The Role of Learning Object Ontology in Building Personal Curricula for Pharmacists

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***Abstract*- Continuing education and lifelong learning is becoming more and more important as the fast development of technologies requires specialized skills that need to be renewed frequently. ELearning adapts well for continued education as it can be done in parallel with other work. However, in the context of continuing professional education building, a personal curriculum is not just straightforward for the reason that there are several educational institutions that provide various courses and there are no unified ways of representing the content of the courses. We have investigated this problem in pharmacies where the building of personal curricula is dictated by regulations that are set by health care authorities. In particular, we have investigated how the educational information that is received from a variety of sources and that is in a variety of format can be managed in building personal curricula. The key idea in our developed solution is the learning object ontology, which is integrated with the pharmacy ontology. In this way the educational information can be stored in pharmacy's knowledge base that provides sophisticated ways for accessing educational information.**

Keywords*- ELearning; Learning Objects; Curricula; Continued Education; Semantic Web; Taxonomies; Ontologies; OWL; RDF; Information Filtering

I. INTRODUCTION

The function of pharmacies is to ensure the safe and effective use of pharmaceutical drugs. As a result, the scope of pharmacy practice is wide, which includes traditional roles such as compounding and dispensing medications, reviewing medications for safety and efficacy, and providing drug information. Further pharmacists are expected to be the experts on drug therapy and primary health professionals, who optimize medication use to provide patients with positive health outcomes.

Ensuring maintaining pharmacists' expertise requires large efforts as healthcare is a field where the fast development of drug treatment and the introduction of new drugs require specialized skills and knowledge that need to be renewed frequently [2, 3]. As a result, the amount of new information concerning new medication also increases rapidly. An interesting question arising from this reality is how medicinal instructions should be organized and retrieved to ensure that the concerned medicinal employees are aware of the new instructions.

In formal education provided by schools and universities, a *curriculum* is the set of courses and their content that a school or a university provides. Based on the curriculum the students build their *personal curriculum*, i.e., choose the courses they will study.

In *continuing education* building, a personal curriculum is not just straightforward as there are several educational institutions that provide various courses, and there are no unified ways the content of the courses is presented. In such an environment, building a personal curriculum is long lasting and frustrating. The situation is very similar with searching and browsing the web. Nevertheless, personal curriculum is of prime importance in successful studies in continuing education as well as in formal education [2].

Building a personal curriculum for continuing and professional education may also be dictated by the regulations set by authorities. For example, in pharmacies, as a result of fast development of new drugs and drug treatments, healthcare authorities presuppose that each pharmacist has a personal curriculum concerning continuing medicinal education.

We have studied the existing personal curriculum building processes as well as the quality of the built curricula in pharmacies. We have recognized the following weaknesses:

- Uncertainty about the ways the personal curricula should be built.
- Only a bookkeeping concerning pharmacists' participations on professional courses is done, but no exact plans for the participations on forthcoming courses have been done.
- Pharmacists have incomplete information about the provided forthcoming courses.
- Pharmacies receive the information of the professional education in variety formats, e.g., by paper mail, e-mail, and fax. However, neither systematic ways nor standardized formats for representing the content of the provided professional education have been used.
- Uncertainty about the relevance of the courses (e.g., should someone participate in the course).

In an ideal case, a pharmacist should be able to build a personal curriculum in a similar way, as within formal education, i.e., the heterogeneity of various educational sources should not burden the pharmacist in searching appropriate courses.

In trying to achieve this goal, we have designed learning object ontology for storing the information of the provided professional education and the educational history of the pharmacists as well as the responsibilities of each pharmacist. Based on such information it is possible to automatically assess the suitability of the courses for the pharmacists. This in turn simplifies the personal curriculum building process.

In developing pharmacy's learning object ontology, we have exploited pharmacy ontology [3] that we have earlier developed for modelling the business rules [4] of a pharmacy. As the learning object ontology and the pharmacy ontology are overlapping, we have developed the learning object ontology by extending the pharmacy ontology. Further, in developing the learning object ontology we have also exploited the standardized metadata vocabularies. In particular, we have included the terms of the Dublin Core [5] and the LOM (Learning Object Metadata) [6] standards in the education ontology.

Our ultimate goal has been the development of pharmacy ontology by integrating all the ontologies used by the pharmacy's systems. Hence, the pharmacy ontology also includes other ontologies such as inventory ontology, information entity ontology and customer ontology. In this sense, we have followed the idea of knowledge centric organization [7], where the key idea is to revolve all the applications of the organization around the shared ontology.

We can gain from the integrated ontology in many ways. For example, as all the application uses the same ontology we can avoid the problems of replicated data. With respect to the building of personal curricula the main gain is the increased expression power of the ontology in the sense that the relationships of the educational concepts and other the pharmacy specific concepts can be expressed. For example we can model the relationships of learning objects and other concepts such as pharmacists' roles, pharmacists' educational history and medicinal products.

Thus, in building personal curricula, it is possible to take into account the responsibilities of each pharmacist, e.g., whether a pharmacist is responsible for the drug inventory or specific medicinal products. For example, if a new course deals pain drugs and a pharmacist is responsible for pain drugs and has not yet participated in such courses, then the system can automatically recommend the course for the pharmacist. That is, the system can behave like an information filtering system [8, 9] that removes redundant or unwanted information from an information stream using (semi)automated or computerized methods prior to presentation to a human user.

Developing user interfaces for the pharmacy ontology is quite straightforward as they can be implemented by knowledge management systems [10] that provide query languages that have high expression power. On the other hand, the price to be paid for maintaining the knowledge base is that the providers of the professional education have to present their provided learning objects' metadata in the format required by the pharmacy ontology.

The rest of the paper is organized as follows. First, in Section Ⅱ, we consider learning objects and metadata standards that can be used in managing medicinal learning objects. Then, in Section Ⅲ, we consider the usability of taxonomies in describing the content of medicinal learning object. In Section Ⅳ, we first illustrate the idea behind knowledge centric organization and its adaptation into pharmacy system. Then we consider the integration of the learning object ontology and the pharmacy ontology. In particular, we first illustrate the pharmacy ontology in a graphical form, and then we present a subset of the ontology in OWL. We also present an instance of the ontology in RDF, and simple examples of querying the pharmacy ontology by RQL. Finally, Section Ⅴ concludes the paper by discussing the disadvantages and advantages of our developed solutions.

II. LEARNING OBJECT METADATA

A. Medicinal Learning Objects

A learning object is regarded as any entity, digital or non-digital, that may be used for learning [6]. For example, a study course, a course book and a lecture are typical learning objects. By the term *medicinal learning object* we refer to learning objects that deal medicinal information.

There are four commonly accepted functional requirements set on learning objects.

- First, learning objects should be usable in different instructional contexts, i.e., learning objects should be reusable.

- Second, learning objects should be independent of the delivery media and learning management system, i.e., learning objects should enable the interoperability of learning management systems.

- Third, learning object should be designed in the way which allows the combination of learning objects.

- Fourth, learning objects should provide appropriate metadata in order to allow easy searching facilities.

Our interest is focused on the fourth requirement. In particular we will consider learning objects metadata [11] and the ontologies that give the semantics for the metadata items.

B. Learning Object Metadata

Metadata is data about data [12]. It is intended to facilitate the discovery of electronic resources from the Web. Metadata describes certain important characteristics of its target. We make the distinction between syntactical and semantic metadata.

Syntactical metadata describes the structural characteristics of its target, such as the format, language, date, creator, and the author of the document. Dublin Core [5] is a widely used metadata standard that represents syntactical metadata. Although syntactical metadata standards are useful in managing learning objects and other information entities, they do not enable content based retrieval and so semantic description are also needed.

Semantic metadata describes the semantic content of the target [12]. For example, the domain specific keywords, attached to documents represent semantic metadata. For example, painkiller could represent a semantic metadata of a drug. Further, in order to standardize the used semantic metadata items certain domain specific taxonomies and ontologies are needed.

We next consider the standards developed for syntactical metadata. Then, in Section III, we consider the suitability of ontologies for standardizing semantic metadata that are related to curricula building processes in pharmacies.

C. Syntactical Metadata Standards

The basic idea behind standardization is to achieve interoperability between systems from different origins. An important point in standardization is that it does not impose a particular implementation but rather a common specification which establishes an opportunity for collaboration by diverse groups.

There are many organizations, which standardize metadata. However, here we will only consider Dublin Core and LOM as we use them in representing medicinal learning objects' syntactical metadata.

Originally, Dublin Core was intended to facilitate the discovery of electronic resources from the Web. It includes fifteen metadata elements that describe the content, the intellectual property rights and the instantiation of the object. For example, the standard includes the following elements: Creator, Date, Description, Subject, and Language.

Dublin Core also includes metadata attributes that can be used in specifying the relationship between resources. Through these attributes we can define resources, for example, a lecture is a part of a course (IsPartOf), a course is a version of another course ((IsVersionOf), a laboratory work requires certain software (IsRequiredBy), and a course is based on another course (IsBasedOn).

LOM is a data model (usually encoded in XML), which is used to describe a learning object. It defines the structure of an instance for a learning object. In addition, the standard facilitates the sharing and exchange of learning objects by enabling the development of catalogues and inventories while taking into account the diversity of cultural contexts in which the learning object will be exploited.

The primary goals of the LOM are to enable the learners to search and use learning objects and enable computer agents to automatically compose learning objects to individual learners. In addition, by using the LOM, it is possible to specify for example the teaching or interaction style of a course, the grade level of a course, the difficulty of a course, typical learning time of a course, the prerequisites of a course and the relationships of learning objects.

All these features of LOM are useful for defining the learning objects used in pharmacy. However, LOM does not provide domain specific semantic metadata items, and therefore we have to introduce domain specific vocabulary. We next consider the usability of taxonomies and ontologies for presenting semantic metadata.

III. REPRESENTING LEARNING OBJECTS' SEMANTIC METADATA BY PHARMACY TAXONOMIES

Semantic metadata is traditionally represented through keywords, which are extracted from the document. In using extracted keywords in searching documents, we can miss many relevant documents as the keywords used with queries and documents descriptions are not standardized [8].

In order to standardize semantic metadata, specific taxonomies, which describe certain topics, are introduced in many disciplines. We next consider the use of medicinal taxonomies in searching medicinal learning objects.

Generally taxonomy is a way to classify or categorize a set of things into a hierarchy [7]. It is a tree like structure consisting of a root and branches where each branching point (i.e., a node) is an information entity. In the context of information technology, taxonomy is generally understood as the classification of information entities in the form of a hierarchy, according to the presumed relationship of real-world entities that they represent [7].

The logic behind taxonomy is that when one goes up the taxonomy toward the root, the information entities [13] become more general, and respectively when one goes down towards the leaves, the information entities become more specialized.

A simple drug taxonomy is presented in Fig. 1. The idea behind this classification is that the medicinal learning objects can be annotated by the metadata items (the branching points and the leaves) represented in the tree. A pharmacist can then query medicinal learning objects by Boolean expressions [8] comprising of operands and operations. The operands are the used keywords (which are taken from the taxonomy) and the operands are typically "and", "or", and "not". For example, by using the drug taxonomy of Fig. 1 the keywords attached to the medicinal learning objects "Using pain drugs in topical use with children" could be "Pain drugs for topical use" and "Prescription based pain drug".

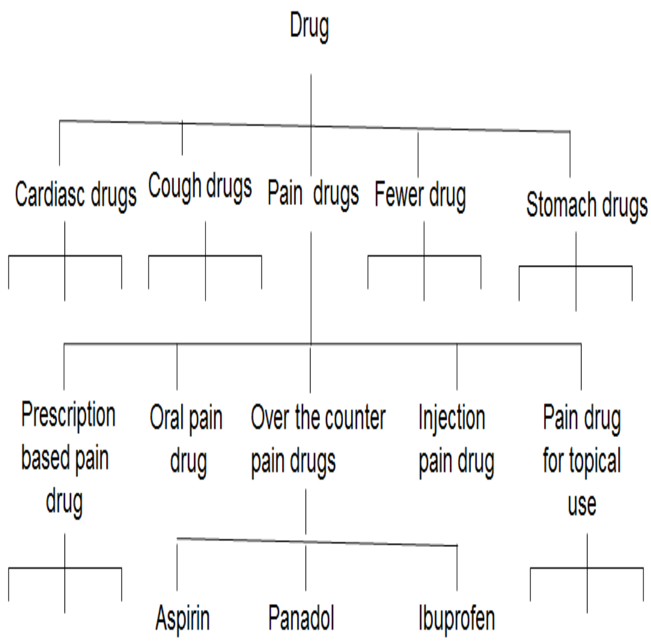

Fig. 1 Medicinal product categories in a taxonomy

Using taxonomies in searching learning objects is intuitive and easily understandable. For example, assume that a pharmacist wants to renew her knowledge about pain drugs and thereby wants to include such a learning object in her personal curriculum, so she enters the Boolean expression: Prescription based pain drug and Pain drug for topical use. Now assume that the result includes at least the learning object "Using pain drugs in topical use with children". After reading the description of the learning object, the pharmacist may insert the learning object into her personal curriculum.

However, although the Boolean model is intuitive and clear, there is a wide variety of queries that cannot be expressed by keywords. In order to be able to execute such queries there must be an ontology that models the relationship of the relevant concepts (terms). Such a feature is included in our designed pharmacy ontology. In addition, as we will illustrate, the ontology captures the used taxonomies, and so it also provide a means for supporting metadata (keyword) based searching of medicinal learning objects.

IV. REPRESENTING LEARNING OBJECTS' SEMANTIC METADATA IN PHARMACY ONTOLOGY

A. *Knowledge Centric Pharmacy System*

Before representing the structure of the pharmacy ontology, which captures learning objects ontology, we consider the architecture of the knowledge base and the software modules of the pharmacy ERP system [14] that access the pharmacy ontology. The architecture is presented in Fig. 2.

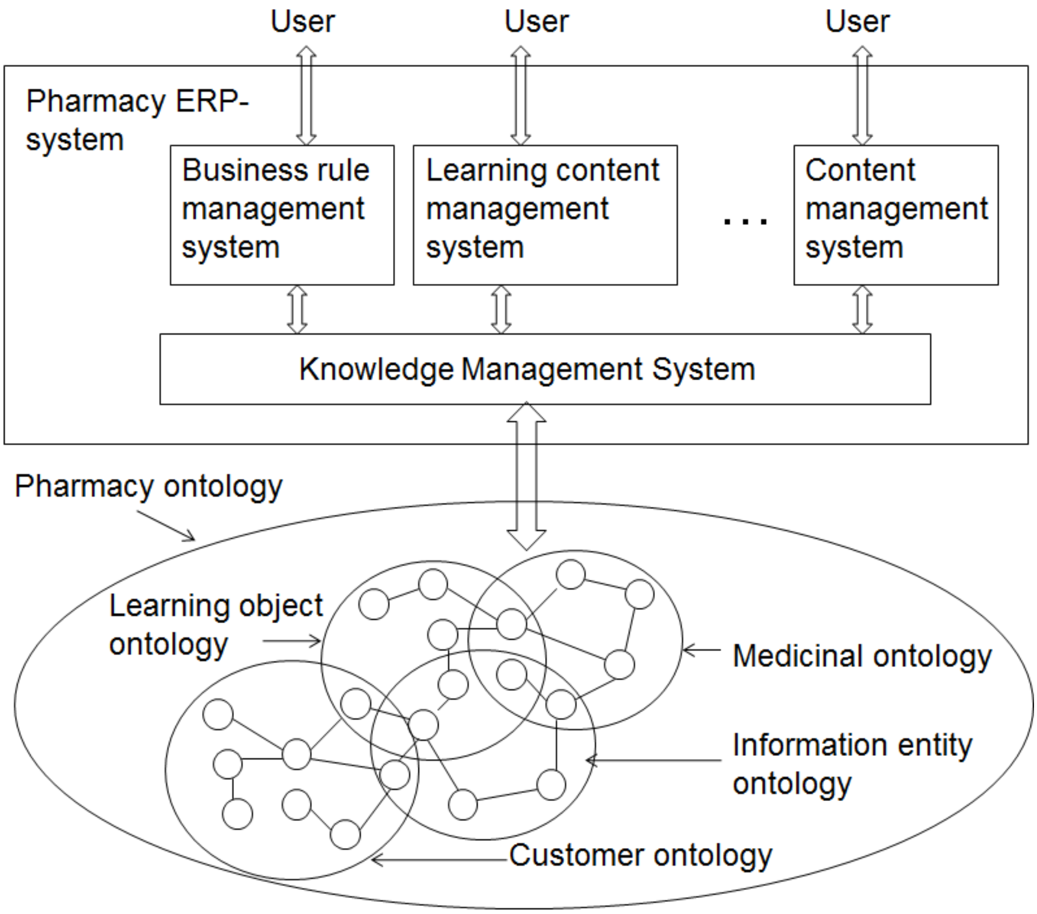

Fig. 2 The architecture of the pharmacy system

Generally, ERP (Enterprise resource planning) system is a software architecture whose purpose is to facilitate the flow of information between all business functions inside the boundaries of the organization and manage the connections to outside stakeholders [15]. Usually it is built on a centralized database. However, as we use Semantic Web technologies in managing data, we use a knowledge base, which is a special kind of database for knowledge management.

In developing knowledge oriented systems the key idea is to revolve all applications around the shared ontology [7]. In our case, it means the integration of the ontologies including learning object ontology, business rule ontology, customer ontology and inventory ontology, and then sharing the integrated pharmacy ontology. So the components of the pharmacy's system interoperate through accessing the shared pharmacy ontology.

B. *Learning Objects in Pharmacy Ontology*

Originally ontology is the philosophical study of the nature of being, existence or reality in general, as well as of the basic categories of being and their relations [16]. In computer science, an ontology is a general vocabulary of a certain domain, and it can be defined as "an explicit specification of a conceptualization" [17]. Essentially the used ontology must be shared and be consensual terminology as it is used for information sharing and exchange.

Fundamentally an ontology tries to capture the meaning of a particular subject domain that corresponds to what a human being knows about that domain. It tries to characterize meaning in terms of concepts and their relationships. It is typically represented as classes, properties, attributes, and values. Fig. 3 represents a subset of the pharmacy ontology.

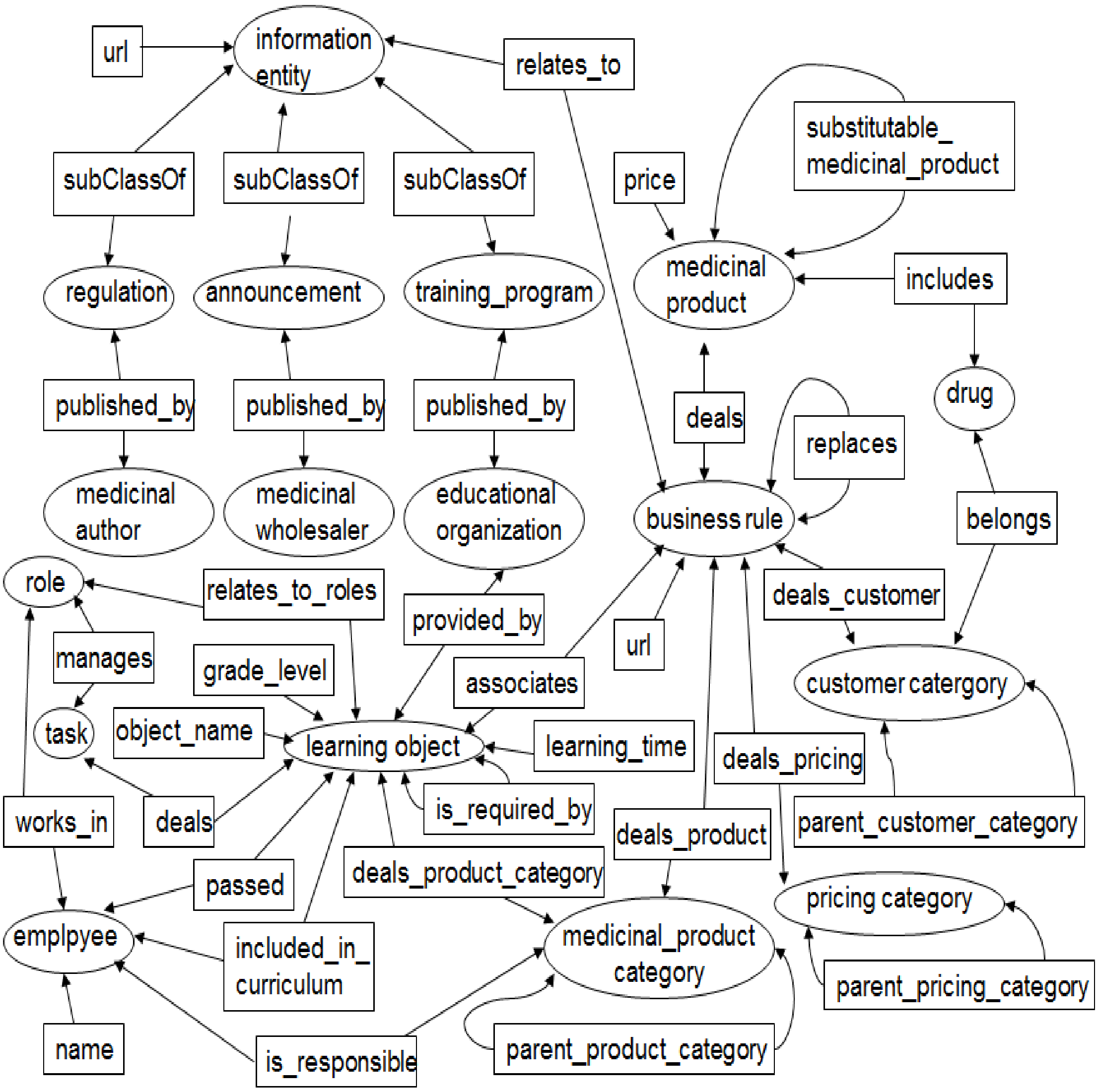

Fig. 3 A subset of the pharmacy ontology in a graphical form

In this graphical representation ellipses represent classes and subclasses, and rectangles represent data type and object properties. Object properties relate objects to other objects while data type properties relate objects to data type values. Classes, subclasses, data properties and object properties are modelling primitives in OWL [18].

Note that in Fig. 3 we have presented only a few of objects' *datatype properties*. For example, in the figure, the class *learning object* has only two data type properties, namely *grade_level*, and *learning_time*, although any of the LOM's metadata item may be a data type property of the class *learning object*.

Also note that the class *medicinal product category* represents a taxonomy. Its data type property *parent_product_category* defines the parent of the node, and so the tree structure can be defined. If the node is the root of the tree, then the property refers to itself.

An example of an object property is *deals_product_category*, which relates the classes *learning object* and *medicinal product category*. The class medicinal product category is shared by the learning object ontology, medicinal ontology and information entity ontology. Hence it represents the item in Fig. 2, which is rounded by these three ontologies.

The pharmacy ontology allows making the following queries that may be useful in building personal curricula:

- Is there any learning object that deals pain drugs.
- Give me the name of the employees that have not passed learning objects that deal pain drugs
- Give me the learning objects that are provided by the Heath Institute and are related to the tasks of which the proprietary pharmacist is responsible.
- Give me the learning objects that are passed by Elisa Ford and deals medicinal information.
- Give me the learning objects that are included in Elisa Ford's curriculum and are provided by the Health Institute.
- Which learning objects are required in order to participate on the learning object "Principles of pharmacy systems".

A subset of the graphical ontology of Fig. 3 is presented in OWL in Fig. 4.

```
<rdf:RDF
        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-nsl#"
        xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
        xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
        xmlns:owl="http://www.w3.org/2002/07/owl#">

        <owl:Ontology  rdf:about=""PharmacyOntology/>
         <owl:Class  rdf:ID="LearningObject/">
         <owl:Class  rdf:ID="Employee">
        <owl:Class  rdf:ID="MedicinalProductCategory/">
        <owl:Class  rdf:ID="Task/">
        <owl:Class  rdf:ID="Role">
        <owl:Class  rdf:ID="InformationEntity/">
        <owl:Class  rdf:ID="EducationalOrganization/">
        <owl:Class  rdf:ID="TrainingProgram">
                    <rdfs:subClassOf  rdf:resource="#InformationEntity"/>
        </owl:Class>

        <owl:DatatypeProperty  rdf:ID="grade_level">
                    <rdfs:domain rdf:resource="#LearningObject"/>
                    <rdfs:range rdf:resource="&xsd;string"/>
        </owl:DatatypeProperty>

        <owl:DatatypeProperty  rdf:ID="learning_time">
                    <rdfs:domain rdf:resource="#LearningObject"/>
                    <rdfs:range rdf:resource="&xsd;string"/>
        </owl:DatatypeProperty>

        <owl:ObjectProperty  rdf:ID="ProvidedBy">
                    <rdfs:domain rdf:resource="#EducationalOrganization"/>
                    <rdfs:range rdf:resource="#LearningObject"/>
        </owl:ObjectProperty>

        <owl:ObjectProperty  rdf:ID="Passed">
                    <rdfs:domain rdf:resource="#Employee"/>
                    <rdfs:range rdf:resource="#LearningObject"/>
        </owl:ObjectProperty>
                    .
                    .
                    .
</rdf:RDF>
```

Fig. 4 A subset of the pharmacy ontology in OWL

The OWL Web Ontology Language is designed for use by applications that need to process the content of information instead of just presenting information to humans. By an ontology language, it is possible to write explicit, formal conceptualizations of domains. So OWL facilitates greater machine interpretability of Web content than that supported by XML [19], RDF [20], and RDF Schema [20] by providing additional vocabulary along with a formal semantics.

On the other hand, in data storage (knowledge base), the instances of the pharmacy ontology are presented in RDF. RDF is a framework for representing information in the Web. Itself is a data model. Its modelling primitive is an object-attribute-value triple, which is called a statement.

A *description* may contain one or more statements about an object. For example, the RDF-element presented in Fig. 5 inserts into the pharmacy ontology a learning object, which is identified by LO-123. The description of LO-123 is comprised of four statements. The first statement specifies that the type of object LO-123 is learning object. The second statement specifies that the name of the learning object is "New Pain Drugs". The third statement specifies that the grade level of the learning object is "Experts". The fourth statement specifies that the product type category related to the learning object is "Pain drugs".

```
<rdf:RDF
    xmlns : rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#
    xmlns : xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns : po="http://www.lut.fi/ontologies/PharmacyOntology#">

    <rdf:Description rdf:about="LO-123">
        <rdf:type rdf:resource="&po;LearningObject"/>
        <po : object_name>New Pain Drugs</po : object_name>
        <po : grade_level> Experts </po:grade_level>
        <po : deals_product_category>
            Pain drugs
         </po : deals_product_category>
     </rdf : Description>

</rdf:RDF>
```

Fig. 5 Representing an instance of the pharmacy ontology in RDF

Representing queries by RQL and SPARQL is easy for those who are familiar with database query languages. For example in RQL, to retrieve all instances of the class learning object, we only have to write "learning object".

To retrieve the medicinal categories that the course LO-123 deals we have to write the following query:

```
select N
from LearningObject{X}.deals_product_category{Y},
        {C}object_name{N}
 where Y= "LO-123" and X=C
```

However, the employees in pharmacies do not have to be familiarized with query languages to retrieve data from the pharmacy ontology as user-friendly interfaces can be easily developed.

V. CONCLUSIONS

Pharmacy is a field where the fast development of drug treatment and technologies requires specialized skills and knowledge. At the same time, the amount of new instructions concerning new medication increases rapidly. How to ensure that healthcare staff is aware of the new instructions is not an easy task. However, applying computing technology for retrieving and disseminating medicinal information, this complexity can be alleviated in many ways.

On the other hand, continuing education sets new requirements for the providers of the education: they have to build global learning infrastructure, course material has to be in digital form, course descriptions and material have to be distributed and learners should have easy access to various descriptions concerning the provided education. However, these descriptions are presented in a non-standard and heterogeneous ways in a variety of formats, which in turn hampers the learners in building their personal curricula.

We have ourselves restricted into this problem in the context of pharmacies, where the building of pharmacists' curricula is dictated by regulations. In our developed solution the descriptions of the provided medicinal education are standardized by introducing specific learning object ontology for pharmacies. In addition to the relevant pharmaceutical terms, the ontology captures the elements of the Dublin Core and LOM standards. So the variety of the terms that can be used in describing medicinal learning objects is rather wide. However, the providers only have to use those terms that are appropriate in attaching metadata with the learning objects they provide.

The gain of including the learning object ontology in the pharmacy ontology is twofold: (i) the building of a curriculum is as easy as within formal education; and (ii) in building the curricula we can exploit pharmacists' educational history and their roles and responsibilities in the pharmacy. The drawback of this solution is that the educational organizations are burdened by requiring them to annotate their provided education by the standardized metadata. On the other hand, in this way the providers can improve the visibility of their provided education, and so in this sense they will also gain of this extra work.

In our future work we will study the suitability of cloud computing for pharmacy systems. Cloud computing is an interesting choice as it allows consumers and businesses to use applications without installation. Thereby the cloud reduces the cost of acquiring, delivering, and maintaining computing power.

In particular, community cloud seems to be most promising as its infrastructure can be shared by several pharmacies that have shared concerns. Thereby community cloud enables pharmacies to purchase only the computing services they need, instead of investing in complex pharmacy systems. Further, as pharmacies have shared concerns with drug and educational information they can share most their used data, and thereby reduce their cost in maintaining pharmacy specific data.

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