INFORMATICA, 2015, Vol. 26, No. 2, 221–240

DOI: http://dx.doi.org/10.15388/Informatica.2015.46

Semantic Web Technologies for e-Learning: Models and Implementation

Valentina DAGIENĖ[1]*, Daina GUDONIENĖ[1], Renata BURBAITĖ[2]
[1] *Institute of Informatics and Mathematics, Vilnius University*
Akademijos 4, LT-08663 Vilnius, Lithuania
[2] *Faculty of Informatics, Kaunas University of Technology*
Studentų 50, LT-51367 Kaunas, Lithuania
e-mail: valentina.dagiene@mii.vu.lt, daina.gudoniene@mii.stud.vu.lt, renata.burbaite@gmail.com

Received: January 2015; accepted: June 2015

Abstract. Nowadays the web can serve as a perfect technological environment for personalized learning which is suggested by educators and based on interactive learning objects. While a range of technological solutions for the development of integrated e-learning environments already exists, the most appropriate solutions require further improvement of the implementation of novel learning objects, unification of standardization and integration of learning environments, based on semantic web services that are still in the early stages of development. The aim of the research is to create a model for the development of semantic learning objects, connect it with the architecture of the educational system for semantic learning object design and to present the experimental part of the model's impact on the course design process. The paper presents the research with the main question on how to improve the e-learning course with semantic learning objects by exploring the application of learning object design approaches, usability, performing modern training facilities and the learning object design model based on semantic web technologies.

Key words: e-learning, learning objects, models, semantic web, semantic technologies, applications.

1. Introduction

One of the hottest topics in recent years has been a semantic web. It is about making the web more understandable by using computers. Redecker *et al.* (2009) analyzed an explicit declaration of the knowledge embedded in many web-based applications, including e-learning courses and virtual education platforms. The semantic web-based technologies introduced a new set of educational opportunities for educators and students. Hsu (2012), Redecker *et al.* (2009), Yarandi *et al.* (2011) discussed the new methods and models of education, based on new semantic technologies and applications, as well as the advantages provided for both teachers and students. They have emphasized the following issues: (1) the increased amount of information; (2) opportunities for interactive learning, based

*Corresponding author.

on the semantic web technologies; (3) interdisciplinary and multicultural perspectives in learning; (4) on-the-job training opportunities.

The resources and materials available via the World Wide Web expand the information supply to a virtually infinite degree. The virtual libraries, collections of articles, dialogue forums, various databases, and historical archives all over the world are available for everyone who uses the Internet. The opportunities of interactive learning based on the semantic web technologies can transcend the potential of most other educational media as a means to connect students with the first person sources beyond the classroom walls and national borders and across cultures. Information technologies allow interactive communication: students can put specific question's topic to an expert regarding any in the respective field.

Many sites, such as Discussion Forums, are designed to facilitate a dialogue and sharing of ideas among educators and students. At the global level, e-learning provides individuals with a wide intercultural competence as well as social and global awareness. The use of semantic web technologies allows teachers and learners to view the same issue from different cultural, national, and religious perspectives, which cannot be done during the traditional lessons/lectures.

e-Learning renders an opportunity to learn without leaving the workplace and using different semantic technologies and applications. According to the data analysis of the research, several papers are analyzing semantic web technologies that are expected to enhance learning processes and outcomes in a number of ways. Firstly, they are widely believed to respond better to the changed cognitive processes and learning patterns that have evolved due to the ubiquity and widespread use of information and communication technologies, thus facilitating knowledge acquisition. Moreover, learning objects, based on semantic technologies, recognize a diversity of users and are thus expected to contribute to the personalization of educational experiences, offering opportunities for flexible, distributed learning, which could provide the learners more varied opportunities to engage in learning.

The idea of the presented research is to find out the way of improving e-learning courses by using semantic learning objects. Usually the learning objects are created and stored in external or internal repositories, contextualized and standardized; there exists, various profiles and models of learning objects (LOs) and applications starting from the semantic network and finishing with educational modeling languages and instructional engineering. Typically, teachers, students, researchers, course designers, groups of scientists and organizations, etc. are the authors and users of LOs. The presented analysis of the-state-of-the art shows that the research of LOs forms a separate branch that is continuously extended and developed. Rutkauskienė *et al.* (2013) had a discussion on the functional architecture and service, namely oriented integrated learning environment. Despite the fact that a number of studies have been carried out, there are many unresolved issues, discussed by the authors (Alsultanny, 2006; Aroyo and Dicheva, 2013). The most important challenges of e-learning, using semantic web technologies, are identified in publications (McIlraith *et al.*, 2001; Aroyo and Dicheva, 2013): (1) interoperability of web-based educational systems; (2) educational standards for the semantic web; (3) semantic web educational services; (4) modulated architectures of adaptive semantic web-based educational systems; (5) authoring of the educational content, instructional process, adaptation, and personalization.

The aim of our research is to create a model for e-learning based on semantic web technologies and link it to the architecture of the educational system, as well as to present the experimental part of the model's impact on the course design process. The paper presents: (1) the semantic web technology in education, its usability, and overview of the existing international practice and facilities to perform modern training; (2) exploration of the existing LOs design approaches and models; (3) a model for the semantic LOs design and architecture of the semantic learning object design; (4) results of the experiment of the model's impact on the course design process.

2. Research Methodology

The research presented in this paper, is based on the constructive research approach (Kasanen *et al.*, 1993). The constructive research approach consists of 6 phases (Fig. 1): (1) to identify a practically relevant problem (*Practically relevant problem identification*); (2) to obtain a general and comprehensive understanding of the research topic (*Theoretical body of knowledge*); (3) to construct a problem solution idea (*Theoretical framework* + *Problem solution*); (4) to demonstrate that the solution works (*Practical relevance*); (5) to show the theoretical connections and the research contribution of the solution concept (*Theoretical relevance* → *Theoretical body of knowledge*); (6) to examine the scope of applicability of the solution (*Practical relevance* + *Theoretical relevance*). There are some different research sub-methods used in each phase.

A systematic review of the related research works and analytical research methods as used for revealing the advantages of the use of semantic web technologies in e-learning (phase 2) and for raising issues, related to the semantic learning objects use in semantic education (phase 1), as well as for exploring the existing LOs design approaches and models (phase 2) and for extracting the initial data from our model linked to a theoretical framework (phase 3).

A descriptive research was used: (1) to explain the created model and architecture of the educational system for semantic learning object design belonging to problem solution

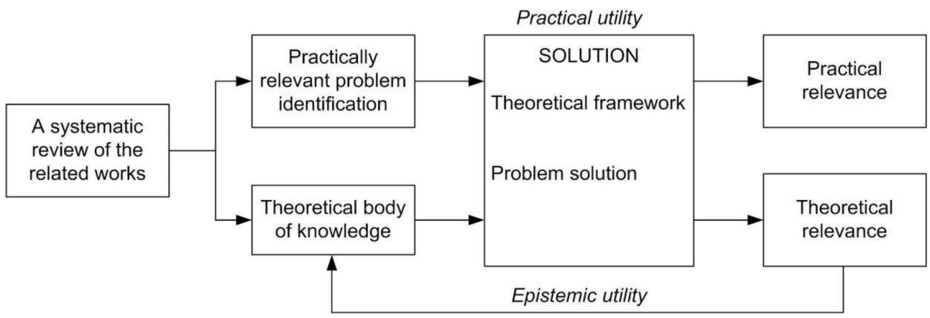


Fig. 1. Diagram of a constructive research approach.

(phase 3); (2) to evaluate the theoretical relevance (phase 6); (3) to present the results of the experiment (phase 4). The case study method involves the experiment of the model's impact on the course design process (phase 4).

The presented research is related with computer course design for eventual use of 94 respondents in higher education institutions in Lithuania. The researchers have prepared a test to evaluate the effectiveness of the course developed using the e-learning object design model, based on semantic web technologies. A test was organized and piloted in the different higher education institutions, entrusting 94 respondents to evaluate the impact on the course design process.

3. Related Works: Learning Objects and Models of Semantic Web Services

This section discusses the features and challenges of e-learning. The most important e-learning features can be presented as follows:

1. Networked Knowledge, i.e. knowledge derived from the professional knowledge databases;
2. Arbitrary Learning, i.e. the student can choose a flexible learning schedule and location;
3. Regular updating of the learning objects and teaching resource diversification vaults;
4. Design of e-learning methods, resources, evaluation systems;
5. Intelligent e-learning systems, closely related to data storage, which use intelligent algorithms and are based on artificial intelligence, and data mining algorithms referred to as smart in the e-learning research.

A comparative analysis of smart e-learning systems and architectures for benchmarking (Sakarkar *et al.*, 2012; Raju and Ahmed, 2012) highlights the challenges of e-learning: (1) development of architecture of semantic web-based e-learning systems mobile agents, while the agent knowledge is improved; (2) increased number of visualized educational resources; (3) new cooperation and communication with the learner to apply artificial intelligence achievements and updating of internal and online databases, wikis, etc.

e-Learning personalization problems are analyzed by Essalmi *et al.* (2012), Mbendera *et al.* (2010) and Klašnja-Milićević *et al.* (2010) who considered that there is no single strategy for personalization. Each strategy depends on the personalization settings: learner characteristics, learning methods used for e-learning. Nedungadi and Raman (2012) proposed to solve the LO personalization problem, addressing the integration of e-learning and mobile learning, as well as mobile devices by exploiting the flexibility. Ramadhanie *et al.* (2009) and Luís *et al.* (2012) concentrated on the LO ontology that supports personalization of e-learning, integrated with the student model ontology.

Bettio *et al.* (2013) present the strategy for selecting the course content, directed to the diversification of knowledge areas and promoting the permanent incorporation of the resources, developed in the teaching-learning process. They focus on the organization of the production process of Learning Objects, based on the Scrum method, and suggests a set of best practices, inspired by the management of agile software development, as well as the contextual motivation of its use.

Menolli *et al.* (2013) explain that learning objects and units of learning are two e-learning concepts that allow the content to be organized in a suitable sequence, thus improving its learning and reuse. Therefore, the approach is to generate learning objects and units of learning from social tools in order to organize information for easy reuse.

The adaptation of the learning context to the learner's needs is closely related to the content of the context for improving the adaptive learning process. Jovanović *et al.* (2007) suggest to address the problem by introducing the LO context as a unique set of interrelated data characterizing the specific learning situation, which is defined as a unique set of interrelated data characterizing the specific learning situation.

3.1. *Contextual Analysis of Learning Objects and the e-Learning Field*

One of the most important tasks of the contextual analysis and modeling is the context analysis and modeling which is essential information on the context and presentation isolation for further processing. The modeling method and many factors are selected to distinguish the key, highlight the essential links between them. Gradually, a complex problem becomes more understandable, various events are merged into a whole logical system, and can see the whole thing as a set of such systems. So we get a computer model that systematically reflects the essential characteristics of a subject and helps to explore it (Schmohl and Baumgarten, 2008). With the view of modeling the context, a graphic systematic model is created that operates with real images and objects, i.e. the real context. It is necessary for a computer model and creation of design of the information model, that formally describes the systematic patterns. The context is complex and dynamic, it courses various problematic situations. According to the wide used Learning Object Metadata (LOM) specification, a context is the environment in which LO can be created beyond the context. The context information model consists of data and information received, which describe the subject area of the elements, their relationships and patterns of change (Baniulis *et al.*, 2005).

During modeling it is important to identify the specific context of the area and to look for relationships between the context by describing the elements, intended to identify possible changes in the dynamic context, and to take into account the context of the developed model (Schmohl and Baumgarten, 2008). e-Learning and LOs areas of researchers emphasize different aspects of the context briefly discussed by them.

Weitl *et al.* (2004) defined the context as a content fragment encompassing the entire design and the scope of information, while the terms and conditions offered a contextualized LOs reuse process model.

Dias de Figueiredo (2010) defined a context as a knowledge-generating learner using a LO appropriate set of conditions, and proposed a model linking the learner to the learning content and the context of learning.

Safran *et al.* (2006) defined the context as interrelated conditions in which something exists or takes place and learning activities, based on the concept of the context modeling system, using a dynamically generated LO in the context-dependent information spaces. Azouaou and Desmoulins (2006) have written as follows: "the context of an element X is the properties P of any element Y such as: (1) Y is around X; (2) Y gives meaning to X; (3) P is meaningful for X". Moore *et al.* (2010) have noted that the context is composed of a subcontext describing the entities and relationships among them. Such approaches to the context define that not all the elements of contextual features are available in mind, but rather those which are significant.

Liu *et al.* (2009) have described the context by identifying the entities of the state, i.e. the place of a learner, learning activities, used tools and learning objects. Allen and Mugisa (2010) have called contextual learning as the general situation of LOs and the scope of LOs. Zheng *et al.* (2009) have noted that the context includes two subject-oriented, integrated and dynamic properties. The information associated with the subject can be called a constantly changing subject context.

Das *et al.* (2010) proposed a context known in the e-learning system architecture, where the Standardized Context Model used is designed after reviewing the literature.

The researchers have identified that the LO context model should include different types of contextual information that could be adapted to the changing environment. In addition, contextual elements are related to one another, i.e., namely, a change in one value of a property causes changes in the values of other properties.

3.2. *The Role of Learning Objects in Semantic Education*

Learning objects, based on semantic web technologies, are expected to promote independent, autonomous and self-directed learners, endowed with a variety of social skills that enable them to connect, interact and collaborate successfully with a variety of people on different tasks and in diverse environments.

Education institutions are susceptible to all of these strategies, although the focus and implementation differ substantially between higher and secondary or primary education.

Azouaou and Desmoulins (2006) and Essalmi *et al.* (2012) describe the importance of the property of the semantic web architecture that, enabled by a set of suitable agents, establishes a powerful approach to satisfy the e-learning requirements. The process is based on semantic querying and navigation through learning materials, supplemented by the ontology. The semantic web can be exploited as a very suitable platform for implementing an e-learning system, because it provides all means for e-learning: ontology development, ontology-based annotation of learning materials, their composition in learning courses and proactive delivery of the learning materials through e-learning portals (Lee, 2008). Table 1 shows the proposed advantages of the possibility of using the semantic web for releasing the e-learning requirements.

The informal conceptual system, indicates the importance of a formal semantic account; specification of "conceptualization" as a representation of the conceptual system via the logical theory, characterized by specific formal properties, only by its specific purposes as a vocabulary used by the logic theory, and (meta-level) specification of the logical theory. Although social computing originated outside the educational institutions, it has

Table 1
Advantages of using the semantic web as a technology for e-learning.

Functionality	e-Learning semantic web features	e-Learning semantic web advantages
Delivery	Pull – student determines the agenda	LOs are distributed on the web, but they are linked to commonly agreed ontologies. That enables us to design a specific course by semantic querying.
Responsiveness	Reflection – response to the problem	Software agents of semantic web technologies may use a commonly agreed service language, which enables a coordination among agents and proactive delivery of LOs where the personalized agent communicates with other agents.
Access	Accessibility – direct access to LOs	Direct access to LOs and performance of semantic querying for the suitable learning material. Access to LOs can be expanded by semantically defined navigation.
Symmetry	Symmetric – LOs as an integrated activity	The semantic web offers the potential to become an integrated platform for all educational processes including LOs,
Modality	Continuous – LOs in the educational process	Active delivery of information (based on personalized agents) creates a dynamic learning environment that is integrated in educational processes.
Authority	Distributed – content comes from the interaction of the participants and educators	The semantic web will be as decentralized as possible. It enables an effective cooperative content management.
Personalization	Personalized – content is determined by the individual user's needs	Using user's personalized agent searches for LOs customized for her/his needs. The ontology is the link between user needs and characteristics of LOs.
Adaptivity	Dynamics – content changes constantly through user input, experiences, new practices	The semantic web enables the use of distributed knowledge provided in various forms, supplemented by semantic annotation of the content. The distributed nature of the semantic web enables a continuous improvement of LOs.

a huge potential in formal education and training for enhancing learning processes and outcomes and supporting the modernization of education and training institutions. Many different tools and technologies are used to study processes to assure the learning objects design and learning enhancement.

Usually the LOs design consists of three parts: (1) Learning Management System (LMS) use; (2) Promoting use; (3) Evaluation Impact. The LMS use covers content repositories, student's assignments, academic information students, collaborative approach, strategies for autonomous self-learning, the supervision process, and evaluation testing. The promoting use is related to: (1) ICT support for teachers which includes the development of e-learning strategies and use of the system and (2) development of e-learning strategies, including resources such as institutional LMS and others, and two types of initiatives: individual and institutional (Alsultanny, 2006; Beydoun, 2009).

The semantic web technologies are currently not deployed on a large scale for informal education and training in Europe. However, there is a vast number and variety of locally-embedded systems, that illustrate the variety and scope of e-learning approaches in formal education and training (Gaeta, 2009). The problem is that there are not so many LOs, described by semantic metadata, and they cannot be shared and used semantically.

Meyer (2006) analyzes the concept of learning objects. The concept has been applied in the e-learning field to promote the accessibility, reusability, and interoperability of the learning content. Learning Object Metadata (LOM) specification has been developed to achieve these goals by describing learning objects in order to provide meaningful metadata. Unfortunately, the conventional LOM lacks the computer interpretability needed to support the knowledge representation when searching for and finding relevant learning objects (Gladun, 2009).

The course design and teachers' role in the study process, proposed by the authors, describe a way of adapting and transforming the existing video sequences, not specifically created for learning, into ready-to-use learning resources in a semantic web (Gasevic *et al.*, 2009). Yarandi *et al.* (2011) have proposed an ontology-based knowledge modeling technique for designing an adaptive e-learning system in which learner's knowledge, abilities, learning styles and preferences are considered in the learning process. In this system, the ontological user profile is updated, based on the abilities achieved by learners. This approach also classifies the learning content into finer levels of categories that are explicitly annotated, using the descriptions from the domain and content ontology. Šimko (2012) has proposed a lightweight domain model with respect to the facilitation, together with the methods to acquire the respective parts of the domain model. The lightweight semantics were introduced here as a suitable form of domain conceptualization for an adaptive educational system. The context of the Educational semantic web, most of the practical implementations and usage of the standards are related to the learning object annotation, which creates a number of additional requirements for a successful use of standards. Courses have to be improved with LOs, based on the semantic web technologies. The development of simple methods and tools is very important for LOs annotation, differentiation between objective and subjective metadata, combination metadata sets and schemes from multiple sources, seamless integration of production and annotation, introduction of formal semantics into the existing standards, and a flexible and dynamic association of metadata with Los. These are some of the challenges the standards have been dealing with (Bittencourt *et al.*, 2008).

3.3. *Outline Learning Object Models Used in e-Learning*

Learning objects in e-learning systems are defined as independent and autonomous learning content units that should be used in many learning contexts. In the educational material formation process the main principle is to reuse small information chunks (also called "reusable learning objects") flexibly (Essalmi *et al.*, 2012; Nath, 2012). This principle is closely related to the use of objects in software engineering.

Littlejohn *et al.* (2006) and Nikolopoulos *et al.* (2012) have defined the requirements for learning objects: (1) accessibility means that LOs should be described by metadata with a view to retrieve them from repositories and libraries more easily; (2) reusability ensures that LOs will be used in many educational contexts; (3) interoperability defines that LOs are independent of the presentation tools and knowledge management systems; (4) LOs should provide possibilities for active learning; (5) LOs should be of high quality.

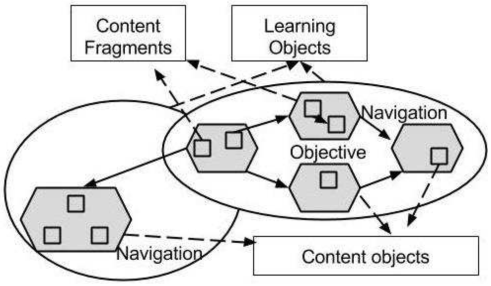


Fig. 2. Content model of the general learning object (Verbert and Duval, 2004).

The main task of LOs is to be reused. CISCO systems propose a structural Learning object model to support reuse in education. The proposed model consists of 5 main components such as objective, metadata, content, practice, and assessment. LOs may be static and interactive and may contain practice as a separate component. The model aims at achieving one learning objective. The quality of the LOs model is measured by evaluating whether or not the objective was achieved. The interior of the content is created from the text, audio, video, animation fragments, and Java code applets. The model is described using metadata for storing and striving to support reuse.

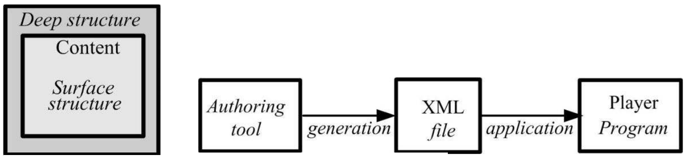
The general learning object content model proposed by Verbert and Duval (2004), has shown how the authors distinguish content fragments, content objects and learning objects (text, audio and video) (Fig. 2). They represent individual resources not combined with any others. A further specialization of this level has to take into account the different characteristics of time-based media such as audio, video and animation, as well as static media like photos, text, etc.

Content objects are sets of content fragments. They aggregate the content fragments and add navigation. Content fragments are instances, whereas content objects are abstract types and the authors argue that it is possible to extend content fragments with activities and analogously content objects with activity types and roles.

Meyer (2006) proposes the model as a Testable, Reusable Unit of Cognition (TRUC), which consists of concepts, skill, and assessment. The following attributes characterize the model:

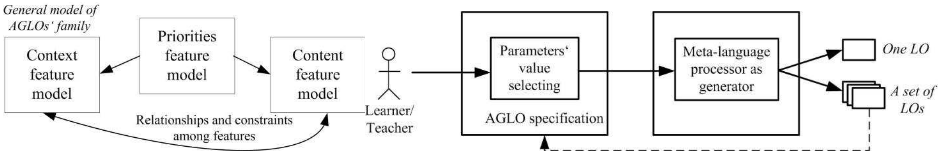
1. LOs components are created, based on a clearly defined concept.
2. LOs components are clearly defined and oriented to multiple uses.
3. LOs have one or more assessment criteria.
4. The scope of the LOs use covers a few lessons.

Multiple ideas and approaches are offered and dealt with in this branch of research on Learning object design. Leeder *et al.* (2004) have introduced the generative learning objects (GLOs) concept and approaches, based on them aiming to enforce the reuse potential in the e-learning domain. ‘Generative’ should be understood as a property of the learning content to be produced and handled either semi-automatically or automatically under the support of some technology. The importance of GLOs in e-learning is that the e-learning participants involved in the learning process, receive a sign to move from the *component-based reuse model to a generative-based reuse model*, which relates to the use of GLOs.



(a) (b)

Fig. 3. Template-based GLO models: structural (a) and behavioral (b) (adapted, Boyle, 2006).



(a) (b)

Fig. 4. Meta-programming-based AGLO models: generalized model of the AGLO family (a) and behavioral (b).

The structural model of the Generative Learning Object (GLO) (Fig. 3(a)) contains a deep structure and surface structure (Boyle, 2006). The behavioral model of GLO consists of Authoring Tool, XML file, and Player Program (Fig. 3(b)). As the main merit of the model, Boyle emphasizes the opportunity to change the XML file flexibly, using the authoring tool in order to create instances from the template-based GLO.

In 2008, Štuikys and Damaševičius (2008) have proposed an approach of the generative LOs that enables us to express the learning content variability aspects explicitly, using feature models and meta-programming, based on the generative technology and implementation of generic LOs. Advanced generative learning objects (AGLOs) came from a heterogeneous meta-programming technology with extended capabilities that enable us to express a variety of learning aspects, such as content, pedagogical, social, and technological aspects through the parameterization, explicitly (Burbaite, 2014). A generalized model of the AGLO family (Fig. 4(a)) consists of the context and content feature models that are semantically connected with relationships and constraints between them, and the priority model.

Structurally, AGLO is a high-level specification that describes a family of related LOs instances. From the behavioral point of view, AGLO is a generator that generates instances of LOs according to users' requirements (Fig. 4(b)). In practice, AGLOs comes from a LOs library or it is a part of it, in which a set of related LOs is stored as a compact package.

The proposed AGLO designing method covers two levels: development of the concrete feature-based models and their transformation into the meta-programming-based executable specification.

After the outline of LOs models, we argue that the semantic annotation of the existing models consists in generating specific metadata and usage schema that enables the access to the new information methods and extend the existing ones, not intended or expressed implicitly (e.g. the context model, AGLO model).

4. Design of a Model for e-Learning Objects Based on Semantic Technologies

During the research, LOs are composed of content elements with semantic relations, and the automatic generation before describing the content elements with semantic relations have to be identified. The semantic annotation tools for some types of content elements have already been developed (Azouaou *et al.*, 2004). Garcia-Barriocanal (2011) and Repp *et al.* (2007) have described video LOs and multimedia objects, developed according to semantic annotation principles. We present a model for the development of semantic LOs as a sequence of semantic learning objects pre-design, design, and post-design processes (Fig. 5).

The pre-design process of semantic learning objects and design-based research is a LOs-based research paradigm, holding the promise of introducing more teachers and trainers to work for improving the content with semantic learning objects for educational purposes. However, there is a lack of methodological standards and established research processes and there are general principles and procedures of the LOs design model research when creating technology-based innovative learning environments. Our research is aimed at the case study of learning object design, based on semantic web technologies with the main interest of teachers and trainers to get the guidance for e-learning courses improvement of semantic technologies. In this case, the educational system architecture model has been developed for semantic learning objects design with the aim to find out the individual conceptual model, ontology or workflow and the tutorial path for teachers and trainers (Fig. 6).

Semantic web services have the functionalities to ensure the automatic discovery, composition, and invocation of the services of different agents. In this research, the semantic web services have been used to develop Los, based on semantic technologies for the educational content, assessment, problem solving, and the use of artificial intelligence techniques (case-based reasoning and rule-based reasoning).

Table 2 connects the processes described in the model (Fig. 5) and the components of the educational system (Fig. 6). We have also defined the activities and methods that were used to achieve the results in each stage. The content of Table 2 can be interpreted as a sequence of instructions to introduce the proposed model into a real platform for learning object design and delivery.

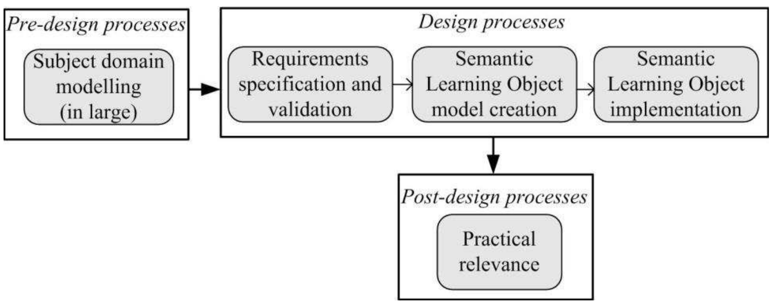


Fig. 5. A model for the development of semantic learning objects.

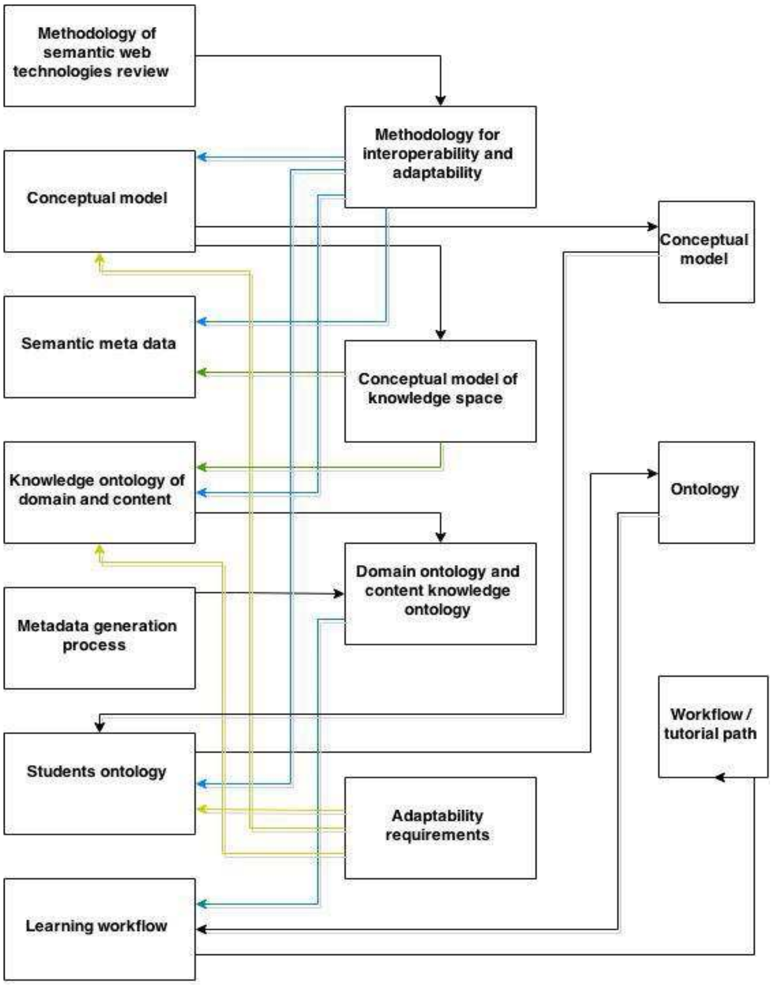


Fig. 6. The architecture of the educational system for designing semantic learning objects.

The processes of the subject domain modeling are closely related to methodological issues how to use the semantic web technologies and ensure interoperability and adaptability in the e-learning domain in the most effective way. Well-known, adapted, and newly created methods and activities are more suitable at the development stage in this model. The output of the subject domain modeling processes is a domain, knowledge space, students' conceptual models, and semantic metadata.

The requirement specification and validation stage allows us to specify the adaptability requirements explicitly, using requirement mining, analysis, specification, and validation techniques. The output of this stage is an adaptability requirement model which is very important for a further development of the general model.

Conceptual models, metadata, and semantic metadata are used as input data at the stage of the semantic learning object creation. At this stage, the development of ontologies using

Table 2
Relations among the model's processes and the educational system's components.

Model's processes	Educational system's components	Activities and methods used	Outcomes
Subject domain modeling (in large)	(1) Semantic web technologies, review & methodology (2) Methodology for interoperability and adaptability	Literature analysis Experts' knowledge Domain modeling using well known or created methods	Conceptual domain model Knowledge space Conceptual model Students' conceptual model Semantic metadata
Requirements specification and validation	(1) Specification development (2) Adaptability requirements	Requirement mining Requirement analysis Requirement specification Requirement validation	Set of adaptability requirements (a model)
Semantic Learning object creation	Conceptual domain model Knowledge space conceptual model Students' conceptual model Semantic metadata Metadata generation	Development of ontologies, using ontology creation methodologies Description of the overall structure and behavior of the educational system	Ontologies Relationships among the educational system's components
Semantic Learning object implementation	Developing of learning workflow, based on ontology learning workflow → workflow/tutorial path	Implementation of ontologies	Adaptive semantic learning objects
		Experimental evaluation	LOs quality metric values Data for improving the LOs design model

ontology creation methodologies is presented. We also describe here the overall structure and behavior of the educational system. The output covers a set of created ontologies and relationships among the educational system's components.

The stage of semantic learning object implementation is closely related to the design of learning workflow, based on the ontology. This process can be called as "implementation of ontologies". As a result, we develop a set of adaptive semantic learning objects.

At the practical relevance stage, the experimental evaluation of developed objects is integrated into the learning environment to be carried out. The outcomes of experimental evaluation are the values of quality metrics of the developed learning objects that will be used as data for improving the learning object design model.

5. Experiment on the Model's Impact on the Course Design Process

We propose an architecture for implementing the learning object design model, that can be applied in various domains and that the authors could easily work with for the design and integration of learning objects. During the research on usability and interoperability of the learning object design, learning object phases have been identified and will have influence on improving the study process as well as on finding technological solutions to

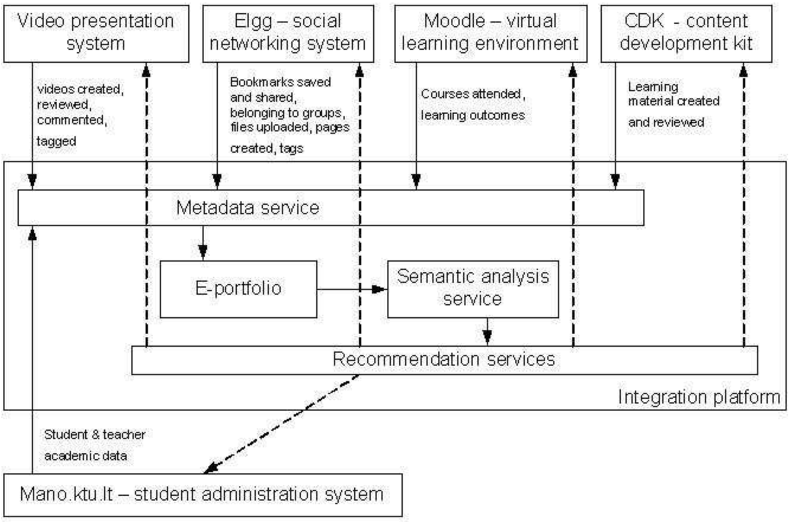


Fig. 7. Platform for learning objects design and delivery.

design learning objects and on the development of our architectural model. During the first phase of the research the data were analyzed for the e-learning process implementation according to the needs, testing feedback and delivery phase searching for the learning object design and the methods of e-learning. However, the researchers identify that the learning objects' implementation, quality, and effectiveness are usually related to the technologies and technological solutions. The research presents many-years implemented ideas on the unified information system, that supports the implementation of e-learning possibility.

The architectural model was designed theoretically and started to implement step-by-step. The researchers discussed that metadata of a section could be used to provide any other information about the goal, keywords, background, etc. With an increase of the knowledge granularity level, multiple sections can form a component. Multiple components, related to a learning topic, can be grouped. When a learning object, based on semantic technologies, is generated by an instructor/author, the expert experience can be embedded into the configuration of the course, such as selection of section contents, selection of components, sequence of components, display modes of components, etc. When it is generated by the learning environment, certain organizational patterns can be applied to generate a course corresponding to the learner's profile and the learning goal (Fig. 7).

Not many LOs could be adapted to the semantic education. A new model will be tested by inserting into IS with the architecture, based on SOA principles (Sakarkar *et al.*, 2012) and Bittencourt *et al.* (2008), however the functions will be provided as services. The internal service processes are intended to optimize the use of provision of direct procedure calls that can be realized directly in the server application procedures. Some kinds of activities are to be performed as services and will be directly agreed during the analysis and design of learning objects.

By means of the web service, components of the system will be able to take advantage of the Virtual Learning Environment (VLE) and its functionality, which provides a specific

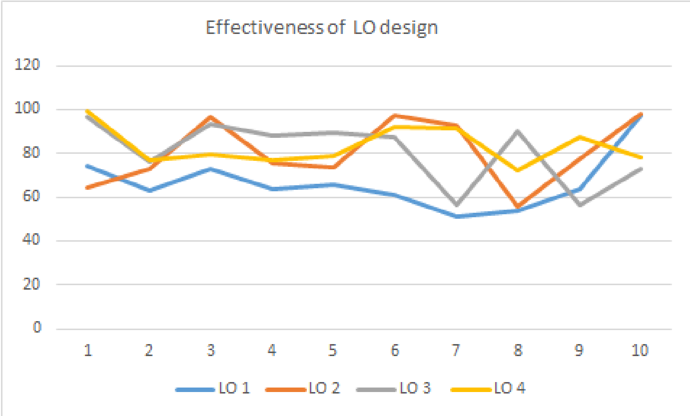


Fig. 8. Effectiveness of the LOs design process.

service, such as to record data, to get a report, etc. In addition, the service component of the system can be used to participate in the workflow. Workflow can be used for both VLE information systems and services, provided by external integrated systems.

High resolution digital objects are stored in the VLE information system repository (open.ktu.lt). However, in order that these objects could be used in a further creation of the learning process (learning programs), and to create training programs and courses, these objects must be transformed into different formats and quality facilities. The information system and its components are meant to work in the environment adapted to communicate with the standard IT platforms, operating systems, and the computer network. Transparency of data available at institutions could be supported by exposing their various databases to relevant parties in semantic, interoperable formats.

Semantic technologies could enable information integration, searching and matching to this end. Collaboration among the institutions cannot be easily facilitated, since the relevant information systems of universities are not interoperable and the deployment of linked data repositories in each institution involves additional costs. Large repositories, like triple stores, in which information can be efficiently stored, searched and managed, could be of benefit.

In our integrated information system, learning objects are distributed on the web, but they are also linked to an agreed network of ontologies, in fact, construction of user-specific courses, allowing semantic query on various topics of interest. Software agents of the semantic web can be used to enable a coordination among other system agents and proactive delivery of learning materials in the context of actual problems.

The semantic web can be as decentralized as possible. That enables an effective cooperative content management (Fig. 8). The content is determined by the individual user's needs and is aimed to satisfy users' needs. The users will be customized for her/his needs by applying personalized agent searches for learning material. The ontology is a link between the user's needs and characteristics of the learning material, integrated into the system environment. In this case, we may select the standard learning objects, developed

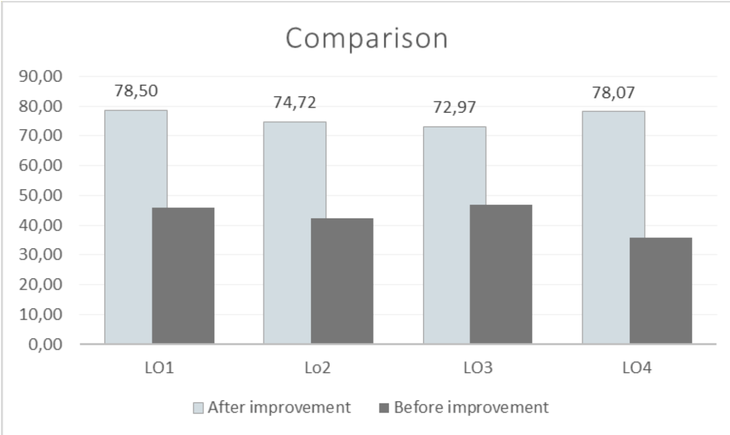


Fig. 9. Comparison of LOs before and after the course improvement.

in the standard virtual environment, and not the standard learning objects developed using the learning object model, based on semantic web technologies.

The distributed nature of the semantic web enables a continuous improvement of learning materials. It enables the use of distributed knowledge provided in various forms, achieved by semantic annotation of the content. The distributed nature of the semantic web enables a continuous improvement. Performing an experiment we have noticed that the semantic web improves the use of knowledge, provided in various forms, regarding the semantic annotation of the content, and the content modifies the learning objects, based on semantic technologies in the educational sector (Fig. 9).

The experiment was organized at the institutional level, but the university is a technical university, while the others were mostly technical subject professors and lecturers. From our experiments that were taken for comparison between the standard learning objects and not the standard learning objects of the educational process, we can see that the users are more friendly with the standard learning objects. However, after the improvement of LOs by the model, based on semantic technologies, the respondents indicated that the improved LOs are more friendly than the standard ones.

6. Conclusions

The web can serve as a perfect technological environment for individualized e-learning, proposed by education providers and based on interactive learning objects. Since there already exists a range of technological solutions for the development of integrated e-learning environments, the most appropriate solutions require a further improvement of the implementation of novel learning objects, unification of standardization and integration of learning environments, based on semantic web services that are still in the early stages of development.

The model, proposed for the development of semantic learning objects, is connected with the components of the architecture of the educational system for semantic learning object design, describing the activities and methods used and outcomes of each stage. The research presents the experimental part of the model's impact on the course design process. The developed learning object design model, based on semantic web technologies, can be applied as a methodology to create e-learning courses step-by-step. Educators will have a possibility to adapt and improve the e-learning courses or even program design.

Having in mind the semantic web, the proposed model can be exploited as a very suitable solution for implementing the e-learning system, based on semantic learning objects. It provides all means for e-learning: ontology development, ontology-based annotation of learning materials, their composition in the learning courses, and proactive delivery of the learning materials via e-learning platforms.

References

Allen, C.A., Mugisa, E. K. (2010). Improving learning object reuse through OOD: a theory of learning objects. *Journal of Object Technology*, 9(6), 51–75.

Alsultanny, Y. A. (2006). e-Learning system overview based on semantic web. *The Electronic Journal of e-Learning*, 4(2), 111–118.

Aroyo, L., Dicheva, D. (2013). The new challenges for e-learning. *The Educational Semantic Web Educational Technology & Society*, 7 (4), 59–69.

Azouaou, F., Desmoulins, C. (2006). A flexible and extensible architecture for context-aware annotation in e-learning. In: *Proceedings of Advanced Learning Technologies, IEEE International Conference on Advanced Learning Technologies, ICALT'2006*, Kerkrade, The Netherlands, pp. 22–26.

Azouaou, F., Chen, W., Desmoulins, C. (2004). Semantic annotation for learning material. In: *Proceedings of Semantic Web and e-Learning Workshop*, *Adaptive Hypermedia, AH'04*, Vol. 2. CS-Report 04-19. Eindhoven University of Technology, pp. 359–364.

Baniulis, K., Tamulynas, B., Aukstakalnis, N. (2005). Case study of virtual organization learning and knowledge testing environments. In: *Towards the Learning Grid*, pp. 79–87.

Bettio, R.F., Pereira, D.A., Martins, R.X., Heimfarth, T. (2013). The experience of using the scrum process in the production of learning objects for blended learning. *Informatics in Education*, 12(1), 29–41.

Beydoun, G. (2009). Formal concept analysis for an e-learning semantic web. *Expert Systems with Applications*, 36 (8), 10952–10961.

Bittencourt, I.I., Costa, E., Isotani, S., Mizoguchi, R., Bittencourt, I.M. (2008). *Towards a Reference Model to Semantic Web-Based Educational Systems*.

Boyle, T. (2006). The design and development of second generation learning objects. In: *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Chesapeake, VA, pp. 2–12.

Burbaite, R. (2014). *Advanced generative learning objects in informatics education: the concept, models, and implementation*. Summary of PhD thesis, Kaunas University of Technology, Kaunas, Lithuania, 38 pp.

Das, M., Bhaskar, M., Chithralekha, T., Sivasathya, S. (2010). Context aware e-learning system with dynamically composable learning objects. *International Journal on Computer Science and Engineering*, 2(4), 1245–1253.

Dias de Figueiredo, A. (2010). Learning contexts: a blueprint for research. *Digital Education Review*, (11), 127–139.

Essalmi, F. Ayed, L.J.B., Jemni, M., Graf, S.A. (2012). Personalization strategy of e-learning scenarios. *Computers in Human Behavior*, 26(4), 581–591.

Gaeta M. (2009). Advanced ontology management system for personalized e-learning. *Knowledge-Based Systems*, 22(4), 292–301.

Garcia-Barriocanal, E., Sicilia, M.A., Sanchez-Alonso, S., Lytras, M. (2011). Semantic annotation of video fragments as learning objects: a case study with YouTube videos and the Gene Ontology. *Interactive Learning Environments*, 19(1), 25–44.

Gasevic, D., Djuric, D., Devedzic, D. (2009). *Model Driven Architecture and Ontology Development*. Springer, Berlin/Heidelberg, 378 pp.

Gladun, A. (2009). An application of intelligent techniques and semantic web technologies in e-learning environments. *Expert Systems with Applications* 36(2–1), 1922–1931.

Hsu, I.C. (2012). Intelligent discovery for learning objects using SW technologies. *Educational Technology & Society*, 15 (1), 298–312.

Jovanović, J., Gašević, D., Knight, C., Richards, G. (2007). Ontologies for effective use of context in e-learning settings. *Journal of Educational Technology & Society*, 10(3), 47–59.

Kasanen, E., Lukka, E., Siitonen, A. (1993). The constructive approach in management accounting research. *Journal of Management Accounting Research*, 5(1), 243–263.

Klašnja-Milićević, A., Vesin, B., Ivanović, M., Budimac, Z. (2010). e-Learning personalization based on hybrid recommendation strategy and learning style identification. *Computers & Education*, 56(3), 885–899.

Lee M.C. (2008). A practical ontology query expansion algorithm for semantic-aware learning objects retrieval. *Computers & Education*, 50, 1240–1257.

Leeder, D., Boyle, T., Morales, R., Wharrad, H., Garrud, P. (2004). To boldly GLO-towards the next generation of learning objects. *e-Learning in Corporate, Government, Healthcare, and Higher Education*, 1, 28–33.

Littlejohn, A. Falconer, I., Mcgill, L. (2006). Characterizing effective eLearning resources. *Computers & Education*, 50(3), 757–771.

Liu, L., Chen, H., Wang, H., Zhao, C. (2009). Construction of a student model in contextually aware pervasive learning. In: *Proceedings of Joint Conferences Advancing technologies in Humanity*, pp. 511–514.

Luís, A., Menolli, A., Reinehr, S., Malucelli, A. (2012). Ontology for organizational learning objects based on LOM standard. *Advancing Technologies in Humanity*. 978-1-4673-0793, 2–12.

Menolli, A.L.A., Reinehr, S., Malucelli, A. (2013). Improving organizational learning: defining units of learning from social tools. *Informatics in Education*, 12(2), 273–290.

Mbendera, A.J., Kanjo, C., Sun, L. (2010). Towards development of personalized knowledge construction model for e-learning. *Mobile, Hybrid, and on-Line Learning*, 29–35.

McIlraith, S.A. Son, T.C., Zeng, H. (2001). Semantic web services. *Intelligent Systems*, 16(2), 46–53.

Meyer, B. (2006). Testable, reusable units of cognition. *Computer*, 39(4), 20–24.

Moore, P., Hu, B., Wan, J. (2010). Smart-context: a context ontology for pervasive mobile computing. *The Computer Journal*, 53(2), 191–207.

Nath, J. (2012). e-Learning methodologies and its trends in modern information technology. *Journal of Global Research in Computer Science*, 3(4), 48–52.

Nedungadi, P., Raman, R. (2012). A new approach to personalization: integrating e-learning and m-learning. *Educational Technology Research and Development*, 60(4), 659–678.

Nikolopoulos, G., Solomou, G., Pierrakeas, C., Kameas. A. (2012). Modeling the characteristics of a learning object for use within e-learning applications. In: *Proceedings of Fifth Balkan Conference in Informatics, BCI'12*, New York, USA, pp. 112–117.

Raju, P., Ahmed, V. (2012). Enabling technologies for developing next-generation learning object repository for construction. *Automation in Construction* 22, 247–257.

Ramadhanie, M.A., Aminah, S., Hidayanto, A.N., Krisnadhi, A.A. (2009). Design and implementation of learning object ontology for e-learning personalization. In: *Proceedings of International Conference on Advanced Computer Science and Information System*, 428–433.

Redecker, C., Ala-Mutka, K., Bacigalupo, M., Ferrari, A., Punie, Y. (2009). *Learning 2.0: the impact of web 2.0 innovations on education and training in Europe*. Final report, European Commission-Joint Research Center-Institute for Porspective Technological Studies, Seville.

Repp, S., Linckels, S., Meinel, L. (2007). Towards to an automatic semantic annotation for multimedia learning objects. In: *Proceedings of the International Workshop on Educational Multimedia and Multimedia Education*, New York, USA, pp. 19–26.

Rutkauskienė, D., Mark, R., Kubiliūnas, R., Gudonienė, D. (2013). Functional architecture of a service-oriented integrated learning environment. In: *Proceedings of European Conference on e-Learning*, Nice, France, pp. 431–439.

Safran, C., Garc?a-Barrios, V.M., Gütl, C. (2006). A concept-based context modeling system for the support of teaching and learning activities. In: *Proceedings of International Conference on Advanced Learning Technologies, ICALT'2006*, Kerkrade, The Netherlands, pp. 5–7.

Sakarkar, G., Deshpande, S.P., Thakare, V.M. (2012). Intelligent online e-learning systems: a comparative study. *Computer Applications*, 56 (4), 21–25.

Schmohl, R., Baumgarten, U. (2008, March). Context-aware computing: a survey preparing a generalized approach. *Engineers and Computer Scientists*, 2008(l), 19–21.

Šimko, M. (2012). An acquisition of domain model for adaptive collaborative web-based learning. *Sciences and Technologies*, 2(4), 1–9.

Štuikys, V., Damaševičius, R. (2008). Development of generative learning objects using feature diagrams and generative techniques. *Informatics in Education*, (7(2), 277–288.

Verbert, K., Duval, E. (2004). Towards a global architecture for learning objects: a comparative analysis of learning object content models. In: Cantoni, L., McLoughlin, C. (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Chesapeake, USA, pp. 202–208.

Weitl, F., Kammerl, R., Göstl, M. (2004). Context aware reuse of learning resources. *Educational Multimedia, Hypermedia and Telecommunications*, 1, 2119–2126.

Yarandi, M., Jahankhani. J., Tawil, R.A. (2011). A personalized adaptive e-learning approach based on SW technology. *Webology*, 10(2), 2011.

Zheng, Y., Li, L., Zheng, F. (2009). Context-awareness support for content recommendation in e-learning environments. *Information Management, Innovation Management and Industrial Engineering*, 3, 514–517.

V. Dagienė is professor and head of the Department of Informatics Methodology at Vilnius University Institute of Mathematics and Informatics. She has published over 150 scientific papers and the same number of methodological works, has written more than 50 textbooks in the field of informatics and ICT for high schools. She has been working in various expert groups and work groups, organizing the olympiads in informatics among students, also engaged in localization of software and educational programs, e-learning, and problem solving. She is an Executive Editor of international journals "Informatics in Education" and "Olympiads in Informatics". She has participated in several EU-funded R&D projects, as well as in a number of national research studies connected with technology and education.

D. Gudonienė is a doctoral student at the Department of Informatics Methodology at Vilnius University Institute of Mathematics and Informatics. The research area in Informatics Engineering and subject of interests is e-learning object design based on semantic web technologies. She is a co-author of 45 scientific papers and co-author of 8 books on e-learning technologies and methodology.

R. Burbaitė is a researcher at the Software Engineering Department of Kaunas University of Technology and a teacher of Computer Science at the gymnasium. Her research interests relate to e-learning domain that includes formal methods and the use of metaprogramming-based Generative Learning Objects and Educational Robots based learning environments to teach Computer Science topics.

Semantinio saityno technologijos e-mokymuisi: modeliai ir įgyvendinimas

Valentina DAGIENĖ, Daina GUDONIENĖ, Renata BURBAITĖ

Šiuolaikinės interneto technologijos suteikia galimybę jas naudoti kaip edukacines aplinkas, skirtas personalizuotam mokymui(si) įtraukiant interaktyvius mokymosi objektus. Integruotų mokymo(si) aplinkų projektavimo ir kūrimo sprendimų jau yra pasiūlyta, tačiau mokymui(si) labiau tinkamos semantinio saityno paslaugomis grįstos aplinkos dar tebėra ankstyvos plėtros stadijoje. Todėl kyla būtinybė unifikuoti mokymo(si) aplinkų standartus, integruoti semantinio saityno technologijų paslaugomis grįstas aplinkas į jau naudojamas, tobulinti sukurtus ir kurti naujus mokymo(si) objektus. Straipsnyje siekiama atsakyti į klausimą, kaip pagerinti e-mokymo(si) kursų projektavimą ir kūrimą, į juos įtraukiant semantinius mokymo(si) objektus. Tyrimo tikslas – sukurti semantinių mokymosi objektų projektavimo modelį, susiejant jį su edukacinės sistemos architektūra. Eksperimentinė tyrimo dalis tiria modelio poveikį e-mokymo(si) kurso projektavimo proceso kokybei. Pasiūlytas modelis yra tinkamas e-mokymo(si) sistemų, pagrįstų semantinių mokymosi objektų naudojimu, įgyvendinimui. Modelyje numatytas ontologijų kūrimas, ontologijomis grįstos mokymo(si) išteklių anotacijos, išteklių naudojimas kursams kurti ir kursų pateikimas naudojant e-mokymo(si) platformas.