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The Interoperability of Learning Object Design, Search and Adaptation Processes in the Repositories

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Abstract: Learning environments ensure successful implementation of the learning process but not always the effective design of the e-learning objects (ELOs) and moreover, search and adaptation. A technological solution for the design of the learning objects, repositories, and the semantic web is needed. There are many open educational resources, but not many platforms assure the possibility to adapt learning objects. The existing developed multifunctional platforms do not ensure the effective ELOs adaptation as well as the process of design and adaptation in the multifunctional environment. They do not have an automatic search of ELOs in the semantic web, which is directly targeted to the specific objects in repositories of open educational resources and do not allow for adaptation of the already developed ELO by automatically assigning reusable objects. The structure of the papers consists of the literature review and overview of existing practices, research methodology, research results description and conclusions provided by authors. The objective of the research is to suggest, to teachers, a model for effective e-learning objects design, automatic search and adaptation processes in the multifunctional environment by developing a platform based on semantic technologies for e-learning objects design and adaptation.

Keywords: multifunctional platform; processes; learning objects; adaptation; digital repositories; software engineering in e-learning; e-learning technologies

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1. Introduction

Definitions of learning objects focus on flexibility, independence, and reusability of content to offer a high degree of control to both instructors and students [1,2]. The concept of reusable learning objects (RLOs) has become the central component of current approaches to the standardization of learning objects [3]. The fundamental idea behind learning objects was that instructional designers could build small (in relation to the size of an entire course) instructional components that can be reused in different learning contexts [4]. RLOs can adapt to different learning styles, and each reusable learning object aims for learners to achieve a single learning goal through it [5]. A learning object is defined to be almost anything (IEEE standards).

Web-based learning object systems include various tools designed to support teaching and learning by helping students to explore, share, build and apply their knowledge [6]. Learning resources were often monolithic, the resources had to be taken on an all-or-nothing basis. Ontologies serve as user-repository interfaces that provide views of learning objects from various perspectives to enhance the learning objects repository usability for diverse application domains [7]. The challenges of interoperability, reuse, and repurposing of eLearning resources thus attracted considerable development effort [8], and for this reason, standards had to be developed. The IEEE standardization draft defined a learning object as any entity, digital or non-digital, that may be used for learning, education, or training.

The purpose of metadata standards is to increase re-discovery and reuse of learning objects (LOs) in Learning Content Management Systems (LCMS) or digital repositories [9].

Learning Management System (LMS) is a web-based, cloud-based, or installed software that helps in teaching and learning [10]. LMS has also proposed a standard for learning object packaging [11], allowing to take any learning object and provide a 'wrapper' around this object, describing the component structure of the object, and including the descriptive metadata, packaging into a standard container format and storing in digital repositories. The metadata permits fast effective searches to retrieve learning objects suitable for a particular purpose [12,13]. If the metadata record is provided in an appropriate machine-understandable form, a software module may eventually retrieve and aggregate RLOs to form higher-level units of instruction for a particular set of learning objects. These learning packages should then be interoperable across different LMS as the vendors bring their tools in compliance with the standards [14]. Machine-understanding ability entails the provision of metadata in some kind of formal language or knowledge representation format and also concrete idioms or design practices of annotation that guarantee consistent metadata across repositories and organizations [15]. Learning object design can be improved by greater integration of instructional design, learning theory and software development methodologies.

Learning objects search and adaptation in the semantic web is focused on the LO metadata and standards allowing to find necessary reusable LO for use in educational context or adaptation [16]. There are many existing open educational resources but some of them require additional adaptation or improvement for the year of issue. Information communication technologies (ICT) solutions are changing rapidly but some fundamental theories and practices still could be used. In this case, LO should be improved or adapted.

However, teaching quality in educational institutions relates to the quality of the services for educational needs, which is the most important component of education. The application of digital educational content and information communication technologies and new learning paradigms increase the appliance of mobile and smart technologies in the educational process. Changes in educational processes require new competencies and skills of teachers for learning objects design, development, provision or management of the technology-based educational process [17,18]. It is also related to the quality of the learning environment, e-learning objects (ELOs), repositories of open educational resources [19]. The authors [20] point out the pedagogical quality of learning resources. Many of these repositories follow a production model where the open educational resources (OER) are built by volunteer communities and do not have an effective quality control mechanism.

Learning environments establish the successful implementation of the learning process. However, they do not ensure the effective design of the e-learning objects. The interaction between the environment for the design of learning objects repositories and the semantic web is needed [19]. A multifunctional platform is required for the design of different types of learning objects and to assure the effectiveness of the e-learning process implementation [21].

The existing developed multifunctional platforms of the e-learning objects do not [21]:

1. Ensure the effective design of ELOs and adaptation;
2. Ensure the process of ELO design and adaptation in the multifunctional environment;
3. Have an automatic search of ELOs on the semantic web, which is directly targeted to the specific objects in repositories of open educational resources;
4. Allow the adaptation of the already developed ELOs by automatically assigning reusable objects.

The object of this research is ELOs design and adaptation processes, multifunctional ELO environment that allows to effectively design new or adapt reusable ELOs.

According to the literature review authors identify the objective of the research—to suggest to teachers an effective e-learning objects design, automatic search and adaptation processes in the multifunctional environment by developing a platform based on semantic technologies for e-learning objects design and adaptation.

The scope of the present paper is to analyse the technological solutions related to the e-learning objects design and adaptation by attributing and reusing existing objects with similar content via the search on the semantic web.

2. Overview on Existing Practices

The theoretical multifunctional platform of the ELO design and adaptation is based on the learning paradigm, reusability of learning resources. The basis of the research methodology encloses the analytical, generalizing, constructivist and evaluative methods.

Semantic technologies are important in educational practice. They can be applied to area conceptualization and the educational systems. The educational semantic web is usually related to the practical implementation of the ELOs, where the use of standards is related to the annotation of learning objects. This creates many additional requirements for the successful use of standards. One or several technologies based on e-learning objects can be improved or adapted with new ELOs. Semantics-based resource recommendation is very important for personalized resource recommendation. One of the key issues in developing well-functioning practical personalized e-learning systems is related to the required complex ontological models. However, developing all the necessary ontologies for any intelligent education system is very labour-intensive, costly, and poses serious system interoperability problems [22].

There are many open educational resources in different open repositories (Udemy, OER Commons, Merlot, Khan Academy, etc.) that can be found online (http://roar.eprints.org/, accessed on 4 January 2022), though, for many teachers, it is a challenging task to find a useful ELO in the existing repositories. Three processes of the ELO: namely design, search, and adaptation, are further discussed in the paper.

There are many models for the ELO design presented by different authors, for example, the Verbert and Duval model [2], the Meyer model [3], Boyle model [6], the Santiago and Raabe integrated model [7], Learn activity content model [2], NETg MO model [8], BNTOPM model [23], Navy content model [2], and ALOCOM model [24].

The authors [9,25–28] analyse the design of learning objects based on pedagogical practices in the semantic web as well as search on the semantic web has been analysed by many authors, however, we could not find the platforms where search and adaptation are integrated into the multifunctional environment. The authors [11] discuss the issue of learning to recognize objects by retaining other factors of variation. The authors [12] analyse the problem of the search for interdisciplinary learning objects. Other authors [13,14,29] consider the use of agents to realize a federated searching of learning objects. Basuhail [30] suggests a method for designing learning objects using animation and computer graphics. The learning objects developed using this method are characterized by the reusability, and operability in the e-learning environment. Montoya et al. [31] present a method for creating interactive learning objects to teach students to solve problems using data mining techniques.

Meanwhile, the use of technological devices is a trend in people's lives in many fields [32]. Particularly in educational settings, when real and virtual learning environments are combined with computational support, they can be called Ubiquitous Learning Environments (ULEs). When associated with multimedia capture systems, ULEs can automatically generate documents that reconstruct the experiences taking place on them (e.g., lectures) for later use and review, preventing users from losing any important point while making notes, etc. Technologies offer many ways through interaction with multimedia and through communication and collaboration with peers [33]. Learning occurs in a dynamic and ever-changing environment by using advanced mobile technology. In this way, the surrounding observations can be detected, which ultimately allows for the development of adaptive learning content [34]. Technologies can be used to foster different pedagogical approaches, which can be characterized as associative, constructivist, situative and connectivism [35]. The key limitation of handheld technology for the delivery of learning objects is the small screen that is available for effective display. The smallness of the screen does not only adversely affect the clarity but also negatively affects the acceptance and integration of this potentially useful technology in education. Study [36] investigated characteristics of effective design of learning objects on such devices, reporting user response to learning object design possibilities for mobile devices. Three sets of design recommendations can be distinguished [37]: design presentation of conceptual models, small screen design, and design in relation to specific learning use.

The role of the teacher himself/herself has changed over time, as well as a significant increase in the availability of teaching and learning materials. When e-learning is used, teachers can act as course developers and facilitators, guiding learners through their learning experience. The variety of learning resources available on the web and the flexibility of modern learning management systems can allow teachers, who meet remotely, or find difficulties to meet, to share methodological approaches and learning content, giving them more opportunities through digital technologies [38]. Aspects such as the involvement of teachers and their activities in the e-course, the attitude of students towards the subject and the acceptance of technology have a positive impact on e-learning [39].

Most universities are using various elements of distance learning. The authors [40] explored the possibility of creating an internal repository of university teaching materials for university staff. The paper finds a significant gap between the needs of the technical team to describe learning objects using metadata for the smooth management of learning objects and the needs of academic teachers, for whom the didactic efficiency of the objects is paramount. The creation and management of learning objects using technical repositories must be straightforward. Research and teaching staff should only have a few essential metadata fields visible and filled. Professionals should complete the rest [40].

The authors [22] point out that one of the key issues in developing well-functioning practical personalized e-learning systems is related to the required complex ontological models. To solve the problem, the authors suggest using previously created ontologies collected in the ontological library for e-learning. In this case, researchers should preserve the ontologies created as part of research projects, describe them, and offer valuable mappings to other related ontologies in the library.

The authors [41] discuss possible solutions to the problem of searching for objects of a single topic in learning repositories and suggest that the issue of searching for data in the learning repositories may be solved by applying text-mining algorithms. In addition, methods based on deep learning are being actively developed as they can improve the quality of data search by extracting new characteristics and metadata [42].

After instructional designers, instructors, and learners discover LOs from a digital repository, the next step is to integrate the retrieved LOs into their learning projects. However, the adaption process is not always smooth. Common challenges are system/software dependency, as well as language and culture-related content issues. For example, the lack of availability of an object in the desired language can cause adaptation issues [43]. The problem of recommending learning objects to a group of users or instructors is more difficult than the traditional problem of recommending to only one individual. To resolve this problem, a collaborative methodology was proposed for searching, selecting, rating and recommending learning objects [44]. Lubega et al. [45] propose that the reusability of learning objects with different format assets can be improved by adapting at the asset level. In this case, asset level adaptation can be achieved using RLO decomposition, RLO asset adaptation, and then RLO asset assembly. Some authors [46,47] discuss RLO as a blended learning tool that can extend traditional teaching methods. The research shows that students' academic assessments are likely to increase as RLO is used more frequently [46].

Earlier research have not discussed the technological aspect of the ELOs adaptation in the multifunctional platform. However, the adaptation of ELOs interface based on learning style has been analysed by Carvalho da Silva et al. [15].

The literature review shows that a multifunctional platform is needed to assure reusability, adaptation, the search of existing objects. The main question is how to integrate newly designed objects with already existing objects of similar content.

3. Methodology

3.1. Research Design

The research is developed on the constructive research approach consisting of six phases by identifying a practically relevant problem, obtaining a general and comprehensive understanding of the research topic, constructing a problem solution idea, demonstrating that the solution works, showing the theoretical connections and the research contribution of the solution concept and the evaluation of the scope of applicability of the solution.

We used the most common computer science research method to implement our research. This type of approach demands a form of validation that does not need to be quite as empirically based as in other types of research like exploratory research. According to the constructive research methodology we used "construct" being developed analytically against some predefined criteria or performing some benchmark tests with the prototype (Figure 1).

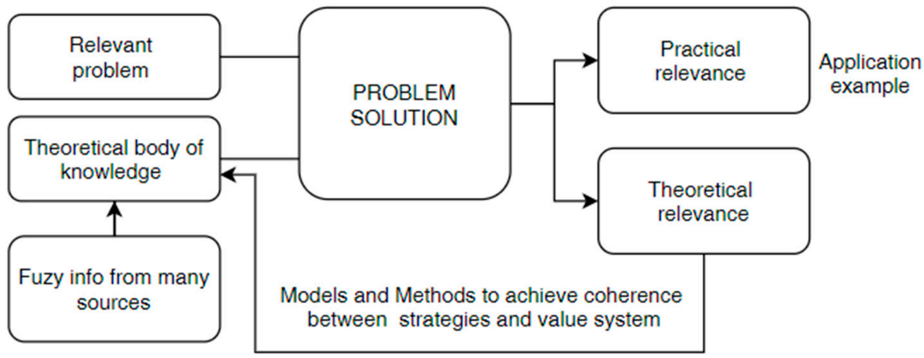

Figure 1. Constructive research methodology.

The authors used a systematic review of the related research works and analytical research methods as used for revealing the advantages of the educational platform and for raising issues, related to the ELO design, search and adaptation. Descriptive research was used to explain the developed model and architecture of the multifunctional educational platform.

An expert group, consisting of seven experts, was invited to evaluate the platform functionality based on three processes. These experts were chosen based on their competencies and educational platform experience. The quality of experts assessed acted as a general indicator of the objective and subjective status or the coefficient of compatibility.

3.2. Ethics

This research is implemented according to the ethical requirements of the organisation related to open science. GDPR data are protected and are not provided for open distribution. The experts also were registered users in the multifunctional educational platform, however we anonymised data for using in the research by indicating experts from E1 to E7. All participants who completed the evaluation survey were experts in e-learning having over 10 years of experience in technology-enhanced learning and have been informed of the purpose of the survey via the website and experts expressed.

3.3. Data Collection

Data collection took place in 2021 and updated in 2022. A total of three groups of the questions were presented for experts related to the (1) modelling efficiency of technologies in an integral way, (2) learning objects design time effectiveness, (3) modelling functionality effectiveness.

3.4. Survey

The online survey was developed using Google sheets and it took approximately 15 min to complete. Multiple questions and open questions were used in the evaluation process. The qualitative data focused on the overall impression, knowledge change and the effectiveness of the educational platform. The data of the survey were analysed according to the Likert scale. The aim of the survey is to evaluate established model effects and conversions provision of e-learning design processes.

3.5. Focus Group

In total, seven experts were invited to evaluate the educational platform (https://oer.ndma.lt/lor, accessed on 1 February 2021) where the model was integrated. By using user-centred design approach, a model for the experts of the focus group was presented, and they also expressed their opinion about the platform in general and the model integrated as well as interface. An expert report is the summary of the opinion of the expert group. The evaluation of special expert skills in the field has been required. Experts can be a source of qualitative information, and the quality of experts is assessed as a general indicator of the objective and subjective status or the coefficient of compatibility.

The requirements for experts: ELO design experience (at least 5 years); ELO delivery experience; scientific articles related to the ELO topic; made presentations about ELO in international conferences (at least two); ELO assessment experience (at least 5 years), experience working in a virtual learning environment.

The expertise of the seven experts groups is used. There were requested expert skills in a certain field, an expert can be a source of qualitative information, and the quality of experts was assessed as an objective and subjective status summary indicator or coherence factor: (1) where η is number of evaluation and η max is the maximum possible number of conflicting evaluation reports. The number of experts was chosen according to the classical theory, which states that the reliability of aggregated solutions and the number of experts are related to the factor determining the effectiveness of the study [48].

The methodological assumptions formulated in the classical test theory, which states that the reliability of 100 aggregated decisions and the decision-making on the chosen number of experts are related by a nonlinear relationship, were used to determine the required number of experts. Research has shown that the accuracy of seven expert group decisions and assessments is not inferior to that of a large expert group [48].

The highest percentage of reliability is obtained with the evaluation of at least 7–10 experts, then the percentage of reliability changes very insignificant; therefore, ten experts were invited to evaluate the model.

Totally three groups of questions were provided to expert for evaluation of the model, to evaluate (1) Modelling efficiency of technologies in an integral way, (2) learning objects design time effectiveness, (3) modelling functionality effectiveness.

3.6. Main Findings

The existing multifunctional platforms of the e-learning objects (ELOs) design do not ensure the effective development and adaptation of ELOs. Teachers and instructional designers need a multifunctional environment with the integrated automatic search in the semantic web, which directly targets the specific objects in the repositories of open educational resources. There are many existing open resources, but they are becoming too old and some adaptation or improvement is necessary before using them in practice.

A systematically consistent multifunctional platform for the design, search and adaptation of ELOs is based on learning objects life-cycle experience and provides the opportunity for teachers to effectively develop and adapt the ELOs [49]. The developed architecture of the multifunctional platform based on three processes (i.e., design, search in the semantic web, and adaptation), may effectively form ELOs. It may enable the unification of ELOs.

4. Results

4.1. Development of the Technology for ELOs Design, Search and Adaptation

To develop a multifunctional platform, the following essential steps—planning, design and search on the semantic web and adaptation phases—must be performed [50]. Different ELOs could be planned and developed using open source tools and tools for organizing different learning activities, including semantic web technologies. The following technological requirements of the multifunctional platform are directly related to the functionality of the multifunctional platform:

1. To meet the requirements for reuse;
2. To describe the structure and functionality of the original e-learning object so that it is suitable for any other ELO;
3. To meet the requirements of integrity (content and pedagogical requirements) and compilation;
4. To be based on the concept of variability, presentation and process management of the ELO;
5. To describe the structure of the ELO in such a way that it does not make it difficult to realize the main attributes of the multifunctional platform paradigm (individuality of learning, communication and discussions, self-control, etc.);
6. The multifunctional platform implementation process should be simple and must be repeated by other users (i.e., educators, instructional designers);
7. Technologically, the multifunctional platform should support the following option of the process control: reading, displaying, recording, modifying, commenting, giving feedback, reusing and communicating;
8. The multifunctional platform should ensure technical implementation of the listed tasks;
9. The integration and implementation of the multifunctional platform must be supported by available tools;
10. The multifunctional platform could be verified by analysing at least a few options.

According to the mentioned requirements, authors developed technological specification of the learning environment. The model does not work without the learning environment, which is developed by using Drupal open source content management system, which is used as also as OER repository. Moreover, we planned H5P solutions for interactive content design and adaptation, however, OAI-PMH Harvester for learning objects search in the open external repositories. EMO search in the semantic net is very important but in the model, the link to the semantic search network will continue to be distinguished from the creation and adaptation of the environment. The analysis and specification of the requirements are planned (Figure 2).

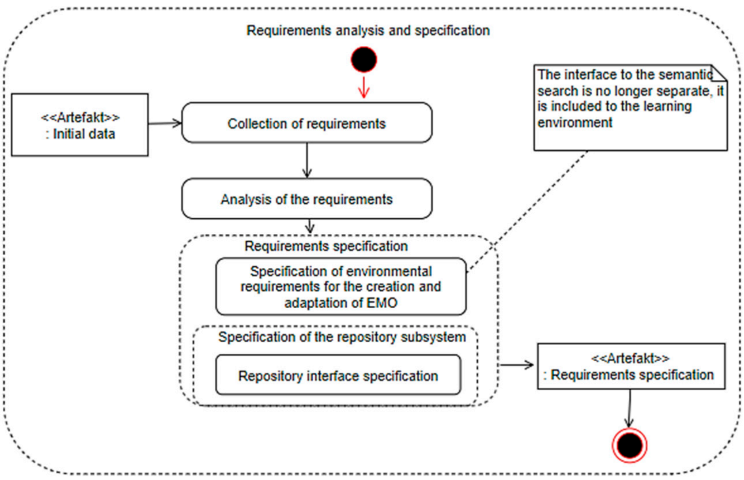

Figure 2. Requirements analysis and specification.

The authors used the Drupal open source content management system (7.63 version, The Drupal Association, https://www.drupal.org/, accessed on 5 January 2021) to develop a platform for open resources (https://oer.ndma.lt/lor, accessed on 1 March 2022). There are many modules used in the system; however, we provide some custom modules directly related to the search, design and adaptation processes that are in the scope of our paper. Moreover, that is done through the configuration and description of the content fields. The main Drupal module H5P Editor (h5peditor) is used to create interactive content or to adapt and redesign already existing interactive learning objects. This content is created as Content types and a description in the following fields (Table 1):

Table 1. Content types and a description.

Label	Machine Name	Field Type	Widget
Title	Title	Node module element	
H5P Action	h5p_type	Choose whether to upload or create/edit content	
H5P Upload	h5p	Upload interactive content	
H5P Editor	h5p_editor	Create or edit interactive content	
Subject	field_subject	Term reference	Select list
Abstract	body	Long text and summary	Text area with a summary
Language	field_language	Term reference	Term reference tree
Media Format	field_media_format	Term reference	Select list
License	field_license	Creative commons	Radio buttons
Repository	field_repository	Term reference	Select list

ELOs consist of semantic interfaces and an automatic search, which make it important to describe content elements and the semantic interface for object identification for specific keywords. The framework for the design of ELO and their adaptation based on three processes, namely design, search, and adaptation, is shown in Figure 3.

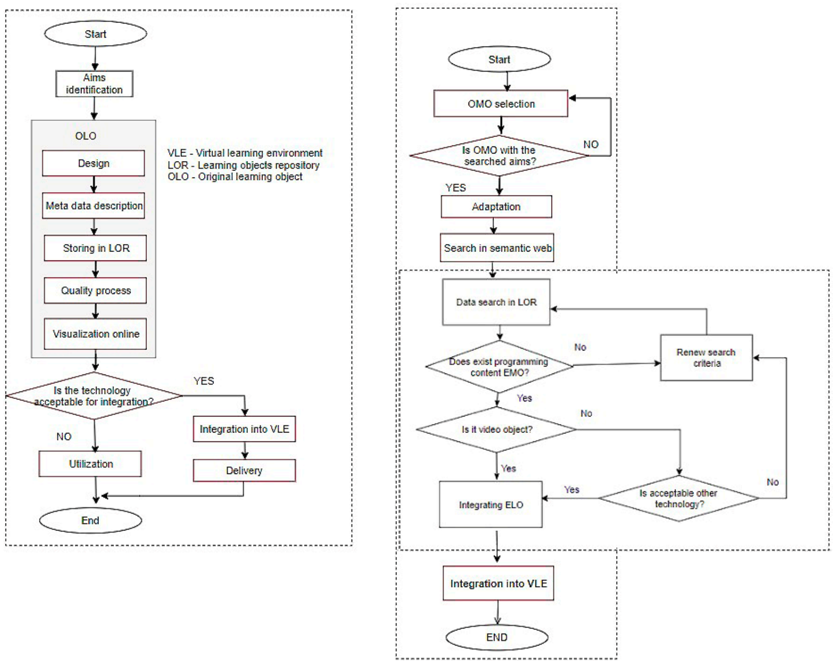

Figure 3. ELOs design, search and adaptation in the multifunctional platform.

The multifunctional platform (Figure 3) has been developed under the lifecycle implementation method. It is systematically consistent and based on the concept of the ELO life cycle. The multifunctional platform will ensure the quality of ELOs, apply the knowledge accumulated on the semantic web, save time for development and maintain a consistent development process starting with the specification of the ELO.

It is important to take into consideration three main processes (design, search and adaptation) and participants that make up the entire ELO design process. Among instances of the use of the repository, the <<include>> case aggregation and the aggregation relationships may be considered. <<include>> connection means that the use case consists of certain necessary instances of reusability (Figure 4). Moreover, figure shows three main processes (1) search design, (2) design and (3) adaptation. The ELO catalogisation in the platform is directly related with search by OAI-PMH Harvester and storing in the repository. The other case shows that ELO can be adapted if the copyright license allows, or it was developed by the author-developer. The third point is important for not only adaptation of learning objects but also new ELO design in the platform. There are many tools for interactive ELO design provided in the platform, that teachers or instructional designers can freely use.

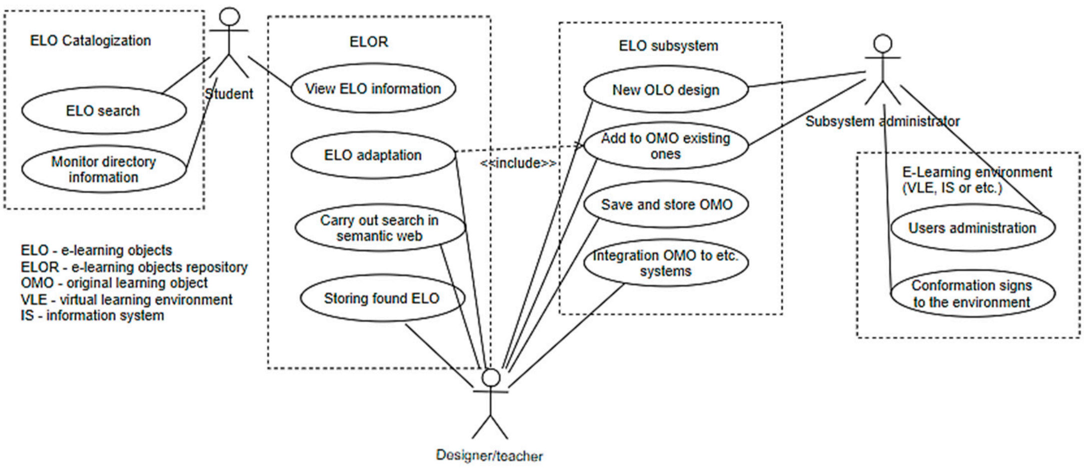

Figure 4. Use case diagram on the ELO design and adaptation on the platform.

The multifunctional platform has been implemented through the integrated multifunctional environment. The multifunctional platform is based on three processes, namely, design, search in the semantic web and adaptation (Figure 5).

Search for the ELO in the semantic web is very important, but on the multifunctional platform, the link to the semantic search network will continue to be distinguished from the creation and adaptation of the environment (http:/oer.ndma.lt/lor, accessed on 1 March 2022).

The multifunctional platform for the ELO design, their search and adaptation based on semantic technologies that allow for the effective ELO design and reusability is shown in Figure 5.

Figure 5 shows how ELO can be used in the platform for delivery process as this can be directly related with the learning process as well, where the existing resources of the topic can be added as extra material from external repositories to the general learning content. Moreover, the processes integrated into the platform and learning objects could be used in the integrated services or as personalized system services.

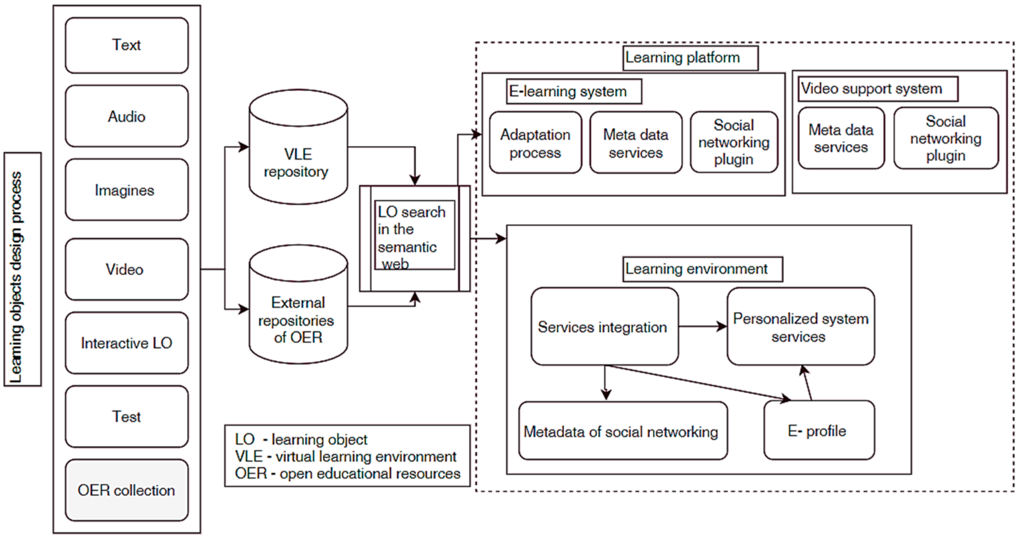

Figure 5. ELO design, search and adaptation.

The multifunctional platform for the ELO design and adaptation (Figure 5) enables e-learning, search in the semantic web as well as the integration into different learning environments, regardless of their origin and type by saving time for design to a minimum, it also integrates ELO into a variety of learning environments and different repositories.

4.2. Educational Platform Implementation

Learning objects can be developed or adapted in the educational platform and also can be integrated into already existing learning objects. The expanded menu can be used to choose the object one would like to create. Another possibility is to upload files and insert interactive learning objects, so the user can choose what object to create. After clicking any of these buttons, the user is given further instructions on creating that particular object according to the need. Newly developed learning object can be uploaded to the repository and can be found by other users. It is important to describe and to provide ELO meta data (a) in the repository to be more visible according to the new search (Figure 6b). On every creation website, on the right side, there is a brief description provided about the purpose of the chosen interactive learning object (Figure 6).

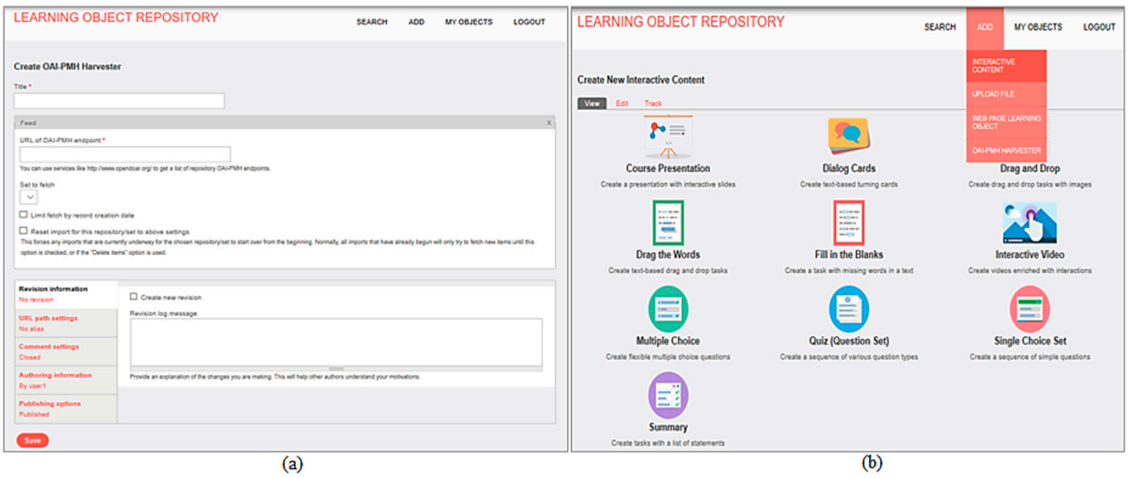

Figure 6. Multifunctional platform: (**a**) ELO search process; (**b**) ELO design and adaptation process.

However, for the adaptation process, there is an important ELO search in the external websites or repositories (Figure 6a). By choosing OAI-PMH Harvester users can upload learning objects from other websites that are protected, by inserting the website link. After inserting the link, learning objects are downloaded from the target website and uploaded to the local website with a technological possibility to adapt (Figures 6 and 7) (http:/oer.ndma.lt/lor, accessed on 1 March 2022).

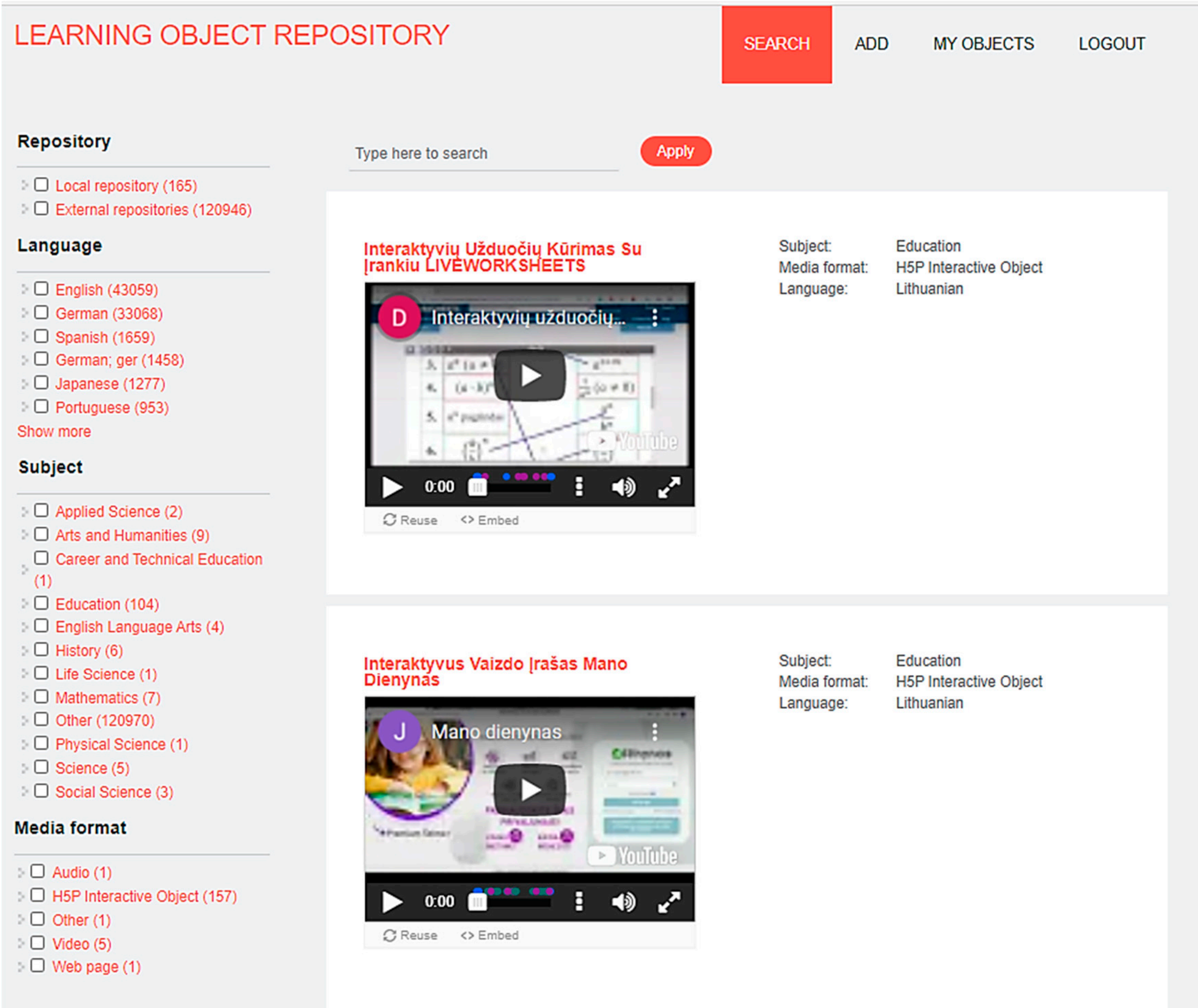

Figure 7. Multifunctional platform based on search, design and adaptation processes.

Figure 7 shows the interactive video object designed by using video and integrated H5P assessment, which assures more effective and engaging learning process. For the evaluation of the effectiveness of the multifunctional platform, expert analysis has been conducted.

5. Results of Expert Evaluation

The aim of this evaluation process is to validate the developed multifunctional platform. The effectiveness of the multifunctional platform based on semantic web technologies has been evaluated.

An expert report is a summary of the opinion of the expert group. The evaluation of special expert skills in the field was required. Experts can be the source of qualitative information, and the quality of experts is assessed as a general indicator of the objective and subjective status or the coefficient of compatibility:

$$k = 1 - \frac{\eta}{\eta_{max}} \quad (1)$$

The number of controversial evaluations by one expert is identified as η, however, η_{max} is identified as the possible maximum number of controversial evaluations.

The main criteria for evaluating the multifunctional platform are the following: (1) accessibility and usability, (2) efficiency, (3) effectiveness and (4) functionality and importance of functions.

Before the interview, the multifunctional platform of the ELO design and adaptation was presented to experts. Then, after describing the evaluation criteria and meaning, experts were interviewed. The evaluation process was performed regarding the following features: (1) accessibility and usability, (2) efficiency, (3) effectiveness and (4) functionality and importance of functions by multicriteria design-making methodology using five Fuzzy uncertainties. The experts were asked what activities have been considered to be priorities in creating ELOs and if the integration is important in the multifunctional platform. Experts used values: Not important at all "VN"; Not important "N", Partly important "TS", Important "S", Very important "LS" (Figure 8).

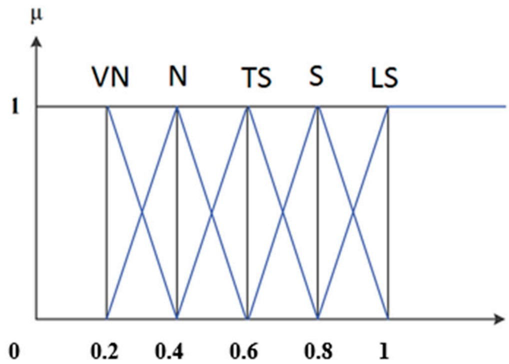

Figure 8. Fuzzy variable values for interfaces.

The criteria for the multifunctional e-learning objects design and adaptation on the multifunctional platform are equally valuable and their values are s_i, where i = 1, 2, . . . , m, and $\sum_{i=1}^{m} s_i = 1,\ s_i > 0$. The metrics of the criteria are subjective, i.e., under the methodology of multi-criteria they are converted to the uncertain triangle numbers (Table 2).

Table 2. The conversion of the linguistic scale into uncertain numbers.

Element of Scale	Fuzzy Numbers
Very important (LS)	(0.8; 1.0; 1.0)
Important (S)	(0.6; 0.8; 1.0)
Partly important (TS)	(0.4; 0.6; 0.8)
Not important (N)	(0.2; 0.4; 0.6)
Not important at all (VN)	(0.0; 0.2; 0.4)

For further steps, the Fuzzy method and the meaning of uncertain triangle numbers are used for the evaluation process: LS—1.0, S—0.8, TS—0.6, N—0.4, VN—0.2. However, the linguistic numbers are replaced by their numerical values (Table 3).

Table 3. Results of the evaluation based on the Fuzzy method.

No.	Criteria	Index	Numerical Values of Experts Evaluations							Mean (v_j)
			E1	E2	E3	E4	E5	E6	E7	
1	The reach and availability of ELOs	0.25	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.97
2	The productivity of the ELOs design and adaptation process	0.25	1.0	1.0	1.0	0.8	1.0	0.8	0.8	0.91
3	The effectiveness of external means for ELOs design and adaptation	0.25	0.8	0.8	1.0	1.0	1.0	1.0	0.8	0.91
4	The functionality of the ELOs in the platform	0.25	0.8	0.8	0.8	0.8	0.8	1.0	1.0	0.86

In this case, the evaluation indexes of all experts are the same (all the weights are equal), s_i = 0.25. The arithmetic mean of each criterion from the experts' evaluation is calculated (v_i). Later on, the total evaluation of the quality of the multifunctional platform is calculated, which is described as the function $f(X)$. Considering that all indexes of the criteria (s_i) are equal to 0.25: $f(X) = \sum_{i=1}^{m} s_i v_i$, after applying the formula, we got:

$f(X) = 0.25 \times 0.97 + 0.25 \times 0.91 + 0.25 \times 0.91 + 0.25 \times 0.86$. According to experimental evaluation results, the efficiency of the multifunctional platform reaches 91.2%.

During the evaluation, we found that the semantic web ensures the openness of ELOs and the usability of knowledge in different forms, seeing adaptations of the learning objects and semantic web annotations based on the semantic web technologies. The advantage of the multifunctional platform is that the tools for the development of ELOs are integrated into one system or learning environment, where the designers of ELOs can develop different technology-based activities for students (tests, questionnaires, exercises, etc.).

The multifunctional platform's novelty and the aim are automated search of ELO's, related to educational content in the semantic web, i.e., in other databases, in the repositories of learning objects and their attribution to the newly developed ELOs.

6. Conclusions

Updating and reusability of existing ELO are some of the challenges for teachers and instructional designers. Changing technologies and applications give a possibility for improvement and updating. Pedagogical and technological changes are very important for many ELOs, existing open online. Some fundamental methodology is not changing that fast. Nevertheless, the technologies we use in the educational process are changing fast, and our ELO should be very mobile to allow teachers and instructional designers to move ELO to the different educational environments without any loss.

After the literature analysis, we can conclude that the existing multifunctional platforms of the e-learning objects (ELOs) design do not ensure the effective development and adaptation of ELOs. There is a need to develop a multifunctional environment with the integrated automatic search in the semantic web, which directly targets the specific objects in the repositories of open educational resources.

The systematically consistent multifunctional platform for the design, search, and adaptation of ELOs is based on learning objects life-cycle experience. It provides the opportunity for teachers to effectively develop and adapt the ELOs.

The developed architecture of the multifunctional platform based on three processes (i.e., design, search in the semantic web, and adaptation) might effectively form ELOs. In addition, it might enable the unification of ELOs.

The process of validation and verification of the multifunctional platform shows the effectiveness of the platform. During the experiment, it has been observed that the semantic web ensures the openness of ELOs and knowledge in usability of different forms, considering modifications of the learning objects and semantic web annotations, based on the semantic web technologies.

At the moment, we are focusing on the AI solutions in the educational platforms that could help teachers to develop and personalise content in the most appropriate way.

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