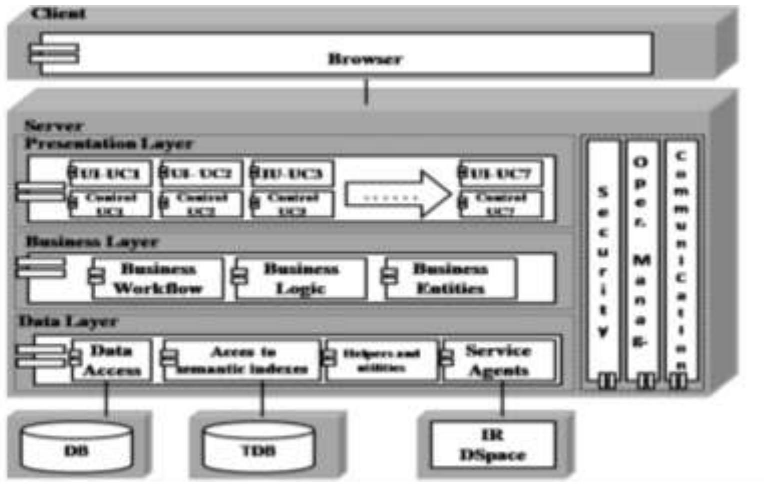

Fig.1. Architecture diagram of the Prototype PMIIDAS (notation: UML, Source: own research).

On the other hand, the Prototype PMIIDAS can also be seen as an integrator of different platforms, since it can superimpose a semantic layer where educational resources can be contained in multiple sites and be queried and retrieved by such prototype. Fig. 2 shows this concept, where a user makes a request for a resource, which is found on some platform, by a graphical interface. The Prototype PMIIDAS processes such request and together the semantic indexes know the location of this through the Unique Resource Identifier (URI). On the other hand, the Prototype PMIIDAS can consume the resources contained in the platforms provided there is a service provider [28].

Table 8. Description of the components that make up the architecture of the Prototype MIIDAS (Source: own research).

Component	Description
Browser	It is the application running on the client machine
UI-UC	It is the graphical interface in charge of the user interaction
UC Control	They are the components in charge of validations, business logics; as well as providing the data to the business layer
Workflow	It is the component in charge of managing the business processes
Business Logic	It is the component responsible for retrieving and processing data according to business logics
Business Entities	This component represents the business domain entities and their association with the business logic component
Access To Data	This component provides mechanisms to persist and retrieve data
Access To Semantic Indexes	This component is responsible for interacting with the Triple Store (TDB) to save and query the semantic indexes that characterize the resources
Tools and Utilities	This module contains functionality common with other modules such as: casting data types, e-mail sending, language coding, among others.
Service Agents	This module is responsible for the communication mechanisms to transfer data and resources to the institutional repository, such as DSpace
Security	Component responsible for authorization and authentication
Operation Management	This module handles exception management, instrumentation and validation
Communication	This module provides communication between the upper layers and physical levels

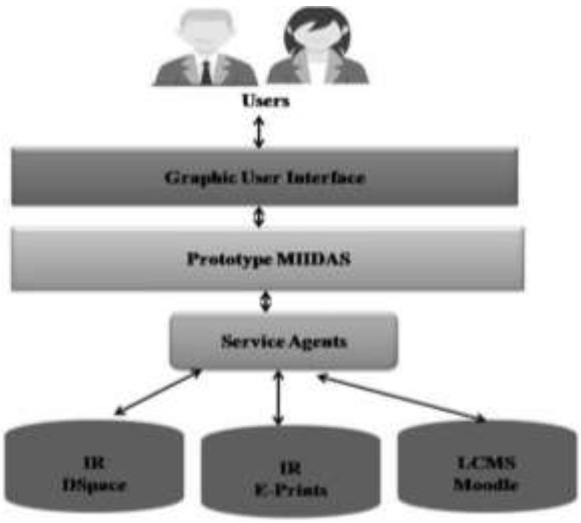

Fig. 2. Prototype PMIIDAS as integrator of different platforms (Source: own research).

Implementation. The building of the Prototype PMIIDAS is based on from analysis, design programming, data storage, educational resources and representation by semantic indexing free software languages and tools.

The prototype was developed in the Java programming language using the Apache Tomcat application server, as PostgreSQL Database Management System Version 9.4, Apache Jena Version 3.4 and DSpace Version 6.0. Fig. 3 shows the different technologies used to create the prototype.

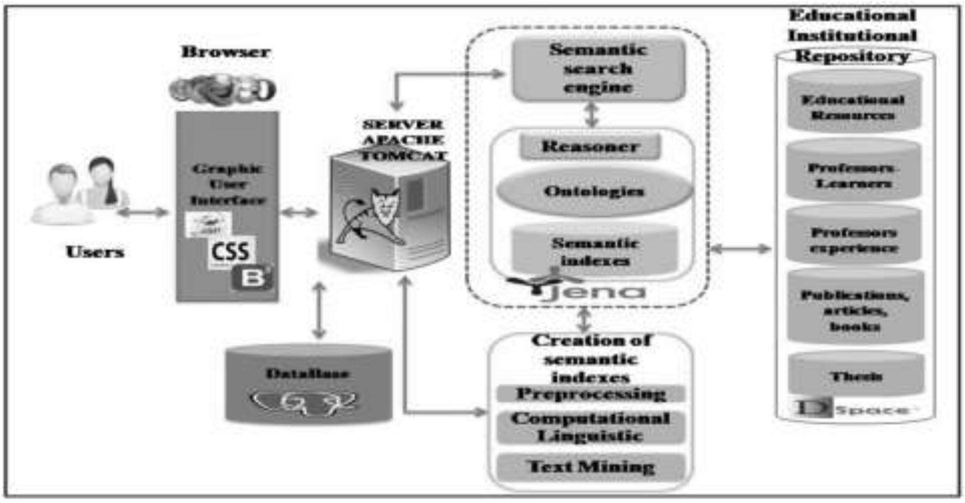

Fig. 3. Technologies used in the development of the Prototype PMIIDAS (Source: own research).

Where:

Interface. Allows communication between users and the system, is responsible for providing a visual environment to perform the different activities provided by the prototype according to the role of each user.

Apache Tomcat Server. Attends user requests from a graphical interface and answers according to the request.

Database. Conformed by user data and catalogues used in the creation of educational resources.

Semantic Search Engine. Recovers educational resources according to the search made by the use with the help of ontologies and semantic indexes.

Ontologies. Establishes the conceptual vocabulary of a field of knowledge (user profile, educational and domain resources: Computing, Military and Electronics) through concepts and relations thereof by constituting a model knowledge, which allows making inferences about the semantic indexing for educational resources.

Semantic Indexing (SMSI). Describes the educational resources made up of three parts: 1) metadata, 2) contents, and 3) links to others OERs.

Creation of SMSI. Creates the semantic indexing that describes each of the educational resources in Resource Description Framework (RDF), which are stored in the

Triple Store (TDB). The creation of semantic indexes is an automatic process, where the metadata is obtained from the form that fills the user to upload the file; to obtain the content and links of the same one is realized a preprocessing, to apply techniques of computational linguistics; as well as text mining.

Institutional Educational Repository: In charge of storing educational resources generated by professors in different formats and contents.

The prototype was developed under the usability quality attribute, which is to be friendly, intuitive and straightforward in navigation.

4 Experiments

The experiments carried out have been focused on testing the ontologies and the prototype.

4.1 Ontologies Testing

In general, the tests performed on the ontologies consisted of entering individuals and interrogating them using the competency questions initially made.

Table 9 shows the questions asked to the user profile ontology; as well as its translation in SPARQL query language and its result.

Table 9. Example of queries to the user profile ontology (Source: own research).

Natural Language Query	Query in SPARQL	Result
Who does Carolina Medina advise?	PREFIXopu: <http://pcyti.izt.uam.mx/pmiidas/ontoperfilusuario#> SELECT ?discente WHERE { ?docente opu:asesoraA ?discente. FILTER regex(?docente, "^Carolina Medina").}	Cristal Galindo, Pablo Contreras
Who is an expert in Semantic Web?	SELECT ?docente WHERE { ?docente opu:esExpertoEn ?tema. FILTER regex(?tema, "web_semantica", "i"). }	Carolina Medina, MaríaAuxilio Medina

Table 10 shows the questions asked to the ontology for digital educational resources. Table 11 shows the questions asked to the educational ontology.

4.2 Prototype Testing

The tests carried out on the Prototype PMIIDAS that have been made are: unitary and integration; As well as configuration. Each of them is detailed below.

Table 10. Example of queries to the ontology for digital educational resources (Source: own research).

Natural Language Query	Query in SPARQL	Result
What are the digital educational re-sources produced by UAMI?	PREFIX ored: http://pcyti.izt.uam.mx/pmiidas/ontored# SELECT ?recursosWHERE { ?recursosored:esProducidoPor ?universidades. }	Exercise 1 Practice 5 PresentationBD
What is the topic of Exercise 1?	SELECT ?temaWHERE { ?recurso ored:tieneTema ?tema. FILTER regex (?recurso, "^Ejercicio1").}	Programming

Table 11. Example of queries to the educational ontology (Source: own research).

Natural Language Query	Query in SPARQL	Result
To which educational institution belongs the Degree in Computing?	PREFIXoed: <http://pcyti.izt.uam.mx/pmiidas/ontoeduca#> SELECT ?ies WHERE { ?PEstudiooed:perteneceA ?ies. FILTERregex (?PEstudio, "^Licenciatura en Computacion").}	UAMI
To which model belongs the auditory learning style?	SELECT ?modelo WHERE { ?eaoed:perteneceAModelo ?modelo. FILTER regex (?ea, "Auditivo" , "i"). }	VAK

Unit and integration testing. Each module has been tested separately to verify the correct operation of the prototype. For this, test cases with repeatable, complete, reusable and independent characteristics were established.

On the other hand, the interaction among the different modules was verified. This test is known as an integration test.

Configuration testing. To discover specific bugs or compatibility issues in a particular environment, the prototype was tested in three Web browsers (Mozilla Firefox, Google Chrome, and Internet Explorer) with the intention of ensuring that the user experience is the same in all of them. Table 12 shows the bugs identified for each browser.

Table 12. Configuration test results (Source: own research).

Web Browser	Identified failures
Internet Explorer	The logo of the Prototype PMIIDAS in the header is traversed to the left
	The input help text does not appear
Google Chrome	Pop-up windows are not displayed
Mozilla	Calendars do not display
	The increment and decrement control for time does not work correctly

Regarding the usability of the Prototype PMIIDAS, an assessment tool (rubric) has been designed to evaluate educational software, which is based on [29] and [30]. This rubric is made up of 5 different sections, which are: 1) structure and display, 2) efficiency, 3) usability, 4) quality, and 5) pedagogical dimension. The first section aims to know the structure of the information in conjunction with the graphic elements. The second section seeks to understand the ease in which the users perform the tasks. The third section is intended to facilitate the interaction of the prototype with the user without having to consult the manual. The fourth section aims to know the accuracy of information retrieval. Finally, the fifth section seeks to know the specific characteristics to contribute to the teaching-learning process performed by the prototype.

The rating scale for each of the criteria is from 1 to 5, with 1 being the lowest rating and 5 being the highest rating.

5 Conclusions

This article has shown the methodology, design and implementation of the Prototype PMIIDAS, which allows the creation, edition, management and reuse of open educational resources that can be part of an institutional repository or any other platform. This is because it superimposes a semantic layer where each resource is characterized by a semantic index in RDF format and that point to the physical location of the resource.

This prototype was designed using the guidelines established by the software architecture and using the spiral model, because of this it was necessary to make different modifications at the level of the proposed design, the relational model, and the structure of the semantic index and technologies planned at the beginning of the process. The application offers the possibility to characterize different types of resources in other domains. Therefore, the prototype can be seen as a generic application to integrate resources in any domain. For which, it is only necessary to incorporate the ontologies according to the particular domain so that their applications and uses can be very diverse.

In addition, it is proposed the total implementation of the educational ontology which models education in the Mexican context, this to build applications that help in the preparation of primary and higher-level Professors to make the knowledge exam stipulated for the Professor assessment established by the National Institute for the Assessment of Education (INEE by the acronym in Spanish). On the other hand, it is suggested to perform tests with other institutional repositories other than DSpace; as well as the characterization of educational resources contained in Learning Content Management Platforms such as Moodle.

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