PRINT: ISSN 0972-0073 ONLINE: ISSN 2456-6802
Anthropologist, 17(3): 883-893 (2014)
DOI: 10.31901/24566802.2014/17.03.21

# A Framework for Web-Based Learning Object Repository in Computer Engineering Education

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**KEYWORDS** Metadata. Computer Engineering. Learning Object Repository. E-learning

**ABSTRACT** Innovative approaches have enhanced and increased the importance and quality of engineering education. In this context, using new techniques and software provides flexible and effective results. In this paper, a web-based educational learning object repository (LOR) software tool, namely *Süleyman Demirel Üniversitesi Nesne Ambari (Sdunesa)*, was developed for computer engineering education. This software uses a developmental research method, which is also a derivative of the design-based research method. The developed web-based educational *Sdunesa* tool is used to store and share learning objects (LO) and their metadata. Moreover, the developed software tool is metadata independent by the help of metadata conversion engine and Extensible Markup Language (XML) web services. To achieve these features, the *Sdunesa* tool was developed with web 2.0 technologies. *Sdunesa* is dedicated to the computer engineering field. Qualitative and quantitative research analyses of the software are applied to the students and instructors for evaluation purposes and to demonstrate that the developed software is beneficial for computer engineering education.

## INTRODUCTION

In recent years, according to Khalifa and Lam (2002), the preparation and presentation of educational content issues have been undergoing major changes in engineering education to support face-to-face training and web-based learning. Hoe and Woods (2010) stated that in engineering education, to make teaching resources more efficient and to enhance the intrinsic motivation of students for learning in many parts of the world, organizations, companies and higher education institutions are making great efforts the use of LOs and use a significant amount of financial resources for the integration of LOs to their e-learning systems. These studies exist to establish an e-learning system used in engineering training, out of computer demand and other requirements motivated to achieve the desired results, the web based system requires a significant amount of time to produce the desired results (Violante and Vezzetti 2012; Tseng and Kuo 2013). Therefore, web 2.0 technologies provide new solutions to educate a massive number of students in a short and effective manner (Usluel and Mazman 2009; Amescua et al. 2010; Barak and Ziv 2013; Millard et al. 2013). Sandars and Schroter (2007) explained that wikis, social networking sites, blogs, video sharing sites, hosted services, and user interactive web sites are some of the examples of web 2.0 technologies. To develop these web 2.0 applications, XML and Service Oriented Architecture (SOA) web services, Asynchronous JavaScript and XML (AJAX) and JavaScript client-side technologies can be used. By using those technologies and methods, Feisel and Rosa (2005) recommended that learning environment software such as web-based learning environments, web-based laboratories and LOR software tools can be developed for engineering education. LORs include LOs that can be stored, searched by keywords and reused according to the content of the course in the LORs (Han et al. 2008; Baki and Cakiroglu 2010). LOs have also been referred to as content objects, educational objects, information objects, knowledge objects, learning resources, media objects, and re-usable learning objects (Harman and Koohang 2005; Sinclair et al. 2013). Therefore, a LO can include anything that has pedagogical value, digital or non-digital such as a case study, a film, a simulation, audio, video, animation, graphic images, a map or a book, so long as the object can be con-

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textualized by individual learners (Harman and Koohang 2005; Zapata et al. 2013). Imsglobal (2003) indicated that learning object repositories used in engineering education and training systems hold fundamental features. These features are searching and finding LOs, controlling quality of LOs, submitting and retrieving LOs, storing and maintaining LOs.

According to these features, there are several LORs in engineering education. Their purposes change according to the diversity, disciplines and the quality of the learning content. For instance, Amescua et al. (2010) developed a knowledge repository for software engineers to improve learning skills. In this repository, the best software practices that are obtained from a wiki as a web 2.0 technology are stored. Cebeci et al. (2007) developed LOR software called Turkey Agricultural LOR (*TurkOnde*). TurkOnde, which has LOs related to engineering areas including the disciplines of food, veterinary science, agriculture, the environment, and forestry, is used by both instructors and students. Hoe and Woods (2010) developed a LOR for first-year engineering students that focuses on basic digital system courses. Various problems exist regarding the waste of time related to the understanding and the implementation of logic circuits in this course. A LOR is used in order to prevent these problems and thus the education of this course is implemented effectively. In another paper, Lau and Mak (2005) developed Interactive Multimedia E-Learning System (IMELS), which is a configurable system for industrial engineering. IMELS aims to expose students to a learning environment, which is seemingly full of complex case problems incorporated in a highly authentic context. Santos et al. (2011) developed a LOR that is based on the Eduse Research Strategy to support software engineering in terms of collaborative and distributed learning environments for software engineering experts and students. Nascimento et al. (2013) developed innovative repository (IRepository). IRepository is system independent and can be integrated with Moodle environment to support engineering education. In another paper, Zapata et al. (2013) developed a LOR for civil engineering students. Barra et al. (2014) developed virtual science hub which is a LOR for teaching science and engineering in social networks. Pyrounakis et al. (2014) indicated that DSpace, Fedora, Greenstone, EPrints and Invenio are open-source LORs that can be used for engineering education. Previous efforts in engineering fields show that LORs are beneficial for engineering education. Consequently, in this paper, a web-based *Sdunesa* LOR was developed for computer engineering education, in light of the priorities and preferences of the field.

The paper is structured in the following manner: Section 2 presents methodology; Section 3 presents the evaluation results; Section 4 discusses paper results and compares existing LORs; Section 5 presents the conclusions and contributions of the paper; finally Section 6 presents recommendations.

## METHODOLOGY

In this paper, the developmental research method is used, which is a derivative of design-based research methodology. Brown (1992) stated that design-based research treats instructional design and learning tools. Moreover, Collins (1992) indicated that the design-based researches involve the stages of development and adoption, and ensure continuity of the information. Richey et al. (2003) explained that design-based research methods-derived developmental research is composed of two types; type 1 of these varieties focuses on a program or product, and type 2 can be described as focusing on the research process. In this paper, the learning object repository software was developed based on the type 1 research method. Moreover, using the type 2 research method, the developed *Sdunesa* LOR was evaluated by students and instructors in the computer engineering field to measure their perceptions about *Sdunesa* LOR. This paper was designed as a survey research in which questionnaire and interview methods were used. Two survey instruments were used to collect data. First, a semi-structured interview method was used to measure instructors' perceptions about *Sdunesa* LOR. Therefore, an interview with 12 instructors was developed in order to understand computer engineering education instructors' ideas related to *Sdunesa*. The interviews lasted approximately 10-15 minutes. There were four questions in the interview form. Based upon the data from the participants, the content analysis method was applied by the basic steps in the analysis and interpretation procedures of qualitative data analysis. Later on, participants' conceptual ideas and thoughts expressed in words

and appropriate codes were established. Using these codes, the interview data became simplified and summarized. Finally, based on the frequencies, the findings were interpreted and conclusions were drawn.

## General Description of the *Sdunesa* Framework

The developed system works over the internet in accordance with the objectives of LOs, which consist of applications to share and reuse over and over again. The fundamental aim of the developed educational tool is to prepare course content for web-based training easily, rapidly, and economically, for Suleyman Demirel University Faculty of Engineering Department of Computer Engineering. For this purpose, the system is composed of relational database applications, web applications, and XML web services.

The primary aims of the system are to store LOs and their metadata in the relational database and reuse them again and again if necessary. The users must register to the system in order to add objects and metadata to the LOR. Users can add objects and their metadata by metadata editor. There are two methods to add metadata to the system by using the *Sdunesa* LOR tool. The first is using the learning object resource file, which is an XML based metadata file. It is shown in Figure 1. If the user adds metadata to the system, the *Sdunesa* metadata tool parses this metadata to the IEEE (Institute of Electrical and Electronics Engineers) LTSC (Learning Technology Standards Committee) LOM metadata (LOM) or Dublin Core metadata (DC) standard. The other method is filling metadata fields such as general, life cycle, or educational (Fig. 2).

The system has three types of roles being administrator, expert, and member for authorization purposes. Membership requests shall be notified through web interfaces to the system; then users who have the administrator role examine these membership requests in order to allot one of the appropriate users a role as administrator, domain expert, or member. Given the role of the domain expert, the user is directed to a web page at the first login to specify the profession areas. After entering the information on this page, the user can start using the system. There are various powers for each user role in the system shown in Table 1. Operation of the system is provided with these different user powers.

LOs and metadata are loaded to the system via web user interfaces. Desired LOs and metadata can be accessed by list and search pages. In the system, metadata of the LO is formed by LOM editor, but any metadata format has been

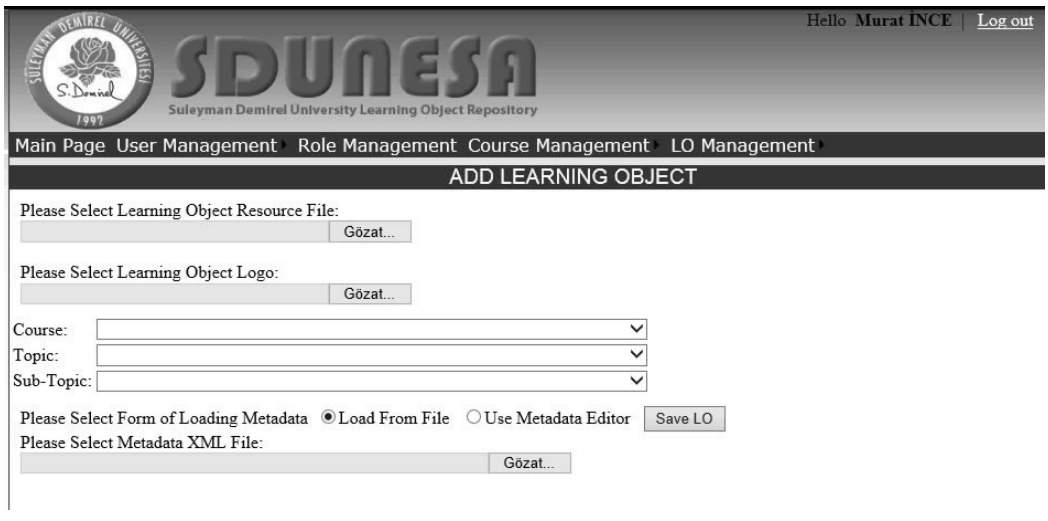


**Fig. 1. XML metadata file loading user interface**

**Table 1: Roles and powers in the system**

| *Powers* | *Administrator* | *Roles Domain expert* | *Member* |
|---|---|---|---|
| Log in-Log out | x | x | x |
| Join to system | x | x | x |
| User add/drop | x | | |
| User acceptance | x | | |
| Domain expert acceptance | x | | |
| Role add/drop | x | | |
| Object problem management | x | | |
| Object comment management | x | | |
| Object problem submission | x | x | x |
| Comment to object | x | x | x |
| Object adding | x | x | x |
| Object summary sighting | x | x | x |
| Object metadata sighting | x | x | x |
| Object metadata editing | | x | |
| Object quality control | | x | |
| Object searching | x | x | x |
| Object downloading | x | x | x |
| Lesson adding | x | | |

adopted as the XML-based file format. Users are able to see the learning objects and metadata; also they can download them to their local drives in the form of an IMS (Instructional Management Systems) package file. One of the features of LORs is that quality control of LOs in repositories is carried out by domain experts. The learning objects and metadata that are added to the system are presented for the control and approval of the domain expert. After making the necessary controls and editing on the LO and metadata by the domain expert, the objects and metadata are accessible to all users on the system (Fig. 3). Through XML web services that are included in the system, *Sdunesa* releases the LOs and metadata to other object repositories and obtains them from other repositories.

## Architecture of *Sdunesa*

The developed *Sdunesa* tool was prepared with multi-tier software architecture and object-oriented programming logic. The system consists of three horizontal layers being the presentation layer, business layer, and data layer. Moreover, in the system, there are vertical layers being the authorization layer, security layer, error layer, and other utility layers that are used by the horizontal layers shown in Figure 4.

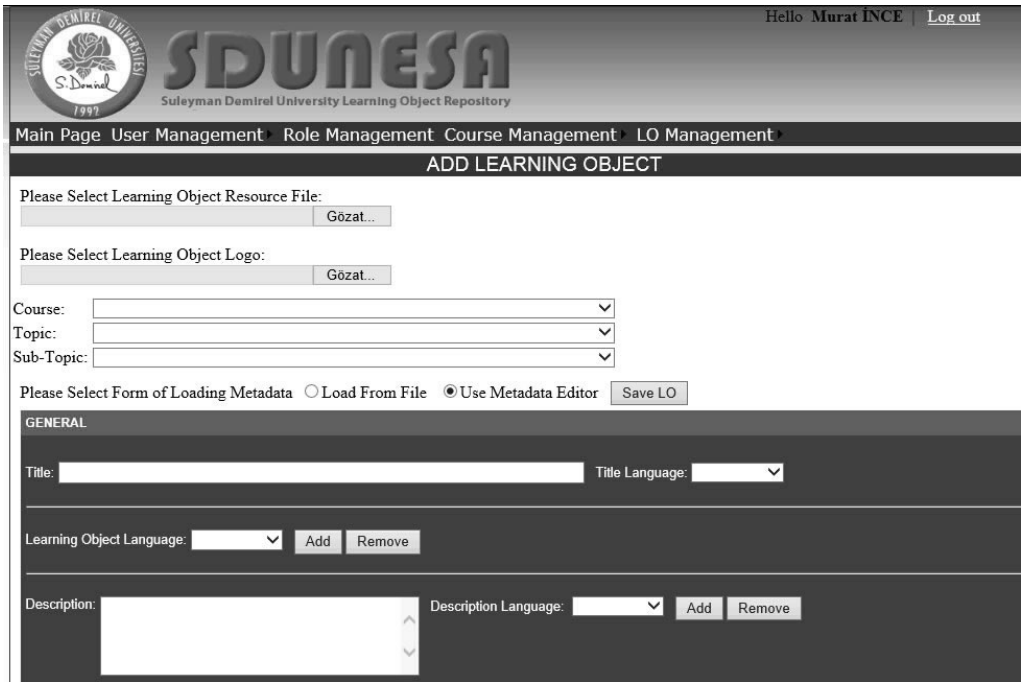


**Fig. 2. Metadata editor user interface**

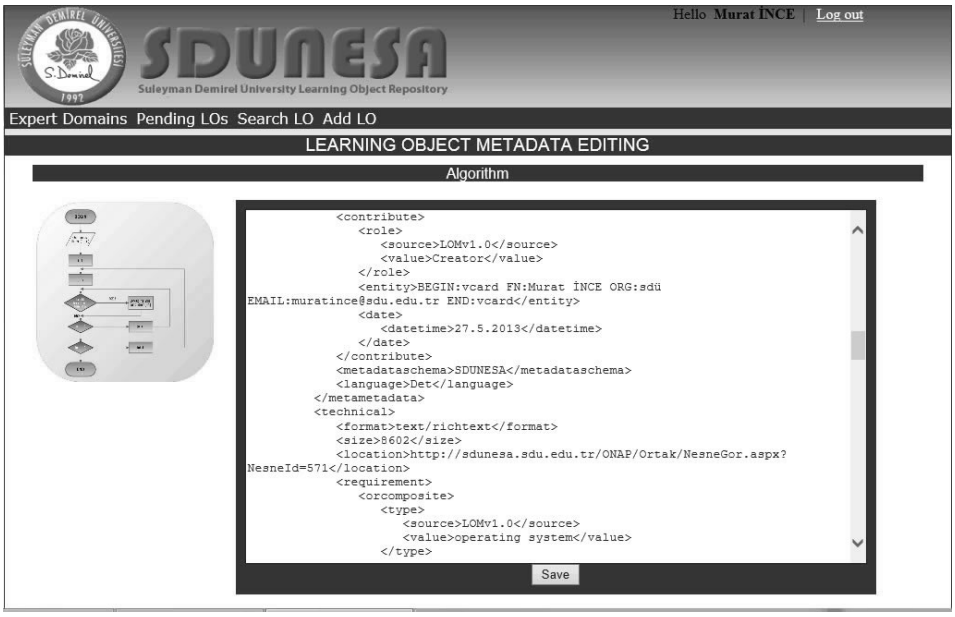


**Fig. 3. Metadata editing user interface**

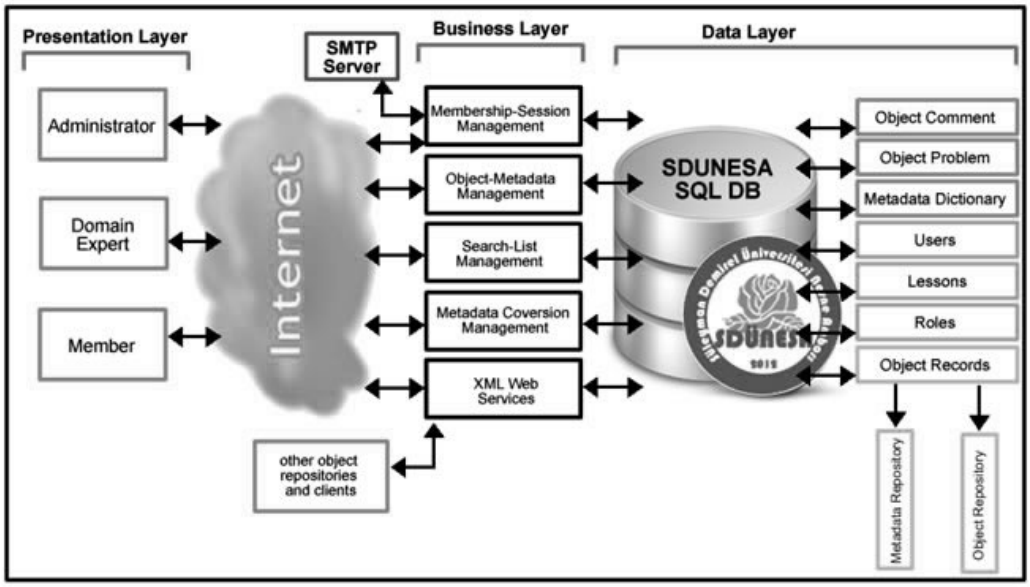


**Fig. 4. System architecture and components**

The multi-tier software architecture layers being presentation, business, and data layers have the components that are required for operation of the system. The presence of different layers provides for the easy and swift expansion of the system if desired. Presentation layer includes web pages that have been prepared by means of the ASP.NET, AJAX technologies

and C#.NET programming language. Users can login to the system and exit through these pages, report prompts such as adding, listing, viewing, and downloading via the Internet to the business layer. The business layer includes user-logged operations, adding, listing, viewing processes of objects, and metadata, as well as the business logic of the metadata conversion engine and XML web services. According to the requests from the presentation layer, the business logic layer processes requests, makes decisions, and transmits it to the data layer that uses the MS SQL Server. According to requests from the business layer, the data layer adds objects and metadata, comments for objects, problem notifications, users, roles, course, topic and subtopic matching, and metadata element dictionary to the database.

**Learning Object Data Model**

LORs are prepared for the purpose of storing LOs and the metadata providing information about the LOs. In order to obtain an effective result from LORs, the most appropriate and accurate way of marking LOs should be provided by metadata. Thanks to the metadata in LORs, LOs can be searched in a simple and rapid manner, and can be reused again and again. In addition, LO and metadata sharing can be provided with other repositories interoperable. For this purpose, standardization work has been done on the metadata and many standards have been developed. Selene (2003) reported that the most widely used metadata standards are DC and LOM.

The developed *Sdunesa* LOR software is based on the LOM metadata standard for learning objects, but also supports the DC metadata standard, as well as other metadata standards. In the system, the metadata conversion engine was designed to convert different metadata standards to each other. Therefore, the most widely used DC and LOM metadata can be converted into each other by the means of a metadata conversion engine. Imsglobal (2003) explained that the LOM metadata standard used in the system consists of nine categories and approximately 70 descriptive elements. The metadata standard used in the system is carried out easily by way of object-oriented programming and LOM metadata stored in an XML format.

**Content Packaging**

Cagiltay and Serce (2005) indicated that the preparation of a package that includes reusable, shareable, and distributable items is called content packaging. The content package includes the location of learning materials, and structure and descriptions of the metadata. Content packages that are packaged in compliance with the standards of learning can be used in course management systems and tools easily. Thanks to the content packaging standards, metadata and learning objects can be shared seamlessly and reliably between learning management systems. Imsglobal (2003) stated that the most widely used standard for content packaging is an XML-based IMS content packaging standard. This content packaging system is used in learning and training software such as Microsoft Learn and Webct. IMS packages consist of an XML file that defines physical resources of learning materials in an organizational structure. There are packaging tools such as Reload and Microsoft Learning Resource Interchange (LRN) for the purpose of arrangement of IMS packets, creation and viewing content. LOs and their IMS packages with zip extension can be downloaded from the *Sdunesa* LOR software. The downloaded version of this zip file consists of the physical source of the learning object, an XML file labeled imsmanifest.xml and files labeled ims_xml.xsd, imscp_v1p1p3.xsd, and imsmd_v1 p2p2. xsd, which are required for the verification of the XML file shown in Figure 5. The downloaded file can be used in learning management systems directly without any processing.

**Metadata Conversion Engine**

The developed system is based on the LOM metadata standard, but also can store any other metadata standard for LOs regardless of any standard. Different metadata standards are converted to each other according to metadata review requests from XML web services and LO metadata view interface on the presentation layer. Selene (2003) stated that the most widely accepted standards for learning object metadata are LOM and DC. The metadata conversion engine called MetadataConvertEngine includes the methods of MetadataLOMtoDC and MetadataDCtoLOM. The MetadataLOMtoDC method converts LOM metadata to DC metadata. Similarly, the MetadataDCtoLOM method converts DC metadata to a type of LOM metadata.


**Fig. 5. Content of IMS package**

## Xml Web Services

The *Sdunesa* LOR works with other LORs under the concepts of compliance and interoperability. Imsglobal (2003) defined four basic functions labeled making, sending, collecting, and publishing according to the interoperability standards of Instructional Management Systems Digital Repositories Interoperability (DRI IMS). These basic functions are provided through XML web services in the *Sdunesa* LOR software and should have been provided, thanks to the web service methods in the developed system shown in Table 2.

**Table 2: *Sdunesa* web service methods**

| *Web service method name* | *Web service method description* |
|---|---|
| AdvancedSearch | This method allows an advanced search on the developed object repository. The method returns a list of objects in a type of LOM metadata information. |
| BasicSearch | This method allows a simple search on a metadata. Method returns a list of objects in type of LOM metadata information. |
| ConvertDcMetadataToLom Metadata | This method provides a conversion from the Dublin Core metadata standard to LTSC IEEE LOM metadata standard. |
| ConvertLomMetadata ToDcMetadata | This method provides a conversion from the LTSC IEEE LOM Metadata standard to Dublin Core metadata standard. |
| DisciplineSearch | This method allows searching on the object repository according to lessons, topics, and sub-topics. The method returns a list of objects in type of LOM metadata information. |
| GetAllAltKonuListesi | This method returns the list of all subtopics under AltKonuObject in the system without any parameters. |
| GetAllDersListesi | This method returns the list of all lessons under DersObject in the system without any parameters. |
| GetAllKonuListesi | This method returns the list of all topics under KonuObject in the system without any parameters. |
| GetAllMetadataList | This method returns the list of all metadata that are approved by the domain expert that are LOM in the system without any parameters. |
| GetAllMetadataObjectList | This method returns the list of all metadata that are approved by the domain expert that are MetadataObject in the system without any parameters. |
| GetAllObjectList | This method returns the list of all metadata that are approved by the domain expert that are NesneObject in the system without any parameters. |
| GetAllSozlukGrupListesi | This method returns the list of all the dictionary group values that are MetadataSozlukGrupObject in the system without any parameters. |
| GetAllSozlukListesi | This method returns the list of all the dictionary values that are MetadataSozlukObject in the system without any parameters. |
| SaveObjectAndMetadataBytes | This method is used to add objects and metadata to the system and save them in the repository for later use. The given object and metadata bytes as parameters are saved to the system. |
| SaveObjectAndMetadataString | This method is used to add objects and metadata to the system and save them in the repository for later use. The given object and metadata string, as parameters, are saved to the system. |

## RESULTS

Qualitative and quantitative research analyses of the software are applied to the students and instructors for evaluation purposes and to demonstrate that the developed software is beneficial for computer engineering education. The first question of the semi-structured interview was, "According to you, which of the following are more effective? Place your responses in order: lessons, textbooks, laboratory experiments, distance education learning management systems, and learning objects." According to instructors' responses, textbooks and learning objects (which are in the learning objects repository) were of equal efficacy, as shown in Table 3. Lessons choice was ranked second, followed by laboratory experiments and distance education learning management systems, which were ranked third equally.

The second question of interview was, "According to you, for what purpose can a learning object repository be used?" Lecture notes had the highest frequency of response for this question according to participants as shown in Table 4. The instructors also suggested subject review, homework preparation, and distance learning education for learning object repository use. Also for distance learning education lesson content preparation usage was mentioned. It is determined that defined codes were corresponding to learning object repository aims.

The third question of the interview was, "According to you, what makes the learning object repository effective for students' education?" Access to information at any time was the most

**Table 3: Instructors' perspectives on a comparison of effective methods**

| *Code* | *P1* | *P2* | *P3* | *P4* | *P5* | *P6* | *P7* | *P8* | *P9* | *P10* | *P11* | *P12* | *f* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Textbooks | X | | | | X | X | | | X | | | X | 5 |
| Learning objects | X | | | | X | | X | | X | | | X | 5 |
| Lessons | | X | | X | | | | | | X | | X | 4 |
| Laboratory experiments | X | | X | | | | | X | | | | | 3 |
| Distance Education (LMS) | | | X | | | X | | | | | X | | 3 |

[1]P: Participant, f: Frequency

**Table 4: Instructors' perceptions on LOR usage areas**

| *Code* | *P1* | *P2* | *P3* | *P4* | *P5* | *P6* | *P7* | *P8* | *P9* | *P10* | *P11* | *P12* | *f* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lecture notes | X | | | | X | | X | X | | X | | X | 6 |
| Subject review | | | X | | X | | | X | | X | | X | 5 |
| Homework preparation | | X | | | | X | X | | | | X | X | 5 |
| Distance learning education | X | | X | | | X | | | X | | X | | 5 |
| Lesson content preparation | | | | X | | | | | X | | | | 2 |

[2] P: Participant, f: Frequency.

**Table 5: Instructors' perspectives on the efficacy of LOR on education**

| *Code* | *P1* | *P2* | *P3* | *P4* | *P5* | *P6* | *P7* | *P8* | *P9* | *P10* | *P11* | *P12* | *f* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Access to information at any time | X | X | | X | | X | | X | | | X | | 6 |
| Saving time when searching for lecture notes | X | | | X | | X | | X | | | X | 5 | |
| Studying for the examination | X | | X | | X | | | X | | | X | | 5 |
| Understanding the subject clearly | X | | | X | | | | | | X | | X | 4 |
| Increasing attention to the lesson | | X | | X | | X | | | | X | | | 4 |
| Subject review | | | X | | | | | X | | X | | | 3 |

[3]P: Participant, f: Frequency.

frequent response for this question. Additionally, saving time when searching for lecture notes and studying for examinations were highlighted as shown in Table 5. In addition, due to the system of learning objects (animation, simulation, video, etc…), the subjects of a lesson could be understood more clearly and attention to the lesson increased due to the diversity of the learning objects.

According to the interview with instructors, textbooks and LOs are the most effective learning methods. The most popular use of *Sdunesa* LOR is lecture notes, subject review, and homework preparation, respectively. Users can access information from *Sdunesa* whenever they desire. Moreover, *Sdunesa* saves the users time in accessing information and is also beneficial for studying for exams. Based upon the data from the findings of the interview results, a questionnaire survey was developed, which is a quantitative form of research analysis. The questionnaire consisted of seven questions that measured students perceptions about *Sdunesa* LOR software usage on a *Likert* scale (strongly disagree, disagree, undecided, agree, and strongly agree) (Appendix 1). Statistical data analysis (mean and standard deviation) was used to analyze the data collected from the questionnaire. The sample size was 47. According to the questionnaire survey results, *Sdunesa* LOR increases the motivation of the students to lessons (mean=3.68, standard deviation=0.95). Furthermore, *Sdunesa* helps students to understand subjects clearly. Other outcomes of the questionnaire are shown in Table 6.

**Table 6: Statistical analysis of the students' opinions about *Sdunesa***

| *Questions* | *Mean* | *Standard Deviation (sd)* |
|---|---|---|
| I can access information whenever I want with *Sdunesa*. | 3.57 | 1.281 |
| The *Sdunesa* saves my time to access learning resources. | 3.51 | 0.997 |
| I use *Sdunesa* for studying for exams. | 3.53 | 1.120 |
| I understand the subject clearly with the help of *Sdunesa*. | 3.61 | 1.054 |
| *Sdunesa* increased my motivation for the lesson. | 3.68 | 0.957 |
| I used *Sdunesa* for subject review. | 3.59 | 0.970 |
| *Sdunesa* is easy to use and user friendly. | 3.51 | 0.997 |

## DISCUSSION

There are several LORs that are used for different purposes based on the diversity and quality of LO contents. Cakiroglu and Akkan (2009) stated that MERLOT, CAREO, ESCOT, SHODOR, GEM and MIT are the some important LORs in the world. Sampson and Zervas (2014) developed a hierarchical open access LOR for general education and engineering education. Moreover, DSpace, Fedora, Greenstone, EPrints and Invenio are some open-source LORs that can be used for engineering education (Piedra et al. 2014; Pyrounakis et al. 2014). In another paper, Mobile2Learn LOR was developed by Zervas and Sampson (2013) to use LOs in mobile platforms. Mobile2Learn can be used for engineering education. Barra et al. (2014) developed virtual science hub which is a LOR for teaching science and engineering in social networks.

Although there are general engineering education LORs, also there are specific purpose engineering education LORs. For example, Amescua et al. (2010) developed a LOR for software engineering education. Another field specific LOR, *TurkOnde* has LOs related to engineering areas including the disciplines of food, veterinary science, agriculture, the environment, and forestry, was developed by Cebeci et al. (2007). Hoe and Woods (2010) developed a LOR for basic digital system courses. IMELS which was developed by Lau and Mak (2005), is a configurable system for industrial engineering. Another software engineering LOR was developed by Santos et al. (2011). Nascimento et al. (2013) developed IRepository to support engineering education. Furthermore, Zapata et al. (2013) developed a LOR for civil engineering students. When compared other LORS, the *Sdunesa* software is a specific LOR for computer engineering education but also can be used for other engineering fields related with programming courses. Moreover, the *Sdunesa* has internal metadata editor which provides flexible metadata creation and edition.

Although many LORs have an internal metadata editor, there are many external tools to manage and edit the metadata of LOs. Kyriakou et al. (2010) indicated that such metadata editing tools are LOM Editor, Reggie Metadata Editor, ALOHA II, Curriculum Online Tagging Tool, eRIB Metatagging Tool, Explor@-2, and LomPad. LOM Editor is a desktop application. It cannot export

metadata as an XML document. Similarly, eRIB and ALOHA II are not web-based and do not have web services. Therefore, working with these tools and accessibility of LOs from any location is not possible. Reggie Metadata Editor, Explor@-2 and LomPa support the most popular metadata standard, which is LOM. However, the Curriculum Online Tagging Tool is based on the CanCore metadata standard. Moreover, ALOHA II is also not based on LOM. Instead, it uses the IMS metadata standard. Although these tools have features to manage and create metadata, they are not integrated to a LOR and also are not metadata standard independent. However, the *Sdunesa* LOR software is metadata independent and supports LOM and DC metadata by the help of metadata conversion engine.

## CONCLUSION

The usefulness and effectives of LORs depends on organizing, categorizing, and storing the LOs properly, and also being interoperable with other LORs. The *Sdunesa* educational LOR software tool was prepared with multi-tier and object-oriented programming methods in order to meet any future expansion requirements quickly and easily. Compatibility and interoperability with other object repositories were achieved through the XML web services. One of the important contributions of the *Sdunesa* LOR software framework is metadata standard independence. By the metadata conversion engine, *Sdunesa* can convert metadata to LOM or DC. Moreover, if users do not desire any conversion, other metadata XML files (IMS, ARIADNE, CanCore) can be stored in the developed system as a raw XML file. Another contribution of *Sdunesa* software tool is that users can convert their metadata schema without login to the *Sdunesa* tool by using XML web service methods. IEEE LTSC LOM-based metadata editor tools have many fields (9 categories and approximately 70 elements) that must be completed by the user. Sometimes completing this metadata element may be time consuming. In order to prevent this situation, *Sdunesa* LOR software has a smart metadata adding module. Users can add metadata XML files to the system by browsing the metadata XML file from the file system and upload it to *Sdunesa*. The system parses this metadata and converts it to LOM or DC metadata schema according to users' preferences. If users do not want any conversion, metadata XML files are stored as their original type.

In addition to being prepared for use to provide content for all courses at Suleyman Demirel University Faculty of Engineering Department of Computer Engineering, *Sdunesa* is available for all courses based on material aided content. The web-based *Sdunesa* software was developed especially for computer engineering education; therefore, this LOR includes computer engineering education LOs in particular. Similarly, if LOs regarding different academic discipline are added to the *Sdunesa* software, it can be used to support learning and teaching activities. Moreover, not only does the computer engineering department employ this software, but also other engineering departments use *Sdunesa* for computer related courses. For example, the Introduction to Programming course is a mandatory course given in different engineering departments such as electrical-electronics engineering, industrial engineering, and chemical engineering. The *Sdunesa* software includes LOs for this course. Thus, students and instructors in different engineering departments can use these LOs. For these reasons, the *Sdunesa* is interdisciplinary engineering education software.

Consequently, quantitative and qualitative research analyses show that the innovative and educational *Sdunesa* LOR software tool is useful and beneficial for both students and instructors to enhance their learning and teaching activities, both individually and collaboratively. In the future, the developed framework can be enhanced with intelligent algorithms to obtain intelligent tutorial systems.

## RECOMMENDATIONS

Instructors, students and other users can use LOs in *Sdunesa* to develop engineering games, simulations; web-based remote and virtual laboratories, mobile education applications, and also 3D virtual environments. Moreover, users can make comments and share their preferences about LOs and metadata.

## ACKNOWLEDGEMENTS

The authors wish to thank Suleyman Demirel University Scientific Research Projects Management Unit Presidency that supported this project financially with project number 3183-YL1-12.

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