Abstract: The Semantic Web technologies have been used in many educational projects over the last few years. As ontologies are the best known knowledge representation mechanism, allowing both humans and machines to model and work with knowledge, their usage in eLearning systems is of great importance for achieving a high quality learning and authoring process. In this paper we make a brief exploration of eLearning projects, using ontologies and propose a model of an open eLearning system, using ontologies for knowledge representation, sharing, reusing, integration and reasoning. We discuss the strengths and drawbacks of the model; outline the main areas of an effective ontology application in eLearning and its role in achieving better educational quality.

Keywords: ontology, semantic web, web 2.0, eLearning system, knowledge.

I. INTRODUCTION

Educational resources, ranging from simple text-based materials to highly interactive systems, can be searched, accessed and reused only if they are described by appropriate metadata. Several cataloguing schemes exist for marking-up learning objects: Dublin Core [1], IEEE-LOM [2], ARIADNE [3], IMS LD [4]. Metadata standards have been developed to semantically annotate educational materials of any kind for supporting both machine interoperability (information exchange) and resource discovery by human users. Although they incorporate important Learning Object (LO) metadata, their main drawbacks are the lack of expressiveness, difficulty in automatic processing by software programs, and problems in the interoperability of systems, based on different standards.

Ontology is a knowledge representation mechanism that can make meaning explicit, more accessible to automatic processing and easily understandable for learners. That is why most research has been made during the last few years about ontology usage in describing the structure, content, teaching, learning strategies and learners’ profiles to achieve flexibility, adaptability, knowledge integration and reuse.

Nowadays, eLearning systems propose a wide variety of tools and services for content, knowledge and students management to support an effective learning process organization. In spite of this, the recent information flow can assist learning for every individual who desires to do so, if it is open, searchable and easily accessible. In the educational domain, several ontologies have been developed and experimentally used to describe the learning contents, model the elements required for the design, analysis, and evaluation of the interaction between learners in computer-supported cooperative learning, formalize the semantics of learning objects that are based on metadata standards (like LOM).

The aim of this paper is to present and discuss a model of an eLearning system, based on multiple ontologies for describing learning objects (from pedagogical, structural and scientific point of view), user profiles, as well as related to LO external web resources (for achieving a high level of personalization, openness, and flexibility). For this purpose a brief exploration and classification of the eLearning ontology-based approaches is made.
II. RELATED WORK

Searching publications about ontologies in eLearning in digital libraries leads to the conclusion that there are many research projects in this field. Ontologies have successfully been used in every stage of eLearning: authoring [5], tutoring [6], and assessment. In order to have a comprehensive view on ontology usage in eLearning systems, we explored about 20 research projects, which reported results about ontologies in eLearning. Our brief analysis aims to extract valuable dimensions for explicit description of the main ontology-usage areas and classify the systems according to them. Our classification (Figure 1) assumes three dimensions as the most valuable approach for understanding: what elements are described by ontologies (LO [7], user profile [8]); which main learning approach relies on used ontologies; what type of programming technologies are used for the implementation of effective ontology-usage in a Learning system. Other implementations (apart from the agent-based and Web 2.0 [9]) include state of the art stand-alone or server applications, and web service-oriented applications. Motivated and semantically explained recommendations have been recently proposed, based on the combination of Web 2.0 and semantic Web technologies. The new eLearning resource-recommender system, called FIRST (Folksonomy-based Item Recommender system [10]) allows users to express their preferences for items by entering a numerical rating as well as to annotate rated items with free tags.

![Figure 1. Ontology-based eLearning approaches](image)

One of the new trends in ontology usage for eLearning is about topic map-based visualizations. In [11], for example fuzzy domain ontology extraction algorithm is used for concept map generation based on the messages posted in online discussion forums. By browsing these concept maps, instructors can quickly identify the progress of their students and adjust the pedagogical sequence on the fly. Usage of Web resources is of great importance for course dynamics. In VICE project [12] ontology-based architecture and platform for semantically tagged metadata using ontologies freely imported from the web is proposed. As it is mentioned above, research projects have shown that ontologies are useful in every stage of eLearning for various purposes. We believe that incorporating multiple ontologies into one learning environment (for LO, learner profile, assessment, learning process organization, etc.) is the next stage of evolution of eLearning systems. We call such a system Open Semantic eLearning system and will discuss its model in the next chapters.

III. MODEL OF ONTOLOGY-DRIVEN ELEARNING SYSTEM

The metadata quality and organization is very important for effective organization and searching LO, reuse and integration of learning content. Every standard enables interoperability only among systems that use it and within the same domain, but can’t guarantee compatibility between domains or systems that use different standards. The lack of a shared understanding between terms in
various metadata vocabularies, insufficient metadata (proposed by eLearning metadata standards) and lack of formal semantics and reasoning capabilities may be disallowed by using semantic web technologies (ontology) to represent and manage eLearning metadata.

Open flexible eLearning systems are based on semantic search and information integration. In order to interact on a semantic level or effectively organize development and the learning process, all the needed information has to be specified explicitly in a machine-processable way. The shared-understanding problem in eLearning occurs on several orthogonal levels, which describe several aspects of document usage: learning content, course structure, and instructional content. Ontologies may be used for describing the semantics of the learning process, structuring activities and communication facilities, and defining the context and the environment of eLearning. In an ontology-driven eLearning environment we have to model and represent the relevant aspects and domains of knowledge which contain the knowledge about students, domains, learning facilities processes, and communication. The overall architecture of an ontology-driven eLearning system is shown on Figure 2. The main components include: internal and external parts. The internal part consists of the knowledge, implemented and managed by the eLearning system. eLearning system collects information about related systems or objects in the web through an external part and proposes information and knowledge to the learners in the appropriate manner.

![Figure 2. Architecture of an ontology-driven eLearning system](image)

IV. METADATA CREATION

In this section detailed explanation of models included in the ontology-driven eLearning system is performed.

**Document model:** Document model (Learning object content structure) ontology includes ontologies for the explicit definition of the structure of the LO (Document Structure Ontology, DSO), and the needed visual presentation of LO. The LO structure is of great importance in the process of choosing the best resources for achieving a concrete learning goal. If the structure of compound LOs (as chapters or courses) is represented in a machine-processable way (as ontology), assistant agents may use it for making useful recommendations about the usability of the resources. The document ontology defines Content Fragment types such as images, text, audio and video, content object types,
and their structure using DITA (Darwin Information Typing Architecture [13]) and it’s extension Abstract Learning Object Content Model (ALCoM [13]) concepts to define information types (e.g. concept, principle, task) and their building blocks (e.g. example, definition, analogy). DITA is a recent architecture with rich documentation and online support. This ontology is a basis for enabling on-the-fly access and a combination of learning object components that will facilitate the repurposing of these components. Document Presentation Ontology (DPO) is used for describing the structure relevant for visualization. Such ontology may be developed by adapting FOHM ontology, which introduces context and behaviour objects. It may be used for example for dynamic generation of various visual representations of the learning content according to the learner preferences and learning style.

Learning Design Model [14]: Pedagogical metadata describes the instructional content as well as the educational activities. The XML-Schema language is not expressive enough to represent all the knowledge, needed for semantic description of pedagogical metadata. Mainly, hierarchical taxonomies, relation properties, and semantic constraints between the learning design elements cannot be represented in XML-Schema. To solve these limitations, our model includes standard ontologies for learning materials like LOM. The learning goal is the most important concept that plays a central role in the decision making process of the agents in resource finding, aggregating and presenting. Learning goal ontology is a basis for forming effective learning groups in the case of collaborative learning. It conceptualizes course goals, resource goals, individual, group learning goals, learning group type and learning scenario characteristics, roles and activities. Learning Object Context Ontology (LOCO) [15] is an ontology originally developed to promote the integration and reuse of LOs and learning designs.

Communication model: Collaborative Learning Ontology (CLO) [16] has been developed to facilitate shared understandings of several early presented models of collaborative learning. CLO offers the general framework and vocabulary to describe collaborative learning scenarios based on theories; standard vocabulary and knowledge that can be used by pedagogical agents facilitating the communication and negotiation among them; clarification of the behaviour and roles for learners. Negotiation Ontology (NO) proposes a system of concepts for modelling the negotiation process such as opinion exchange, persuasion, compromise and agreement. Tag Ontology [17], UTO (Upper Tag Ontology) [18], SCOT (Social Semantic Cloud of Tags) [19], MOAT (Meaning of a Tag) [20] ontology may be used to add semantics to folksonomies, and facilitate a semantic communication and collaborative personalization in such a way.

Student model: Information about the learner (his learning style, knowledge level, motivation, etc.) is very important for the organization of an effective learning process. The student model consists of two kinds of data: static data, which is not altered during the student-system interaction; and dynamic data, that changes according to the student learning progress and with the system interaction. The Static Model Ontology (SMO) comprises of five different parts: personal, personality, cognitive, pedagogical and preference data. The Dynamic Model Ontology (DMO) comprises two sets of data: the performance data, and the student knowledge data, describing the knowledge concepts and competences relevant for the current course that the student possesses and must possess until the end of the course. All of this data is gathered from the student-system interaction. The learner model is partially open. This means that learner can view all information about him/herself, but can change only a little part.

Knowledge model: This model is the formal representation of domain knowledge, which the system proposes for learning. All defined in the course concepts have to be formally described. This model includes Precise Domain Ontology (PDO) of all the course knowledge, Upper Domain Ontology (UDO), containing general course concepts and many related to them external for the learning system and small specific Etalon Ontologies (EO) for testing examples. There are concepts, which must be traced during sessions to determine the student’s knowledge about the associated concepts. It is preferable to organize them in a separate ontology (Tracing ontology, TO) as each traced concept needs four associated parameters: correct answers, wrong answers, completed tests and uncompleted tests. The main drawback of the ontology-based knowledge model is the difficulty and complexity of knowledge acquisition and representation as an ontology tack. Some learning techniques have been proposed for automatic or semiautomatic extraction of domain ontology during the recent years.
The main purpose of the external model is to collect, store, manage and propose to agents information from included in the eLearning system or related to them topics. The external model ontology (EMO) includes some of the main elements of internal ontologies (profile, document or domain) and additional web resource characteristics as server, service characteristics, license agreements, domain dependency, as well as resource URLs and valuable metadata (as ontology individuals). Addresses and annotating information about searched by search engines external resources are stored temporarily in the external model for future usage by internal agents (as resource recommenders) or directly by the teachers or learners. The external model is case-based. There are several types of web resources, useful for the eLearning process: digital libraries, Wiki’s, Web 2.0 external communities ontology grid systems, web repositories, containing learning resources or ontologies, online ontology development tools, online tutoring tools, (semantic) web services. When an external resource agent recognizes some of these cases, it uses its specific behaviour to manage it and send a query to the corresponding external agent.

V. DISCUSSION AND CONCLUSION

Current eLearning systems use different metadata standards to describe their content objects, stored in repositories. It will be unrealistic to expect that all eLearning resources will be described in a uniform way as different people sometimes interpret the same things in different ways, or use different words to describe them. This is the well-known semantic heterogeneity problem. Semantic web proposes approaches and technologies to solve it: knowledge has to be represented in a semantic way, using ontologies. Then by means of reasoning and ontology mapping agents will manipulate not words and sentences, but the sense of the thoughts. Using appropriate ontologies, pedagogical agents can help in locating, browsing, selecting, arranging, integrating, and otherwise using educational material from different educational servers.

The proposed model is knowledge-centric. Several domain ontologies on a different granularity level represent the domain knowledge in different points of view and are useful for a deep understanding of domain knowledge as well as in the self-testing process and for proficiency control. Representation of domain knowledge implemented in LOs as ontology will simplify searching; automatic recommendation and combination of LOs for generating compound LOs and dynamic learning scenarios.

The main drawback of the model is its complexity. But that is only at first glance. We download from the web initial versions of the above discussed domain – independent ontologies, use Protégé for adding some adaptation to the eLearning tack. We make experiments in the school learning geometry terminology. We build domain ontologies, using school textbook definitions and mathematical terminology classification in [21] and [22]. As in this domain the terminology system is relatively poor and closed, we don’t use automatic ontology learning approaches for dynamic ontology building. Our developed eLearning system that use these ontologies in the eLearning process is agent-based (it uses JADE Multiagent framework [23]) and is described in another paper. The results show that visualization of the implemented in the ontology model terminology structure and interrelationships are very useful for its understanding. Such a representation is suitable for automatic generation of flexible tests. For advanced learners we propose a lightweight ontology development agent that helps learner in the development of a little ontology, implementing the relationships between some selected learned concepts. Automatic checking of all the relationships understanding is made by mapping the student ontology to the previously developed etalon one. Comprehensive learning resources semantic description makes possible dynamic selection of the most suitable for concrete learner learning resources according to his/her learning style and personal achievements in mathematic.

One drawback of many such tools is that they assume significant user involvement and this makes ontology building a difficult and time-consuming task. Automatic ontology development or annotation tools are far from their maturity. It may be successfully used for initial annotation or ontology learning and results have to be verified from experts. A lot of freely available on the Internet ontologies from educational semantic web portals, semantic document repositories or retrieved by
semantic document search engines may also be used (only after manual evaluation and corrections). Community-driven ontology management approaches and tools that have been developed in the last years will also facilitate the ontology development process.

In conclusion, the presented model for knowledge gathering, which includes ontologies for all parts of the eLearning process, is modular, flexible and extendable, as any ontology can easily be replaced by a better one, or new ontologies can be included. The proposed model of shareable educational ontologies makes the learning content reusable, machine understandable, machine-processable, and hence agent-ready. Ontology-based technologies can also be used in web-based learning technology systems (LTS), which are typically based on software, multimedia, and hypermedia technology, to support learning and training activities. These LTSs facilitate authoring and the delivery of content. Initial agent-based system evaluation is made in learning school geometry domain and it shows promising results. As every learning domain has its specificity, results can’t be generalized and evaluation in many other domains is needed.

References