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CONTRIBUTION TO THE AUTHORING, DISTRIBUTION, EVALUATION AND INTEGRATION OF LEARNING OBJECTS

TESIS DOCTORAL

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Ingeniero de Telecomunicación

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Abstract

Learning Objects have emerged in recent years in the field of educational technology as a key strategy for creating and delivering digital educational resources. The fundamental idea behind them is that educational content can be broken down into small chunks that can be independently created and reused in different contexts and e-Learning systems.

Learning Objects are educational resources that aim to improve reusability in order to minimize production cost, save time and provide better learning experiences. Various benefits of using Learning Objects have been exposed by several studies that have examined their acceptance and effectiveness as well as their capacity to be reused. Nevertheless, and in spite of the immense amount of work done in this research field, there are still several barriers hampering the use and adoption of Learning Objects. To overcome these barriers and fully exploit the potential of Learning Objects, various challenges must be addressed at different stages of their life cycle.

This thesis encompasses the design, development and evaluation of various systems, metrics and models in order to address and overcome several of the main barriers that hamper the authoring, distribution, evaluation and integration of Learning Objects. Moreover, the use of Learning Objects in various educational environments is studied. The thesis starts with the identification of the main barriers that hamper the use and adoption of Learning Objects along the different stages of their life cycle. Thereafter, an e-Learning platform that supports the whole Learning Object life cycle is presented. Then, results of the design, implementation and evaluation of an authoring tool to create Learning Objects are reported. Next, the thesis presents the first system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. Furthermore, two new evaluation models and several new quality metrics for Learning Objects are proposed. One of these metrics is based on learning analytics and allows to estimate the quality of Learning Objects based on learners' interactions. This thesis also presents a hybrid Learning Object recommendation model for Learning Object Repositories and two recommender systems implemented based on this model. After that, three integration models are detailed: a model to allow e-Learning authoring tools to assemble Learning Objects by integrating and combining other ones, a model to enable the integration of Learning Objects into web videoconferencing services, and a model to integrate Learning Objects into web games in order to create educational web games. Afterwards, several projects and learning experiences in which different contributions have been validated are described. Finally, the thesis concludes with answers to the stated research questions, a summary of the main contributions and some suggestions for further research.

Resumen

Los Objetos de Aprendizaje se han erigido en los últimos años en el campo de la tecnología educativa como una estrategia fundamental para crear y distribuir recursos educativos digitales. La idea fundamental detrás de ellos es que el contenido educativo puede ser desglosado en pequeños trozos que pueden ser creados y reutilizados en diferentes contextos y sistemas de e-Learning de forma independiente.

Los Objetos de Aprendizaje son recursos educativos que pretenden mejorar la reusabilidad a fin de minimizar el coste de producción, ahorrar tiempo y proporcionar mejores experiencias de aprendizaje. Diversos beneficios del uso de Objetos de Aprendizaje han sido expuestos por varios estudios que han examinado su aceptación y efectividad así como su capacidad para ser reutilizados. No obstante, y a pesar de la inmensa cantidad de trabajo realizado en este campo de investigación, todavía hay varias barreras que obstaculizan el uso y adopción de los Objetos de Aprendizaje. Para superar estas barreras y explotar completamente el potencial de los Objetos de Aprendizaje, diversos desafíos deben ser abordados en diferentes etapas de su ciclo de vida.

Esta tesis abarca el diseño, desarrollo y evaluación de varios sistemas, métricas y modelos con el fin de abordar y superar varias de las principales barreras que dificultan la creación, distribución, evaluación e integración de Objetos de Aprendizaje. Además, se estudia el uso de Objetos de Aprendizaje en diversos entornos educativos. La tesis comienza con la identificación de las principales barreras que obstaculizan el uso y adopción de los Objetos de Aprendizaje a lo largo de las diferentes etapas de su ciclo de vida. Después, se presenta una plataforma de e-Learning que soporta el ciclo de vida completo del Objeto de Aprendizaje. Luego, se reportan resultados del diseño, implementación y evaluación de una herramienta para crear Objetos de Aprendizaje. A continuación, la tesis presenta el primer sistema diseñado para proporcionar evaluación sistemática de Objetos de Aprendizaje y generación de puntuaciones de calidad a sistemas de e-Learning de acuerdo a múltiple modelos de evaluación y métricas de calidad de Objetos de Aprendizaje. Además, se proponen dos nuevos modelos de evaluación y varias métricas de calidad nuevas para Objetos de Aprendizaje. Una de estas métricas se basa en analíticas de aprendizaje y permite estimar la calidad de los Objetos de Aprendizaje en base a las interacciones de los estudiantes. Esta tesis también presenta un modelo híbrido de recomendación de Objetos de Aprendizaje para Repositorios de Objetos de Aprendizaje y dos sistemas de recomendación implementados en base a este modelo. Después, se detallan tres modelos de integración: un modelo para permitir a herramientas de creación ensamblar Objetos de Aprendizaje integrando y combinando otros, un modelo para permitir integrar Objetos de Aprendizaje en servicios de videoconferencia web, y un modelo para integrar Objetos de Aprendizaje en juegos web a fin de crear juegos web educativos. Posteriormente, se describen varios proyectos y experiencias educativas en las que se validaron diferentes contribuciones. Finalmente, la tesis concluye con respuestas a las preguntas de investigación planteadas, un resumen de las principales contribuciones y algunas sugerencias para investigaciones futuras.

A mi familia y amigos

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List of Acronyms

API	Application Programming Interface
ARS	Audience Response System
CSS	Cascading Style Sheets
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IMS	IMS Global Learning Consortium
IMS CC	IMS Common Cartridge
IMS CP	IMS Content Packaging
IMS LD	IMS Learning Design
IMS LTI	IMS Learning Tools Interoperability
IMS QTI	IMS Question and Test Interoperability
JSON	JavaScript Object Notation
JSON-LD	JavaScript Object Notation for Linked Data
LMS	Learning Management System
LO	Learning Object
LOEP	Learning Object Evaluation Platform
LOM	Learning Object Metadata
LOR	Learning Object Repository
LORI	Learning Object Review Instrument
MOOC	Massive Open Online Course
OAI-PMH	Open Archives Initiative Protocol for Metadata Harvesting
OER	Open Educational Resources
RDF	Resource Description Framework
REST	Representational State Transfer
RS	Recommender System
RSS	Really Simple Syndication
SCO	Shareable Content Object
SCORM	Sharable Content Object Reference Model
SPOC	Small Private Online Course
SUS	System Usability Scale
TEL	Technology-Enhanced Learning

TF-IDF	Term Frequency-Inverse Document Frequency
UPM	Universidad Politécnica de Madrid
URL	Uniform Resource Locator
ViSH	Virtual Science Hub
VLE	Virtual Learning Environment
WBLT	Web-Based Learning Tool
WBLT-S	WBLT Evaluation Scale for Students
WBLT-T	WBLT Evaluation Scale for Teachers
xAPI	Experience API
XML	Extensible Markup Language
YAML	YAML Ain't Markup Language

Chapter 1

Introduction

Learning Objects have emerged in recent years in the field of educational technology as a key strategy for creating and delivering digital educational resources. The fundamental idea behind them is that educational content can be broken down into small chunks that can be independently created and reused in different contexts and e-Learning systems [1]. Based on this idea, Learning Objects constitute a type of educational resource which aims to improve reusability in order to minimize production cost, save time and enhance the quality of learning experiences.

Learning Objects became an important area of research in educational technology in the year 2000 due to their potential for providing unprecedented efficiency of content design, development and distribution as well as better learning. Since that time, a huge amount of literature has been published on this topic [2]. Various benefits of using Learning Objects have been already exposed by several studies that have examined their acceptance and instructional effectiveness in terms of student engagement and academic performance across different educational environments [3]–[23] as well as their capacity to be reused [24]–[28]. Once their success has been widely recognized, some studies have begun to explore the factors that influence the acceptance and effectiveness of this kind of educational resource [29]–[37].

Nowadays Learning Objects are still an important and challenging research field and remain as a major focus for research and development in the authoring, distribution, evaluation and integration of educational resources. The number of Learning Objects distributed through Learning Object Repositories is continuously increasing and their use is growing day by day.

The rise of the Open Educational Resources (OER) movement as a consequence of the increasing recognition of the benefits of sharing educational resources has given even more attention to Learning Objects. This has happened because Learning Objects can be an ideal strategy for OER since if these resources are created as open Learning Objects their discoverability, sharing and reuse potential can be maximized. The question of to what extent OER are merely open Learning Objects has arisen and some researchers have started to study the similarities and contrasts between the two concepts [38] while others treat them as synonyms [39]. Open Learning Objects seem to be the best path forward for OER in order to achieve their goals and fostering OER communities. They can help to build collaborative environments in which educational materials created by motivated individuals and non-profit organizations are freely shared with a global community of teachers and learners. In these environments, users would be able to enhance the materials and adapt them to their needs if necessary, as well as sharing the new versions with the community leading to an iterative process of OER development and refinement. Open Learning Objects have also been considered essential to the success and development of MOOCs (Massive Open Online Courses) [40].

In addition to OER, other emerging and promising research fields in which Learning Objects are acquiring relevance are learning analytics [41] and recommender systems for Technology-Enhanced Learning [42].

Despite the huge potential of Learning Objects, the immense amount of work done in this field and the progress made in the adoption of ICT (Information and Communication Technology) in education, there are still several barriers hampering the use and adoption of Learning Objects.

Firstly, although there are many Learning Object Repositories available on the Web, learners and educators find it difficult to locate suitable Learning Objects [43]–[45]. There are some measures that Learning Object Repositories can adopt to alleviate this problem such as the use of enhanced ranking metrics, quality control mechanisms or recommender systems. However, the fact that this problem continues to exist brings out the limitations of current mechanisms to search and distribute Learning Objects and indicates that further work is required.

Moreover, the educational community is demanding new functionalities from Learning Object Repositories and at the same time new challenges are arising as a result of the rise of the OER movement. As a consequence, Learning Object Repositories are starting to implement new features beyond storage, searching and retrieval of Learning Objects [46]–[50]. This trend has led to the development of enriched Learning Object Repositories which some researchers have called Learning Object Management Systems [51]. However, not much work has been done to study which features should be considered in the implementation of such systems, develop software for their creation or evaluate their effective use, and this constitutes another obstacle.

Thirdly, even supposing that the search process of Learning Objects could be drastically enhanced, there is a lack of Learning Objects on certain topics and educators usually need to customize the Learning Objects they find to adapt them to their needs [52]. These issues could be solved if educators were able to create their own Learning Objects and modify the ones they find. Nevertheless, the authoring of Learning Objects is a highly technical and time consuming task. For this reason, many authoring systems called e-Learning authoring tools have been developed to allow teachers to create educational resources with little effort without requiring them strong computer skills. Numerous works have been published on this topic, but further research on authoring tools to create Learning Objects is required to determine if educators can actually use these tools to create effective Learning Objects easily, as well as the characteristics that should be taken into account in the design and implementation of such tools.

Fourthly, the huge growth of Learning Object Repositories and Learning Objects has led to an urgent need to systematically evaluate and measure the quality of these resources in order to establish quality control mechanisms [53]. Thus, there is a claim for evaluation models, quality metrics and evaluation systems for Learning Object Repositories. Besides, repositories of open Learning Objects (OER repositories) seek sustainable solutions capable of providing quality assurance for large quantities of resources [39]. Quality control mechanisms based on community seem to be the most promising approach, but their effectiveness and scalability need to be evaluated. The use of learning analytics could help to provide a solution to this challenge, but such an approach has to be studied further.

The fifth barrier is related to the integration of Learning Objects into virtual environments and software systems to enable their use by users and applications. Learning Objects were envisioned as building blocks which could be easily combined among them in order to build more complex ones forming a hierarchy. However, in practice, this process known as authoring by aggregation is still a challenge and more efforts are needed to achieve an easy and effective assembling of Learning Objects by integrating and combining other ones. Furthermore, the integration of Learning Objects into non-educational contexts such as videoconferencing or video games has not been exploited to its full potential. New integration approaches and systems could incentivize the adoption and use of Learning Objects and could make contributions to relevant areas of educational technology such as Game-Based Learning.

Lastly, the use of Learning Objects in novel educational environments such as OER repositories and MOOCs as well as their use in combination with different instructional strategies such as inquiry-based or project-based learning has not been fully addressed yet. Thus, studies on these topics would provide insights into the benefits and drawbacks of the use of Learning Objects for education.

As a consequence of the barriers described above, the use of Learning Objects in educational environments is not as widespread as may have been expected. In order to overcome these barriers and make a step forward to fully exploit the potential of Learning Objects, several challenges must be addressed at different stages of the Learning Object life cycle, mainly in the authoring, distribution, evaluation and integration of Learning Objects.

All these challenges are tackled in this thesis, which aims to answer the following central research question: *How could educational technology facilitate and enhance the authoring, distribution, evaluation and integration of Learning Objects?*

In order to answer this question, the following research questions are addressed:

1. *Which features need to be considered in the implementation of a system to create and distribute Learning Objects?*
2. *Can educators create effective and reusable Learning Objects easily if they are provided with suitable authoring tools? And if so, which characteristics should be taken into account in the implementation of these tools?*

3. *How can the quality of Learning Objects be evaluated, measured and transformed into quality scores that can be understood by humans and automatically processed by information systems? Can these quality scores be used to filter low quality Learning Objects and to enhance search services as well as recommender systems?*
4. *Which features should have a system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems?*
5. *Is there any relationship between the learners' interactions with a Learning Object and its quality? And if so, is it possible to estimate the quality of Learning Objects based on the interactions that learners have with them?*
6. *What kind of recommendation model is suitable for implementing Learning Object recommender systems? Which factors need to be contemplated in their implementation?*
7. *How can Learning Objects be assembled by integrating and combining other ones?*
8. *How can Learning Objects be integrated into contexts in which educational technology is not typically present such as web videoconferencing or web games?*

The work presented in this thesis encompasses the design, development and evaluation of various systems, metrics and models in order to address and overcome technical and socio-technical challenges in the Learning Object domain. Several barriers affecting the different stages of the Learning Object life cycle are identified, and solutions to address these barriers are proposed, implemented and evaluated.

The main contribution is the design, implementation and evaluation of an ecosystem of web applications for authoring, distributing, evaluating and integrating Learning Objects, including an e-Learning platform which supports the whole Learning Object life cycle, an authoring tool to create Learning Objects, a platform that provides systematic evaluation of Learning Objects and generation of quality scores, a Learning Object recommender system, and an application to create educational web games by integrating Learning Objects. All these systems have been released under open source licenses. Thereby, they can be freely used, distributed, studied, adapted and improved by the research and educational communities.

As part of the development of the aforementioned systems, various metrics and models have been designed and evaluated, including evaluation models and quality metrics for Learning Objects, a metric to estimate the quality of Learning Objects based on learners' interactions, a model to generate Learning Object recommendations, and three models to integrate Learning Objects into e-Learning authoring tools, web videoconferencing services and web games.

Finally, the use of Learning Objects in different educational environments was examined. The thesis describes learning experiences in secondary and higher education, as well as in two online courses (including a MOOC) and in a blended course in which a project-based learning methodology was used.

1.1 Objectives

The main objective of this thesis is the proposal, implementation and evaluation of new systems, metrics and models to address and overcome several of the main barriers that hamper the authoring, distribution, evaluation and integration of Learning Objects. In addition to this main goal, the thesis intends to study the use of Learning Objects in different educational environments.

These general objectives of the thesis are broken down into the following specific objectives:

1. *Identify the main barriers hampering the use and adoption of Learning Objects along the different stages of their life cycle. This objective requires identifying not only technical challenges but also needs of the educational community concerning the authoring, distribution, evaluation and integration of Learning Objects.*
2. *Identify and study the current approaches, systems, technologies and standards used for the authoring, distribution, evaluation and integration of Learning Objects.*
3. *Design, implement and evaluate an authoring tool to facilitate the creation of Learning Objects.*
4. *Design, implement and evaluate a system that provides systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems and that supports multiple evaluation models and quality metrics.*
5. *Propose and evaluate new quality metrics for Learning Objects. This goal includes the conception, proposal and evaluation of a predictive metric to estimate the quality of Learning Objects based on the interactions that learners have with them.*
6. *Design a recommendation model for Learning Object Repositories, implement a Learning Object recommender system based on it and evaluate this system in a real environment.*
7. *Propose and validate a model to allow e-Learning authoring tools to assemble Learning Objects by integrating and combining other ones.*
8. *Propose and validate a model to enable Learning Object Repositories to integrate Learning Objects into web videoconferencing services.*
9. *Propose and validate a model to integrate Learning Objects into web games.*
10. *Design, implement, deploy and evaluate an e-Learning platform to create and distribute Learning Objects. This e-Learning platform will integrate most of the systems implemented and presented along the thesis: a Learning Object authoring tool, a system to evaluate Learning Objects and a Learning Object recommender system. This goal also pursues to build a community of users on the platform that creates and openly shares educational resources with the entire world.*

11. *Study the use of Learning Objects in various educational environments including secondary and higher education as well as MOOCs. This objective also seeks to address the use of Learning Objects in combination with learning methodologies such as project-based learning. The implemented systems will be used to support the different learning experiences.*

Lastly, based on the achievement of these objectives, this thesis aims to answer the research questions previously stated.

1.2 Research Methodology

This section describes the methodology followed in this thesis in order to achieve the specific goals previously stated and answer the research questions.

The starting point of this thesis was the GLOBAL excursion (Extended Curriculum for Science Infrastructure Online) project [54] funded by the European Commission under the Seventh Framework Programme. This project gave me the opportunity to work on the design and implementation of a collaborative e-Learning platform. The requirements for the system were collected by applying a participatory design process that involved technology developers, scientists and teachers [55]. In this participatory design, the development team responsible for implementing the e-Learning platform (to which I belonged) and the future users engaged to work together, exchanged perspectives and defined a set of requirements. Thus began the design and implementation of this e-Learning platform which was called ViSH (Virtual Science Hub) [56] in the GLOBAL excursion project.

One of the aims of ViSH was to foster the authoring, distribution and sharing of OER (Open Educational Resources). Based on the gathered requirements and a study on educational technology literature, Learning Objects were identified and selected as the best approach to implement the ViSH e-Learning platform.

Then, I carried out a literature review on Learning Objects identifying the main barriers hampering their use and adoption along the different stages of their life cycle. I also identified the current approaches, systems, technologies and e-Learning standards used for the authoring, distribution, evaluation and integration of Learning Objects.

After that, I started to work on the design and development of the ViSH platform. At the same time and as part of this development, I started to design and implement an authoring tool to create Learning Objects. This authoring tool was called ViSH Editor and was integrated into the ViSH platform from the beginning. In order to allow an effective reuse of Learning Objects obtained from other repositories or created with different authoring systems, I designed and implemented in the ViSH Editor authoring tool a model to assemble Learning Objects by integrating and combining other ones compliant with multiple e-Learning standards.

Around a year after the GLOBAL excursion project began, the first mature version of the ViSH e-Learning platform was released and made publicly available on the Web. The platform was offered to the entire educational community for free. The ViSH platform managed to establish a relatively large community of users. A continuous dialogue was established between the development team and the community which allowed gathering feedback. Based on this feedback, various needs of the educational community concerning the authoring, distribution, evaluation, integration, use and reuse of Learning Objects were identified and several enhancements, features and services were implemented. Thereby the systems were continuously improving based on the dialogue with the community. The users not only used the systems, they contributed to their design. As of today, more than three years after the GLOBAL excursion project ended, the platform remains available at http://vishub.org. It has a growing community of users and it is being used in several projects. New enhancements, features and services continue to be implemented.

During the GLOBAL excursion project, the need to integrate the Learning Objects hosted on the ViSH platform into a web videoconferencing system arose. In order to satisfy this need, a generic model to enable Learning Object Repositories to integrate Learning Objects into web videoconferencing services was designed and implemented.

The growth of the ViSH platform made evident the urgent need to establish a quality control mechanism for Learning Objects. It was at that time when I started the design and development of LOEP (Learning Object Evaluation Platform), the first system designed to provide systematic evaluation of Learning Objects to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. The existing evaluation models and quality metrics for Learning Objects were studied to design and implement the system. Furthermore, I proposed and implemented new evaluation models and quality metrics. One of these metrics enabled a new approach based on learning analytics to estimate the quality of Learning Objects based on the interactions that learners have with them. The LOEP system was successfully integrated into the ViSH platform, and was used to implement a quality control mechanism as well as to enhance the features to search and discover Learning Objects.

Around a year and a half after the ViSH e-Learning platform was deployed and made publicly available on the Web, I started the design and implementation of a novel recommendation model for Learning Object Repositories. The idea was to build a Learning Object recommender system which not only uses traditional content-based techniques, but also uses demographic and context-aware techniques along with the quality scores provided by the LOEP platform. This recommender system was successfully implemented and integrated into the ViSH platform. In September 2015, I conducted a three-month research stay at the HCI (Human Computer Interaction) research group of the Computer Science Department at KU Leuven (Katholieke Universiteit Leuven) in order to implement a new recommender system based on the prior recommendation model for Europeana [57], a digital repository that provides access to millions of digitised materials from European museums, libraries, archives and multimedia collections. During the research stay, I developed and evaluated EuropeanaRS, a recommender system for Europeana. I also collaborated in the Europeana Cloud project [58], concretely in the development of a tool called Newspaper Exploration Environment [59], which facilitates visual exploration of digitised newspapers through faceted search across coordinated multiple views and recommendations. My role in the development of this tool was the implementation of the functionality to generate the recommendations. This functionality was implemented by using and integrating EuropeanaRS. In summary, this research stay allowed me to evaluate the recommender model for Learning Object Repositories in a second environment.

To connect the developments in the Learning Object domain presented in this thesis to the research field of Game-Based Learning, I designed and implemented a model to integrate Learning Objects into web games in order to create educational web games. This work initiated a new research line on Game-Based Learning in the Next Generation Internet research group (to which I belong) of the Telematic Systems Engineering Department at UPM (Universidad Politécnica de Madrid). The authoring of educational video games by integrating Learning Objects into game templates could be an interesting topic for a future thesis.

Although the GLOBAL excursion project ended, the ViSH platform has continued to operate and expand its community. The platform attracted interest from the educational sector resulting in several new projects. Two of these projects, EducaInternet and StoryRobin, are described in this thesis.

The EducaInternet project, funded by Orange and with the collaboration of the Spanish public entity Red.es, started in January 2015 with the main aim of building an e-Learning platform to learn and teach about safe and responsible use of digital technologies. The software that runs the ViSH platform was used to develop this new e-Learning platform, which was called EducaInternet [60]. This project not only allowed to further improve ViSH, but also to implement a lot of customization features in order to facilitate the creation of customized e-Learning platforms for new environments. The Ministry of Education, Youth and Sports of the Madrid Region, Orange and Red.es have organized several learning experiences with EducaInternet and they are planning to organize more in the future.

StoryRobin was another project in which the ViSH software was used to create a new e-Learning platform. The name of the created platform was StoryRobin and its central goal was to provide digital educational content created by the community. StoryRobin also aimed to nurture children's creativity, imagination, and critical thinking skills by engaging them in real-life projects. This project allowed me to implement new features in ViSH.

Thereby, since I started this thesis, I have worked in several projects that have given me the opportunity to design, implement and evaluate in real environments several systems, metrics and models to facilitate and enhance the authoring, distribution, evaluation and integration of Learning Objects. The specific methodologies used to validate each of the contributions are explained in their respective chapters. Moreover, I was able to supervise, participate in and conduct several educational experiences with Learning Objects, which allowed me to study the use of Learning Objects in various educational environments. In conclusion, all these designs, implementations, evaluations and studies have allowed me to successfully achieve all the objectives of the thesis.

1.3 Structure of this Document

Chapter 2: State of the Art

This chapter provides an introduction to the field of educational technology, an overview of the most relevant e-Learning standards and a review of the literature on Learning Objects. The basic notions and terms used throughout the thesis are introduced to the reader. The review covers several topics including the definition and life cycle of Learning Objects, OER and their relation with Learning Objects, instructional effectiveness of Learning Objects, Learning Object Repositories, authoring tools, models and tools to evaluate Learning Object quality, metrics for Learning Objects, learning analytics, Learning Object recommender systems, and integration of Learning Objects. Besides, the chapter provides a new definition of the term "Learning Object" and a simplified representation of the Learning Object life cycle. Related work on Learning Objects is also exposed. Objectives 1 and 2 of the thesis are addressed in this chapter.

Chapter 3: An e-Learning Platform to Create and Distribute Learning Objects

This chapter presents the results of the design, implementation, deployment and evaluation of a web-based e-Learning platform to create and distribute Learning Objects called ViSH. The architecture and the main features of the platform are explained including, among others, the Learning Object manager, the Learning Object authoring tools, the search services, the catalogue, the recommender system, the evaluation system and the social network. This chapter also presents the results of the evaluation of ViSH, which included user surveys, a usability test, a feature comparison and a quantitative analysis. Research question 1 and objective 10 of the thesis are addressed in this chapter.

Most of the systems implemented and presented along this thesis have been integrated into the ViSH platform. Besides, the proposed solutions have been mainly evaluated in the ViSH scenario and several of the described learning experiences have been carried out using ViSH. Therefore, this chapter lays an important foundation for the following chapters because it introduces not only the ViSH platform and its scenario, but also the roles played by most of the systems described in these chapters.

Chapter 4: An Easy to Use Authoring Tool to Create Effective and Reusable Learning Objects

In this chapter, results of the design, implementation and evaluation of an open source authoring tool called ViSH Editor that aims to facilitate the creation of effective and reusable Learning Objects are reported. The chapter contributes to the state of the art of open source Learning Object authoring tools by describing a tool with novel and distinguishing features and providing a complete evaluation. Three factors were evaluated: the user acceptance and usability of the authoring tool, the quality and learning effectiveness of the Learning Objects created with such a tool, and the reusability of these resources. Research question 2 and objective 3 are addressed in this chapter.

Chapter 5: A Web-based Platform to Provide Learning Object Evaluation

This chapter presents results of the design, implementation and evaluation of an open source web-based platform called LOEP, which was designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. The main components and features of the system are described, as well as its main scenarios of use. Furthermore, the chapter describes one by one the Learning Object evaluation models and quality metrics supported by LOEP. Two new evaluation models and several new quality metrics for Learning Objects are proposed. The evaluation of LOEP included a quantitative analysis of an instance used by two Learning Object Repositories, user surveys, and three experiments in which several evaluation models and quality metrics were tested. This chapter addresses research questions 3 and 4 as well as objectives 4 and 5.

Chapter 6: A Quality Metric for Learning Objects based on Learning Analytics

This chapter proposes a new approach grounded on learning analytics to estimate the quality of Learning Objects based on the interactions that learners have with them in open environments. Firstly, the relationships between the learners' interactions with Learning Objects in an OER repository and the quality of these Learning Objects are analyzed. Then, the chapter proposes a predictive quality metric for Learning Objects based on learning analytics that allows to estimate the quality of Learning Objects based on the learners' interactions. Thereafter, the metric is evaluated and the reported results are discussed. Lastly, an implementation of the proposed quality metric in an OER repository is described. In this way, the chapter addresses research question 5 and objective 5.

Chapter 7: A Hybrid Recommendation Model for Learning Object Repositories

This chapter presents a hybrid Learning Object recommendation model for Learning Object Repositories that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. The chapter also describes how two recommender systems have been implemented based on this model for two Learning Object Repositories: ViSH and Europeana. Each of these recommender systems was evaluated in terms of accuracy, utility, user satisfaction and usability. Besides, an A/B test was conducted on ViSH to compare the recommendations generated by the recommender system with random suggestions. Thereby, research question 6 and objective 6 are addressed in this chapter.

Chapter 8: Integration Models for Learning Objects

In this chapter, three different Learning Object integration models are explained. Firstly, the chapter describes a model to allow e-Learning authoring tools to assemble Learning Objects by integrating and combining other ones compliant with multiple e-Learning standards. This model was implemented and validated in an authoring tool. Secondly, a model to enable the integration of Learning Objects provided by Learning Object Repositories into web videoconferencing services is presented. In order to validate this model, it was implemented in two different repositories to enable the Learning Objects created with an authoring tool to be integrated into three different web videoconferencing services. Lastly, the chapter describes a model to integrate Learning Objects packaged according to the SCORM standard into web games. The model was validated by implementing an authoring tool to create educational web games. This chapter addresses research questions 7 and 8 as well as objectives 7, 8 and 9.

Chapter 9: Validation and Results

Firstly, in order to provide an additional validation, this chapter describes several projects and learning experiences in which different contributions of this thesis have been validated. Thereby objective 11 is accomplished. Then, the chapter lists the different publications that have been produced as a result of this thesis. Finally, the chapter details all the contributions of this thesis published as open source projects.

Chapter 10: Conclusions

This chapter concludes the thesis with a summary of the answers to the research questions, a recapitulation of the main contributions and some suggestions for further research.

Chapter 2
State of the Art

This chapter presents an introduction to the field of educational technology, an overview of the most relevant e-Learning standards and a review of the literature on Learning Objects. The basic notions and terms used throughout this thesis are introduced to the reader. Besides, this chapter provides a new definition of the term “Learning Object” and a simplified representation of the Learning Object life cycle. Lastly, related work on Learning Objects is also exposed.

2.1 Educational Technology

Educational technology is defined as "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" [61]. The research field of educational technology is very broad and encompasses a wide range of areas including e-Learning, ICT (Information and Communication Technology) in education, Technology-Enhanced Learning (TEL), blended learning, distance learning, mobile learning, Web-Based Learning and Computer-Based Learning among others.

A plethora of different terms have been and are used in the literature to depict the different concepts of the educational technology field. On the one hand multiple terms are used to describe the same concept and on the other hand a same term is defined in different ways. This lack of consistency in the terminology has been subject of study in several works [62]–[65]. The absence of a clear and coherent conceptual framework for educational technology creates confusion and hinders the understanding of the research field. In order to deal with this issue, this section provides the reader with the definitions of the terms related to educational technology used in this thesis.

2.1.1 e-Learning and Other Forms of Learning

One of the most used terms in educational technology is e-Learning, which stands for “electronic learning” and can be defined as “any type of learning that is delivered using electronic media and ICT”. Digital learning resources are frequently called e-Learning resources. In addition to e-Learning, which is a very broad term that encompasses all forms of learning supported by electronic media, many other terms are used to refer to the different forms of learning or the different ways in which learning is delivered.

Blended learning (B-Learning) is “a learning model that combines content and instruction delivered through digital and online media with classroom work that requires the physical co-presence of teachers and students”.

Distance learning is “a form of learning that does not require the regular physical presence of the students and in which students and instructors are separated by location and/or time”. The delivery of content and instruction is usually carried out using ICT. For this reason distance learning is sometimes considered a form of e-Learning where students learn remotely.

Mobile learning (M-Learning) can be defined as “any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies” [66].

Ubiquitous learning (U-Learning) is a term often associated with mobile learning although it has a different meaning. It can be defined as “a type of learning that is delivered through a ubiquitous learning environment which aims to enable anyone to learn at anyplace at anytime”.

Online learning is “a form of e-Learning characterized by the use of the Web and/or the Internet in order to access and use the content and services”. Internet-Based Learning (IBL), Internet-Based Instruction (IBI) and Internet-Based Training (IBT) are used as synonyms of online learning. Web-Based Learning (WBL) is “a form of online learning in which the content and services are accessed and used specifically through a web browser”. The terms Web-Based Instruction (WBI) and Web-Based Training (WBT) are frequently used as synonyms. Although some definitions of these terms state that online learning and Web-Based Learning can only be used for distance learning, they can also be used in blended learning environments.

Other term that has been frequently used is Computer-Based Learning (CBL), which refers to “any kind of learning delivered using computers”. The terms Computer Mediated Learning (CML) and Computer Mediated Instruction (CMI) are used as synonyms of Computer-Based Learning. Other related term is Computer-Supported Collaborative Learning (CSCL), which can be defined as “a learning approach wherein learning takes place via social interaction and the help of computers usually using technology and especially Internet and the Web as the primary means of communication”. A related but different term that is also broadly used is Computer-Based Training (CBT), which can be defined as “a form of Computer-Based Learning in which students learn at their own pace by executing training programs (usually called courseware) which provide a series of activities and feedback”. In Computer-Based Training the participation of instructors is minimal or nonexistent. Several terms have been used to refer to Computer-Based Training including Computer-Aided Instruction (CAI), Computer-Enriched Instruction (CEI), Computer-Based Instruction (CBI), Computer-Assisted Instruction (CAI) and Computer-Assisted Learning (CAL). However, these terms have also been used in some occasions as synonyms of broader terms such as Computer-Based Learning.

Game-Based Learning (GBL) is “a learning approach in which learning is delivered through games explicitly designed with educational purposes”. These games are called “educational games” but the term “serious games” is also frequently used. Serious games are “games designed for a primary purpose different than pure entertainment or fun”. Digital Game-Based

Learning (DGBL) is a narrower term employed in some occasions to refer to Game-Based Learning when only video games are used.

Taking all these into account, the aforementioned forms of learning can be characterized from a technical point of view by the way in which the content is delivered (face to face, remotely, blended), the physical presence requirements (i.e. the intention and ability to enable the learners to learn at anyplace at anytime), the technology used (computers, mobile phones, Internet, the Web, educational software, ...) and the type of services and content employed (e.g. collaborative tools, courseware, educational games). Table 2.1 shows the main forms of learning that have been introduced classified according to these criteria.

Table 2.1: Forms of Learning from a Technical Perspective

	Content Delivery Mode	**Physical Presence Requirements**	**Technology**	**Services and Content**
e-Learning	Any	Any	Electronic media and ICT	Any
Blended learning	Blended (face to face and remote)	Requires co-presence of teachers and students	Digital and online media	Any
Distance learning	Mainly remote	Regular presence of the students is not required	Normally electronic media and ICT	Any
Mobile learning	Any (frequently remote)	Learners may not be at fixed locations	Usually handheld devices and mobile technologies	Any
Ubiquitous learning	Remote	Learners are able to learn at anyplace at anytime	Ubiquitous learning environments	Any
Online learning	Any	Any	Web and/or Internet	Any
Web-Based Learning	Any	Any	Web	Any
Computer-Based Learning	Any	Any	Computers	Any
Computer-Supported Collaborative Learning	Any	Requires interactions that can be face to face, remote or a combination	Computers and usually Internet and the Web	Collaborative tools
Computer-Based Training	Any	Participation of instructors is minimal or even nonexistent	Computers	Courseware
Game-Based Learning	Any	Usually, the presence of instructors is not essential	Electronic media may not be necessary	Educational games
Digital Game-Based Learning	Any		Electronic media and ICT	Educational video games

New forms of learning can be discerned if other criteria are considered. For example, learning can also be classified as synchronous or asynchronous. The difference between the two forms of learning is that in synchronous learning all participants (learners and instructors) interact at the same time.

Depending on formality, forms of learning can be classified as “Formal learning”, “Informal learning” and “Non-formal learning”. Formal learning is always scheduled and structured, has stated learning objectives and is delivered in a systematic intentional way within a formal curriculum and normally by trained teachers within an educational institution, training centre or workplace. Informal learning is not or barely organized, may not have stated learning objectives, is not intentional (at least not necessarily) and usually takes place outside educational establishments and formal curriculum. Non-formal learning is organized, intentional, normally lack of learning objectives and takes place outside the formal sector and curriculum. A total agreement of the meaning of these concepts has not been achieved and therefore definitions with subtle differences can be found in the literature [67].

From a philosophical point of view, different learning theories are discerned such as constructivism, cognitivism and behaviorism [68]. Moreover, from a pedagogical perspective, many learning methodologies have been defined. A learning methodology, also interchangeably called learning/teaching/instructional/educational method/approach/strategy or teaching methodology, can be defined as “a set of procedures, methods, activities, rules and principles used during the process of teaching and learning”. Some of the aforementioned forms of learning (e.g. blended learning and Game-Based Learning) are considered learning methodologies and therefore these terms are not only used to refer to technical aspects but also to a specific methodology. Other examples of learning methodologies are direct instruction, independent study, cooperative learning, hands-on learning, resource-based learning (RBL) and flipped classroom. Among the most relevant methodologies, it is also worth mentioning problem-based learning (PBL), case-based learning (CBL), project-based learning (PBL) and inquiry-based learning (IBL). These four approaches are learner-centred and aim to promote active learning, nonetheless, there are substantial differences among them [69]. A wide range of learning experiences can be provided by combining different learning methodologies with the content delivery modes and different technologies, services and resources.

A learning environment, in its broader sense, refers to the whole range of characteristics and components that determine how and where learning occurs, encompassing a physical and/or virtual context, a set of participants (learners, instructors, ...), learning objectives, learning methodologies, technologies, educational materials and any other resources used (including technological ones such as hardware and software systems). Most of the terms described in this section are also often used in the literature to characterize a learning environment in terms of diverse factors such as the type of technology used or the learning methodology followed. For instance, a “blended learning environment” describes a learning environment in which content and instruction delivered through online media are combined with classroom work that requires the physical co-presence of teachers and students. Similarly, a “project-based learning environment” is one in which students follow a project-based learning methodology.

2.1.2 Technology-Enhanced Learning

Technology-Enhanced Learning (TEL) is a term very present in the literature that refers to “the application of ICT in education in order to obtain some benefit or improvement". The term Technology-Enhanced Education (TEE) is sometimes used as a synonym of TEL.

Since e-Learning encompasses learning delivered using ICT, TEL and e-Learning are often used interchangeably. However, while e-Learning is a form of learning, TEL is a field that aims to provide solutions to support and enhance all forms of education. TEL systems and environments are those in which ICT is used in order to support, provide or enhance some educational aspect or service. TEL environments are also called technology-supported learning environments. In practice, the terms “TEL systems”, “e-Learning systems” and “learning systems” are often used interchangeably. For simplicity, this thesis use all these terms with the same meaning to refer to the whole range of software systems that use ICT for educational purposes including Virtual Learning Environments, Learning Management Systems, Learning Object Repositories, e-Learning authoring tools and Learning Object recommender systems.

The TEL research field aims to design, develop and evaluate systems, technologies and socio-technical solutions with the main goal of supporting and enhancing all forms of education. It is a very heterogeneous research field to which a wide variety of disciplines and domains contribute. This fact is proven in [70], where the interdisciplinarity of the TEL field was analyzed based on 3,476 research articles collected from the Web of Science between 2002 and 2011. In this study, educational science and computer science were identified as the two domains which contribute more to the TEL field. Nevertheless, substantial amount of work was also identified in other domains such as health, business and management, technology, biomedical sciences, environmental sciences, physics and agricultural sciences among others.

A huge variety of topics are being addressed in the TEL field. Some works have performed literature reviews on TEL in order to identify these topics and the research trends in the field.

In [71], 2,976 articles from 5 journals indexed in the Journal Citation Reports (JCR) were analyzed under 3 categories including research topic, research sample group and research domain. The study proposed a classification of TEL research topics which includes among others the following categories: development of new learning systems, platforms and architectures (including topics related to the development of e-Learning platforms and Learning Objects), evaluation of TEL systems, pedagogical design and theories (e.g. new learning methodologies), knowledge and competencies management (repositories of learning resources), artificial intelligence in education (data and web mining in education, recommender systems), Computer-Supported Collaborative Learning (Web 2.0 and social computing for learning and knowledge sharing), mobile and ubiquitous learning, digital games and intelligent toys in education (Game-Based Learning), e-Assessment and new assessment methodologies, and motivation, perceptions and attitudes (e.g. acceptance of technologies in education).

From 2000 to 2009, the most published research topic was “pedagogical design and theories”, followed by “motivation, perceptions and attitudes” and “development of new learning systems, platforms and architectures”. Results also show that topics such as Game-Based Learning and mobile/ubiquitous learning have gained attention in the recent years.

In the period from 2000 to 2009, research samples in “higher education” were utilized most, followed by “non-specified”, “junior and senior high school”, “teachers”, “elementary school”, “adults” and “others”. In this same period, the “engineering and computer science” was the research domain most found in TEL publications, followed by “social studies”, “science”, “art and languages”, “others” and “mathematics”. The research trend in the engineering and computer science domain increased from 12% to 21% between the 2000-2004 and 2005-2009 periods.

A more current study exposes a possible panorama of the most recent trends in the TEL field [72]. The findings of the study were obtained from 555 abstracts published in 2013 from 5 journals indexed in the Journal Citation Reports (JCR). It identified a major research line related to technology which covers, among other topics, Virtual Learning Environments, Computer-Supported Collaborative Learning, mobile learning, Game-Based Learning and learning through communication technologies.

Although these two studies provide a relatively up-to-date overview of the topics and research trends in the TEL field, their results are significantly limited by the small number of journals taken into account. The analyzed works were not fully representative of all the current TEL literature. The analysis of other journals would have produced different results. Thus, further research should increase the sample size of journals in order to obtain more general and broader insights.

More trends, challenges and developments in the TEL field can be found in the NMC (New Media Consortium) Horizon Reports [73]. The reports published since 2014 have pointed out various developments and trends in TEL such as online learning, Open Educational Resources (OER), collaborative learning approaches, e-Learning standards, integration of online, blended and collaborative learning, user-generated content, Game-Based Learning, gamification, virtual and remote laboratories, Internet of things, artificial intelligence, mobile content, adaptive learning technologies and learning analytics.

Another interesting review which covers TEL literature for the period 2005-2010 can be found at [64]. A total of 47 articles reporting TEL interventions were obtained from the Web of Science and Academic Search Complete databases and reviewed. The findings showed that TEL has been used with three main goals: replicate existing teaching practices (in around a 20% of the interventions), supplement existing teaching (50%) and transform teaching and/or learning processes and outcomes (30%). The interventions in which TEL was used pursued three different types of improvements: operational improvements (provide greater flexibility for students and accessibility of resources) (15%), quantitative changes in learning (increase engagement and/or test scores) (70%) and qualitative changes in learning (e.g. promote reflexion on learning or achieve richer understanding) (60%). The review also analyzed the different data collection methods and types of evidence used in the TEL interventions to demonstrate enhancement. Quantitative data were collected in around 85% of the interventions using system usage data, assessment grades, test scores, attitude scales, self-report surveys for students and teachers and scrutiny of student-generated artefacts. Qualitative data were collected in around 70% of the interventions through interviews with students and teachers, students' comments, online discussions and analysis of interactions among others. The study criticizes that it is often taken for granted that technologies can enhance learning and concludes stating that there is still much to be learned about the effective educational contribution of TEL.

A recent article reviewed 22 studies focused on developing or using instruments to measure learners' and teachers' perceptions of TEL environments [74]. The studies were obtained mainly from the Web of Science and covered the period from 1998 to 2014. Based on these studies, 17 different instruments were found. A total of 156 factors were identified in the TEL environments and categorized into one of the six following dimensions: technical, content, cognitive, metacognitive, social and affective. Results indicated that the salient features most often investigated in TEL environments are usability (in the technical dimension), relevance of information (content), inquiry learning (cognitive), student autonomy (metacognitive) and teacher support as well as student collaboration (social dimension).

A summary of the different benefits that can be gained by using TEL is provided by [75]. This literature review examined several studies related to the measurement and demonstration of the effective use of ICT in education. Results suggest that TEL can be used to increase learner engagement, motivation and achievement, enhance teacher training, facilitate the acquisition of basic and 21st century skills, enable new forms of learning and learning environments, facilitate many learning methodologies including learner-centred approaches, increase flexibility so that learners can access the education regardless of time and geographical barriers, facilitate the creation of digital learning resources, promote the sharing of these resources through repositories and help to democratise education.

In conclusion, the use of technology in education by itself does not guarantee better learning, although its effective use can not only enhance learning but also provide many other and diverse benefits and opportunities. In addition to the technology and TEL systems employed, other factors influence the effectiveness of a learning experience including the participants (e.g. teachers, tutors and students), the learning methodology followed or the educational materials as well as the rest of resources used. Nevertheless, TEL has the potential to drastically change the learning experiences as well as the teaching and learning processes.

2.1.3 Virtual Learning Environments

There is little agreement as to which terms should be used to refer to the different types of online learning systems, that is, systems in which the learning is delivered via the Web and/or the Internet. Since is not clear which features and services should have each type of system, there is still less agreement as to where lie the boundaries among them [76].

A common term that encompasses many types of online learning systems is Virtual Learning Environment (VLE). Martin Weller defines VLE as “a software system that combines a number of different tools that are used to systematically deliver content online and facilitate the learning experience around that content” [76]. In this thesis, a slightly different definition is used, which defines VLEs as “web-based systems that combine different applications, services and resources in order to systematically deliver educational content to learners via the Web and/or the Internet and to facilitate and provide learning experiences around that content”. It should be noted, however, that different definitions of VLE can be found in the literature. For instance, [77] proposes a much narrower definition. Lastly, it is worth pointing out that the term VLE refers exclusively to software systems and not to learning environments understood in their broadest sense. This thesis also uses the term “e-Learning platform” to refer to VLEs.

Repositories of digital learning resources, often called Learning Object Repositories, are web-based digital libraries where e-Learning resources can be stored, distributed, discovered and retrieved. Simple Learning Object Repositories are not VLEs according to the definition used in this thesis. However, repositories enriched with features and services to facilitate learning experiences around the hosted e-Learning resources can be considered VLEs. This section focuses on VLEs. Learning Object Repositories are tackled later in this chapter.

The term Managed Learning Environment (MLE) is sometimes used in the literature as synonym of VLE or to encompass all management systems of educational institutions, including those not focused on learning. The Joint Information Systems Committee (JISC) defined this term as “the whole range of information systems and processes of a college or university (including its VLE if it has one) that contribute directly, or indirectly, to learning and the management of that learning” [78].

Several terms are used to refer to distinct types of VLEs. One of the most used is Learning Management System (LMS). Some definitions of LMS are presented in [65], together with common features of LMSs and the main differences with the other systems. Based on these definitions, an LMS can be considered as “a software application that manages and delivers digital learning content, handles administration of courses and enrolments for these courses, tracks and reports students’ progress and performance, and collects and presents data for supervising the learning process of an organization as a whole”. LMSs usually support educational technology standards allowing the importation of external e-Learning resources and can also provide functionalities such as development of content and assessments, scheduling for students, teachers and classrooms, assessing of learners' skills gaps, curriculum management, certifications and access control among others. In the context of LMSs, the term Learning Object is used to refer to the smallest component of content that can be managed and delivered by the systems [65]. There are several popular and widely used LMSs, including both open source LMSs such as Moodle [79] or Sakai [80] and proprietary alternatives like Blackboard Learn [81]. Today, Moodle is the most used LMS by far. Other terms related with LMS are Course Management System (CMS) and Learning Content Management System (LCMS).

A Course Management System is similar to an LMS, but it is focused on the creation and delivery of online courses primarily designed for online or blended learning. So, LMSs have all the functionalities that Course Management Systems have, but they are not limited to them.

Learning Content Management Systems are used to create, assemble, store, manage, reuse and deliver digital learning content (i.e. e-Learning content), usually in the form of Learning Objects. These systems differ from LMSs in that they are focused on content while LMSs are focused on learners, organizations and their learning processes. Learning Content Management Systems do not provide features for managing learners, courses or learning activities. Thus, these systems cannot be considered, in general, VLEs. However, they can be integrated into LMSs to allow the creation of Learning Objects that subsequently can be used in courses.

Literature suggests that LMSs will evolve to include features to facilitate learner-centred methodologies and support collaborative learning, enhance and extend the support of educational technology standards, provide better authoring tools to create Learning Objects, provide adaptive learning and integrate Web 2.0 tools and services [65], [82]. Open source technologies are expected to play an important role in the future. Some authors have stated that future LMSs will be distributed learning systems formed by a range of components built by different organizations that interact with each other over the Internet.

The advances in educational technology and the emergence of Web 2.0 tools and services have led to the appearance of a new type of VLE, which some authors have suggested to call Personal Learning Environment (PLE). These systems are often conceptualized as "single user VLEs formed by a collection of interoperable tools, services and applications, in which learners can take control and manage their own learning". However, there is no consensus on what a Personal Learning Environment is and many researchers have claimed that this term should be understood as a concept or approach instead of as a VLE [83].

MOOC (Massive Open Online Course) providers are another type of VLE that has emerged in recent years. These systems are similar to Course Management Systems, but they are exclusively focused on the creation and delivery of MOOCs. According to Siemens [84], MOOCs meet the following characteristics:

- *Massive*. MOOCs are courses that usually allow unlimited participation and that involve hundreds or thousands of learners. This fact leads to overwhelming learner-instructor ratios. A recent study reported that courses offered by the most popular MOOC providers have on average around 40,000 enrolled students [85].

- *Open*. Learners can access the course content and participate in all activities without fees. Nevertheless, the course materials are not necessarily openly licensed.
- *Online*. MOOCs are exclusively online and do not require physical presence of learners.
- *Courses*. MOOCs have a set start and stop time. Even if the content and archives of a MOOC remain available after the course end date, learners' interactions (e.g. in forums) occur exclusively during the set times of the course offering. Moreover, in MOOCs the content is structured and sequenced to a greater or lesser extent.

Due to the extremely high learner-instructor ratios present in MOOCs, instructor feedback to individual students is not possible. Therefore, MOOCs require instructional designs that enable massive feedback and assessment as well as large-scale interactions. Feedback is usually provided using online forums where teaching assistants and course instructors respond to learner questions. Assignments are generally evaluated through peer review mechanisms or by using automated assessment systems.

MOOCs are generally categorized into two main types: xMOOCs and cMOOCs [84], [86]. The pedagogical model that underpins xMOOCs is one of "teacher as expert" and "learner as knowledge consumer". Weekly course topics are addressed through recorded lectures that normally range from 3 to 30 minutes in length. These lectures are often followed by assessment tasks. In order to evaluate the assignments, xMOOCs often rely more on automated assessment systems than peer review mechanisms. The cMOOCs are based on a connectivist pedagogical model that views knowledge as a networked state and learning as the process of generating those networks and adding and pruning connections. They provide space for self-organized learning where learners can define their own objectives, present their own view and collaboratively create and share knowledge. To achieve this goal, cMOOCs often use social networks (e.g. Facebook, Twitter and Google Plus) and Web 2.0 tools and services (e.g. blogs, forums and wikis). In contrast to xMOOCs, cMOOCs are largely open in terms of learning activities and are much less structured. Normally, activities in cMOOCs are evaluated through peer review mechanisms or are not evaluated at all. Lastly, MOOCs can be also be classified as quasi-MOOCs [84]. This type of MOOC consists of collections of linked Learning Objects intended to support specific learning objectives. There is no instructor and there is no (or barely any) social interaction or feedback beyond the one provided by the resources. Technically, in the cases where the resources are loosely linked and are not packaged in a structured way quasi-MOOCs cannot be considered courses. Therefore, although MOOCs can be classified as quasi-MOOCs not all quasi-MOOCs can be considered MOOCs.

New types of online courses have emerged based on MOOCs including smOOCs (Small Open Online Courses), SPOCs (Small Private Online Courses) and blended MOOCs (bMOOCs). The smOOCs are courses with the same characteristics as the MOOCs except that the number of participants is relatively small. They are open online courses with instructional designs that are characteristic of MOOCs but they are not massive. SPOCs are the same as smOOCs, but the enrolment and access to the course is only allowed for a specific set of people. A blended MOOC is a course that combines content and instruction delivered through a MOOC with classroom work that requires the physical co-presence of teachers and students.

Among the most popular MOOC providers it is worth mentioning edX [87], Udacity [88], Coursera [89], Miriada X [90] and Khan Academy [91]. The latter is the most popular quasi-MOOC provider. The edX platform is powered by open source software. The Open edX platform [92], which code is available at [93], is the software used to run edX. Although several systems have been developed focused exclusively on MOOCs, LMSs like Moodle also can and have been used to create and conduct MOOCs.

There seems to be a consensus in the literature that the use of VLEs per se does not guarantee better learning, although they can provide several benefits such as remove time and geographical barriers, save cost and effort, enable new learning environments and forms of learning (e.g. blended learning), and facilitate many diverse learning methodologies. In order to enhance learning by increasing learner engagement, motivation and/or achievement, VLEs need to be not only effectively used but also be combined with learning methodologies and resources suitable for each case.

A description of how learning experiences using a VLE differ from traditional classroom can be found at [94]. A study that involved 146 students and compared the effectiveness of a traditional classroom environment with a distance learning environment in which students exclusively used a VLE is also described. Results concluded that there were no significant differences in performance between students enrolled in the two environments.

Liaw [95] carried out a study to investigate the self-perceived effectiveness of LMSs which involved 424 university students that used Blackboard as their primary assisted learning tool for 2 months and that then filled out a questionnaire. Results found that self-perceived learning effectiveness had high correlation with self-perceived VLE quality, usefulness, satisfaction and efficacy as well as with self-reported data on interactive learning activities and multimedia instruction.

An investigation of whether the use of VLEs has any impact on the final grades achieved by the students was reported in [96]. The study involved 257 students from 3 different subjects which followed a blended learning methodology. Results showed that the number of visits to the VLE does not correlate with students' final grades in two of the three subjects and authors pointed out that using a VLE as an additional platform does not have an effect on student's academic performance per se. The relationship between students' interactions with VLEs and their academic performance has become a key object of study in the learning analytics field and has been addressed in several works [97]–[103]. In most cases, positive correlations between some students' interaction data and academic performance are found, but not always. For example, [97] found correlations in distance learning courses but not in courses that used a blended learning methodology. Nonetheless, it is worth pointing out that simple correlations must not be interpreted as cause-and-effect relationships. More details about this topic and related work are provided in the "Learning Analytics" section of this chapter.

Regarding MOOCs, one of the key concerns is the high dropout rate of learners. MOOC completion rates, defined as the percentage of enrolled learners who complete the course, range from 0.7% to 52.1% with an average value of nearly 13% [104], [105]. In this regard, it should be considered that only approximately 50% of the enrolled learners become active learners [85]. These data point out that MOOC completion rates are substantially lower than in traditional online courses.

Some studies have attempted to identify the factors that affect student retention and completion rates in MOOCs. A study carried out by Adamopoulos [106] found that the more satisfied students are with the professor, the educational material and the assignments, the more probable is that they will successfully complete the course. On the other hand, the difficulty of the course, the workload and its duration were found to have a negative effect on student retention. The latter finding is consistent with [104], which found that long courses have lower completion rates in comparison with shorter courses. Popularity of the course and the prominence of the university were found to not have significant effect. The study also found that peer assessment has a positive effect on student retention compared to automatic feedback. However, this finding is contradictory to [104], which found that MOOCs which use peer grading have lower completion rates than auto-graded MOOCs. Lastly, the study suggests that, in order to increase student engagement and reduce dropout rates, MOOCs should be of average difficulty and require moderate workload (about 6 hours/week) without spanning many weeks (less than 8). Other study examined the effect of perceived reputation, perceived openness, perceived usefulness, perceived enjoyment and user satisfaction on the intention to continue using MOOCs [107]. Findings revealed that all factors are significant predictors to explain MOOCs continuance intention to use, being perceived reputation and perceived openness the strongest ones. The availability and use of high quality Learning Objects has also been pointed out as a possible factor of the success of MOOCs [40]. Despite the research carried out so far, the learning effectiveness of MOOCs is still an open question. Given that completion rates are not reliable measures to evaluate learning in MOOCs, further research should be conducted to address this issue.

Summarizing, it can be stated that VLEs can help to enhance learning and provide other benefits but there is still much to be learned about their effective educational contribution and hence further research is needed.

2.2 e-Learning Standards

Several technical specifications, standards and profiles have been created for educational technology. A specification is an explicit set of documented requirements to be satisfied for a product, system or service. A standard is basically a specification established generally by consensus and approved and endorsed by a recognized accrediting institution. A profile, in this context, is the interpretation, adaptation, constraint and/or augmentation of a specification. All these specifications, standards and profiles used in educational technology are usually termed "e-Learning standards". This term is the one used in this thesis. Sometimes e-Learning standards are also referred to as learning or educational technology standards.

Mainly, e-Learning standards try to solve two key problems: reusability and interoperability. Reusability concerns the capacity of a resource to be used or exploited repeatedly in different systems and contexts, while interoperability concerns the capacity of a resource or system to work and communicate with other systems. On the one hand, e-Learning standards define standard data models and specifications to represent, package, describe and sequence e-Learning resources as well as to represent and describe learners, learner interaction data, competencies, learning designs and any other entities that may be involved in a learning process. On the other hand, e-Learning standards try to enable interoperability by specifying standard APIs and protocols including the structure and format of the messages interchanged. Broadly, e-Learning standards can be categorized into five categories depending on the facet they aim to standardize:

- *Metadata*. Standards focused on the description of e-Learning resources.
- *Content Integration*. Standards focused on the representation, packaging and/or interoperability of e-Learning resources for their distribution as well as for their integration and use in VLEs and other e-Learning systems.
- *Educational Design*. Standards focused on the representation and interoperability of aspects and entities related to educational design such as the sequencing and organization of e-Learning resources and the learning methodologies.
- *Learner Information*. Standards focused on the representation of learners including their learning related history, goals, achievements, competencies, professional portfolio and preferences as well as data about their interactions in online learning environments.
- *Architecture and Service*. Standards that define architectures, APIs and protocols (including languages and formats for the exchange of messages) to allow e-Learning systems to offer, consume and provide services in an interoperable way.

This section describes the most relevant technical standards used in the field of educational technology including all e-Learning standards used or referenced in this thesis. Some standards are described briefly while for others detailed information is provided in order to help the reader to understand the contributions of the thesis. Table 2.2 lists all the standards described in this section showing for each of them the type according to the aforementioned classification and the latest and most relevant versions.

Table 2.2: e-Learning standards

Name	Type	Latest and most relevant versions (Date of release)
IEEE LOM	Metadata	IEEE LOM 1.0 (2002)
IMS LRM		IMS LRM 1.3 (2006)
Dublin Core		Dublin Core Metadata Element Set, Version 1.1 (2012), DCMI Metadata Terms (2012)
ISO/IEC MLR		ISO/IEC 19788-1 (2011)
LRMI		LRMI 1.1 (2014), Adoption in Schema.org (2013)
AICC CMI	Content Integration	AICC/CMI Guidelines for Interoperability - Revision 4.0 (2004)
IMS CP		IMS CP 1.2 Draft (2007), IMS CP 1.1.4 (2004), IMS CP 1.1.2 (2001)
SCORM		SCORM 2004 4th Edition (2009), SCORM 1.2 (2001)
xAPI		xAPI 1.0.3 (2016)
cmi5		cmi5 Specification Profile for xAPI, Quartz - 1st Edition (2016)
IMS LTI		IMS LTI 1.2 (2015), IMS LTI 2.0 (2014), IMS LTI 1.1 (2012), IMS LTI 1.0 (2010)
IMS QTI		IMS QTI 2.2.1 (2016)
Moodle XML		Moodle XML 3.3 (2017)
IMS CC		IMS Thin CC 1.0 (2015), IMS CC 1.3 (2013)
IMS SS	Educational Design	IMS SS 1.0 (2003)
IMS LD		IMS LD 1.0 (2003)
IMS LIP	Learner Information	IMS LIP 1.0.1 (2005)
IMS ACCLIP		IMS ACCLIP 1.0 (2003)
IEEE PAPI Learner		IEEE P1484.2.1/D8 (2002)
IMS RDCEO		IMS RDCEO 1.0 (2002)
CAM		Contextualized Attention Metadata Schema 1.5 (2011)
IMS Caliper Analytics		IMS Caliper Analytics 1.0 (2015)
OAI-PMH	Architecture and Service	OAI-PMH 2.0 (2002)
IMS DRI		IMS DRI 1.0 (2003)
SQI		CWA 15454 - A Simple Query Interface Specification for Learning Repositories (2005)
PLQL		ProLearn Query Language (2007)
SPI		CWA 16097 - The Simple Publishing Interface (SPI) Specification (2010)
IMS LIS		IMS LIS 2.0.1 (2013)
IMS CPS		IMS CPS 1.0 (2013)
IMS OneRoster		IMS OneRoster 1.1 (2017)

2.2.1 Organizations

This section provides a brief description of the most relevant organizations in the development of e-Learning standards.

The Aviation Industry Computer-Based Training Committee (AICC) [108] was an international association of technology-based training professionals that existed from 1988 to 2014. AICC developed guidelines and specifications for the development, delivery, and evaluation of Computer-Based Training, Web-Based Training and related forms of learning. Its most relevant specification was “CMI001 - AICC/CMI Guidelines for Interoperability” [108]. Prior to its dissolution, AICC transferred all its documents to ADL to ensure continued access for the public. Currently, these documents can be accessed in the AICC document archive [108].

The Advanced Distributed Learning Initiative (ADL for short) [109] is a United States government program that collaborates closely with industry and academia and conducts research and development on distributed learning in order to facilitate interoperability, and promote best practices for using distributed learning to provide the highest quality education, training, and informal learning, tailored to individual needs and delivered cost-effectively, anytime and anywhere. Notable ADL contributions include SCORM [110] and xAPI [111].

The IMS Global Learning Consortium (IMS for short) [112] is a non-profit international organization that develops and promotes the adoption of open technical specifications for interoperable educational and learning technology. IMS stands for Instructional Management Systems because of the original name given to the project when it first started in 1997. A lot of relevant specifications have been developed by IMS including among others IMS CP [113], IMS LTI [114], IMS QTI [115], IMS CC [116] and IMS SS [117].

The IEEE Learning Technology Standards Committee (IEEE LTSC) [118] is chartered by the IEEE Computer Society Standards Activity Board to develop internationally accredited technical standards, specifications, recommended practices, and guides for learning technology. The IEEE LTSC has produced several e-Learning standards such as IEEE LOM [119] and also has significantly contributed to create SCORM [110].

Other relevant organizations that have been involved in the development of e-Learning standards are the Dublin Core Metadata Initiative (DCMI) [120], the International Organization for Standardization (ISO) [121], the International Electrotechnical Commission (IEC) [122], the European Committee for Standardization (CEN) [123] and ARIADNE [124].

2.2.2 Metadata Standards

The National Information Standards Organization (NISO) defines metadata as “structured information that describes, explains, locales, or otherwise makes it easier to retrieve, use, or manage an information resource” [125]. Metadata are often called data about data. In the field of educational technology, metadata are mainly used to describe and provide information about digital learning resources. These metadata, known as “Learning Object metadata”, have been defined as “any piece of information that can be used to search, evaluate, acquire and use digital resources that can be reused to support learning” [26]. Examples of Learning Object metadata are a title, a description, the language of the content, a creation date, a set of keywords, a review, rating or comment from a user, an access URL or a list of technical requirements.

Learning Object metadata standards define a set of data fields to describe Learning Objects as well as the terms, properties and formats that may be used. The aim is to enable interoperability among different systems that handle Learning Object metadata by defining a standardized structure (or schema) for the metadata.

The most used metadata standard for Learning Objects is IEEE LOM [119], although there are others which also have been broadly accepted like Dublin Core [120]. In the IEEE LOM standard, the term “metadata instance” is used to refer to the group of information (i.e. metadata fields) that describes a given Learning Object. This term is used in this thesis as well. Metadata instances can be stored in databases as well as represented in many different formats such as XML, RDF, HTML or plain text. The term “metadata record” is used to refer to these representations including database records that store a metadata instance. The process of representing the information contained in a metadata instance and defined according to an abstract model in a specific format is called “binding”. Typically, metadata instances are represented in XML according to standardized XML bindings. This section describes the most relevant metadata standards for Learning Objects including IEEE LOM and Dublin Core.

2.2.2.1 IEEE LOM (Learning Object Metadata)

IEEE LOM is a metadata standard for describing Learning Objects created by the IEEE LTSC with the collaboration of ARIADNE and IMS. The latest version is IEEE LOM 1.0 [119], which was published on 2002. It defines a total of 45 different main metadata fields grouped into 9 categories. Table 2.3 lists all these metadata fields and their corresponding categories.

Each LOM metadata field may be a simple data element or an aggregate data element that contains sub-elements. All elements are optional. The standard also specifies what elements can be included only once and what elements can be repeated. For each of the simple data elements, LOM specifies the *value space* and the *datatype*. The value space determines the set of allowed values for the simple data element. For some elements, the value space imposes no restrictions on the data to be entered, whereas for other elements it imposes that values must be drawn from a vocabulary (i.e. a specific list of values like the list of language codes ISO-639:1988) or must be entered in a specific format (e.g. vCard or ISO 8601 date format). The datatype indicates whether the value of a simple data element is simply a string of characters or one of the following items: LangString (represents one or more strings of characters and their languages), Vocabulary (represents a value from a specific vocabulary including its source), DateTime (represents a point in time accompanied by a description) or Duration (represents an interval in time accompanied by a description).

Table 2.3: IEEE LOM 1.0 Base Schema: Categories and Metadata Fields

Category Name	**Description**	**Metadata Fields**
General	General information that describes the Learning Object as a whole.	Identifier, Title, Language, Description, Keywords, Coverages, Structure, Aggregation Level
Life Cycle	Current state of the Learning Object and entities that have created it or have contributed in any other way to its state.	Version, Status, Contributors
Meta-Metadata	Information about the metadata instance itself including its contributors.	Identifier, Contributors, Metadata Schema, Language
Technical	Technical characteristics and requirements of the Learning Object.	Format, Size, Location, Requirements, Installation Remarks, Other Platform Requirements, Duration
Educational	Educational and pedagogical characteristics of the Learning Object.	Interactivity Type, Learning Resource Type, Interactivity Level, Semantic Density, Intended End User Role, Context, Typical Age Range, Difficulty, Typical Learning Time, Description, Language
Rights	Copyrights and conditions of use for the Learning Object.	Cost, Copyright and Other Restrictions, Description
Relation	Relationships between the Learning Object and other Learning Objects.	Kind, Resource
Annotation	Comments and reviews of the Learning Object from users and systems.	Entity, Date, Description
Classification	Classification of the Learning Object in specific classification systems.	Purpose, Taxon Path, Description, Keyword

The standard "1484.12.3-2005 - IEEE Standard for Extensible Markup Language (XML) Schema Definition Language Binding for Learning Object Metadata" created by the IEEE LTSC defines how LOM metadata instances should be represented in XML. The IEEE LTSC started to work in another standard entitled "1484.12.4 – IEEE Standard for Resource Description Framework (RDF) binding for Learning Object Metadata data model" to define how to represent LOM metadata instances in RDF, but its development was halted.

The base schema defined by LOM can be extended with new data elements and vocabulary values. Nevertheless, LOM extensions should not replace data elements of the base schema and should retain their original value space and datatype. Several LOM application profiles have been created to extend and adapt LOM to make it more suitable for its application by a particular community. For instance, the LOM application profiles CanCore [126], [127], UK LOM CORE [128] and LOM-ES [129], [130] have been defined to satisfy, respectively, the specific needs of the educational communities of Canada, United Kingdom and Spain. Besides, some Learning Object Repositories such as the ODS portal [131], [132] or the LRE [133], [134] have created their own LOM profile in order to provide richer metadata. In LOM applications profiles LOM elements may be dropped, elements from other metadata schemes may be brought in and LOM vocabularies may be extended. Guidelines about how to build LOM application profiles are provided in [135].

LOM defines two levels of conformance to the standard: strict and non-strict. A strictly conforming LOM metadata instance consists solely of LOM data elements. A (non-strictly) conforming LOM metadata instance may contain extended data elements. All data elements are optional, conforming LOM metadata instances may include any subset of LOM data elements. Three schema validation approaches are provided for LOM metadata instances represented in XML: strict, custom and loose. The strict validation does not allow extensions, only permits LOM vocabulary and enforces uniqueness constraints. It can be used to validate strictly conforming LOM metadata instances. The custom validation permits extensions and custom vocabularies but checks if the used extensions conform to their limitations, validates vocabulary values and enforces uniqueness constraints. It can be used to validate conforming LOM metadata instances. Finally, the loose validation permits extensions and checks if they conform to their limitations but does not check vocabulary values or uniqueness constraints. This validation does not guarantee that a metadata instance is conforming to LOM.

2.2.2.2 IMS LRM (Learning Resource Meta-data)

IMS collaborated in the creation and drafting of the IEEE LOM standard [119]. Early drafts of the LOM schema were endorsed by IMS as the first versions of the IMS LRM specification (versions 1.0 – 1.2.2) [136]. IMS released the first version of IMS LRM to the public in 1999, with minor revisions made based on updates of the LOM schema being released periodically up to the version 1.2.2 in 2001. Feedback and suggestions from IMS LRM implementers were taken into account and incorporated in the development of IEEE LOM resulting in some drift between IMS LRM 1.2 and the final version of IEEE LOM. IMS LRM 1.3 [136], which is the latest version and was published in 2006, realigns IMS LRM with IEEE LOM and specifies that the IEEE LOM XML binding should be used. Therefore, IEEE LOM 1.0 and IMS LRM 1.3 can be considered equivalents (at least with respect to the data schema). The IMS LRM specification also provides guidelines to assist implementers and developers in using the standard and creating application profiles, as well as tools for transforming metadata defined according to earlier versions of IMS LRM to IEEE LOM metadata.

2.2.2.3 Dublin Core

Dublin Core is a set of vocabulary terms for use in the description of any type of resource created by the Dublin Core Metadata Initiative (DCMI) [120]. The "Dublin Core Metadata Element Set" defines a vocabulary of 15 terms: contributor, coverage, creator, date, description, format, identifier, language, publisher, relation, rights, source, subject, title and type. This vocabulary achieved wide dissemination and was endorsed in the following standards: "IETF RFC 5013", "ISO Standard 15836:2009" and "ANSI/NISO Standard Z39.85-2012". "Simple Dublin Core" or "Unqualified Dublin Core" metadata refers to metadata that only use the 15 terms of the Dublin Core Metadata Element Set expressed as simple attribute-value pairs where the values are simply strings of characters. In a Simple Dublin Core metadata instance, all elements are optional and may be repeated if required.

Several changes, refinements and extensions were made to Simple Dublin Core resulting in a new version of Dublin Core, which was historically termed “Qualified Dublin Core”, although nowadays is called just Dublin Core. This new version encompasses several documents including the “DCMI Abstract Model” and the “DCMI Metadata Terms” specifications. All documents are available on the DCMI website [120]. The first specification defines an abstract model for Dublin Core metadata called DCMI Abstract Model. The DCMI Metadata Terms specification details the current full set of Dublin Core metadata terms, including the 15 of the classic Dublin Core Metadata Element Set, and also includes sets of resource classes as well as vocabulary and syntax encoding schemes. DCMI provides guidelines for the creation of Dublin Core application profiles and syntax guidelines for expressing Dublin Core metadata in different formats such as plain text, HTML, XML and RDF. This new version, while guided by sound theoretical principles, is as yet unproven by mass implementation [137].

It is also worth pointing out that Dublin Core defines metadata fields that are generic for any type of resource. It is not focused on education and some major educational characteristics of learning resources cannot be described in an interoperable way. According to DCMI, the DCMI Education Community [138] is working on a Dublin Core application profile for the education domain called DC-Education. More information about this work can be found at [137], [139].

A mapping between Simple Dublin Core and IEEE LOM is provided in the annex B of the LOM standard [119]. The Joint DCMI/IEEE LTSC Task Force initiative elaborated a document entitled “IEEE P1484.12.4/D1 Draft Recommended Practice for Expressing IEEE Learning Object Metadata Instances Using the Dublin Core Abstract Model” to provide recommendations for expressing IEEE LOM metadata using the same abstract model as Dublin Core. However, although this document was intended to be ratified by the IEEE LTSC and by the DCMI [139], it never became a standard and today is not provided in any of their websites. The process of mixing two metadata standards based on different abstract models is quite complex and presents severe limitations, even if metadata mappings are used [140]. This issue was addressed in [141], where a IEEE LOM to Dublin Core mapping was developed and put into use.

2.2.2.4 ISO/IEC MLR (Metadata for Learning Resources)

ISO/IEC MLR is a standard formed by multiple parts defined by standards of the ISO/IEC 19788 family. Its main objective is to specify metadata elements and their attributes for the description of learning resources. ISO/IEC MLR has been developed based on previous experiences in the implementation of metadata standards for learning resources, especially IEEE LOM [119] and Dublin Core [120]. Portability of metadata defined according to these two standards is possible, at least to some extent [142].

At the time of writing and according to the ISO website [121], seven parts of the standard have been published and two more are under development:

- *Part 1: Framework (ISO/IEC 19788-1:2011)*. This part defines how data elements for the description of learning resources should be specified. It provides principles, rules and structures for the ISO/IEC MLR standard.
- *Part 2: Dublin Core elements (ISO/IEC 19788-2:2011)*. It specifies a data element set for ISO/IEC MLR with the same terms as the Dublin Core Metadata Element Set (ISO 15836:2009), enabling this way the representation of Simple Dublin Core metadata instances using ISO/IEC MLR.
- *Part 3: Basic application profile (ISO/IEC 19788-3:2011)*. It has been designed to help implementers with a starting point for adopting the standard and defining an application profile for specifying how the element set defined in Part 2 can be used.
- *Part 4: Technical elements (ISO/IEC 19788-4:2014)*. It specifies technical aspects of the learning resources such as requirements for use, location, size, etc.
- *Part 5: Educational elements (ISO/IEC 19788-5:2012)*. It specifies educational aspects of the learning resources across various educational, cultural and linguistic settings.
- *Part 7: Bindings (ISO/IEC FDIS 19788-7, under development)*. This part is intended to define different bindings for ISO/IEC MLR such as XML and RDF bindings.
- *Part 8: Data elements for MLR records (ISO/IEC 19788-8:2015)*. It specifies how to storage ISO/IEC MLR metadata instances in databases and how to exchange metadata instances through harvesting mechanisms. It also provides data elements for the description of ISO/IEC MLR metadata records.
- *Part 9: Data elements for persons (ISO/IEC 19788-9:2015)*. It provides data elements for the description of entities that are related to the description of a learning resource.
- *Part 11: Migration from LOM to MLR (ISO/IEC TR 19788-11, under development)*. This part is intended to provide guidelines and recommendations for the conversion of IEEE LOM metadata instances to ISO/IEC MLR.

More information about this standard including comparisons with IEEE LOM and Dublin Core can be found in the literature [142], [143].

2.2.2.5 LRMI (Learning Resources Metadata Initiative)

The LRMI specification is a collection of properties to describe educational resources built on the extensive vocabulary provided by Schema.org [144], [145]. Schema.org is a collaborative community activity with a mission to create, maintain, and promote schemas for structured data on the Internet [146]. The idea of Schema.org is that content publishers can insert machine readable information into the HTML code of web pages helping this way search engines to understand the content on those pages. Schema.org relies on an ontology, which defines a hierarchy of resources and a vocabulary for naming the characteristics of those resources, and a specification of how to provide information in machine readable formats.

LRMI was created to identify additions to the Schema.org ontology that would facilitate the discovery of e-Learning resources through search engines. LRMI was initially led by Creative Commons and the Association of Educational Publishers, but it was transferred to DCMI [120] in 2014. The latest version is LRMI 1.1 [144], which was accepted into Schema.org (with the exception of one property) in 2013 and was published by DCMI in 2014. An RDF binding for LRMI was defined and can also be found at the DCMI website.

2.2.3 Content Integration Standards

2.2.3.1 AICC CMI

The “CMI001 - AICC/CMI Guidelines for Interoperability” specification [108], usually known as AICC CMI, defines interfaces and rules to allow e-Learning resources to interoperate with LMSs. It specifies the mechanism that an LMS should used to launch e-Learning resources, common mechanisms and data models for communication between an LMS and the resources, and a common definition for organization and sequencing of those resources. It is the most relevant specification produced by AICC. The first version was released in 1993 and it is considered the first runtime interoperability specification for LMSs in history. The specification had two major updates: one in 1998 to add a web-based API known as HACP (HTTP/S-Based AICC/CMI Protocol), and another one in 1999 to add a JavaScript API. This work was later used in the development of SCORM [110].

2.2.3.2 IMS CP (Content Packaging)

IMS CP is a specification focused on the packaging and transport of e-Learning resources that describes data structures that can be used to exchange data between systems that wish to import, export, aggregate and disaggregate packages of content [113]. IMS content packages enable exporting content from one e-Learning system such as an LMS or a Learning Object Repository and importing it into another one while retaining information describing the packaged content. IMS CP is developed by IMS and the latest version is IMS CP 1.2, which dates from 2007. At the time of writing, IMS CP 1.2 is still a draft and is undergoing standardisation by ISO/IEC. The description provided in this section corresponds to this version.

In IMS CP, a logical package is one which includes all the components of the content package, regardless of whether they are local or remote, or whether they are referred to directly or indirectly. An interchange package is the collection of files that can be exchanged between systems. The interchange package can, but does not have to, physically contain all of the components scoped by the logical package. IMS CP requires the interchange package to have some type of file system representation. The interchange package may be instantiated in a single compressed binary file (typically a ZIP file) or as a collection of files on portable media such as a DVD or a USB memory device. When the interchange package consists of a single file, it is called "package interchange file" (PIF) or just "interchange file". The central part of the interchange package is the manifest, an XML file that adheres to the IMS CP schema and that fully describes the logical package including the content organization, all its resources and the relationships among these resources. A manifest should be included in the interchange package and all resources of the logical package should be described in this manifest. The manifest file contains the following sections:

- *Metadata*. The metadata section describes the logical package as a whole and the packaged content in a structured way. External metadata objects are allowed. IMS CP does not specify how metadata should be provided and therefore any metadata standard can be used, although typically IEEE LOM [119] or IMS LRM 1.3 [136] is used.
- *Organizations*. An organization specifies a way for structuring the packaged resources. At least one organization must be specified in the manifest and more than one can be included. The only structure of content organization defined by IMS CP is "hierarchical". Therefore, organizations are usually used to define linear sequencing of content or content organizations in the shape of a tree.
- *Resources*. It consists of a collection of references to the resources of the logical package and metadata describing these resources. The references can be local or remote.
- *Child Manifests*. One or more child manifests can be included in a parent manifest. Each of them should be included as a new section. Child manifests describe other complete IMS logical packages, which are parts of the package that contains the parent manifest. The child manifests may be local or remote.

IMS CP 1.2 defines several types of IMS content packages:

- *Simple standalone package*. A Learning Object packaged as an IMS simple standalone package consists of a ZIP file that contains the manifest XML file named "imsmanifest.xml" placed at the root directory of the ZIP file and all the local resources of the Learning Object. In this type of package there are no child manifests and metadata are usually included directly inline in the manifest file. Metadata can also be included in other files contained in the ZIP file and referenced in the manifest. However, earlier versions of IMS CP state that the support for external metadata requires the usage of an extension. Although not common, an IMS simple standalone package can have remote resources. In this case, all the remote resources of the Learning Object are referenced in the manifest file. This type of package is also known as "classic package" and it is the most used and supported. By default, this thesis always refers to this type of package.

- *Bare manifest*. This package type consists of either just the manifest file, or the manifest file as the sole content of a ZIP file (or other interchange file). An IMS bare manifest package does not include the resources in the interchange file. Instead, it references all them via links to a known repository.
- *Composite or meta-package*. Similar to the bare manifest package, but it links to other entire IMS content packages rather than just conventional resources such as web pages. The support of this type of package is still limited.
- *Archive package*. It is not intended for presentation to a learner. Instead, it is used to store resources without organization for future use. One typical use of this package type is to exchange raw content files that can be turned into finished packages later.
- *Specialized packages*. These packages are used to convey very specific types of content, typically defined according to other IMS specifications such as IMS QTI [115]. A significant part of the content described in the manifest is neither an external file nor a structure that conforms to IMS CP. Instead, these packages contain descriptions of specific data in some standard XML dialect. Therefore, in these cases IMS CP merely provides a convenient way of aggregating such descriptions. The specifications that use IMS CP for packaging usually provide guidance on how to use it.

In addition to define the content package data structures and their relationships, the IMS CP specification also provides a document that describes an XML binding for IMS CP and guidelines for implementing IMS CP and for creating IMS CP application profiles.

IMS CP has become a widely used and supported e-Learning standard. Several IMS specifications such as IMS QTI rely on IMS CP for packaging. Besides, other e-Learning standards also use IMS CP. For instance, SCORM 1.2 [147] adopted IMS CP 1.1.2 and SCORM 2004 [110] adopted IMS CP 1.1.4. Thus, earlier IMS CP versions are still widely used.

The major differences between IMS CP 1.2 and earlier versions are that IMS CP 1.2 incorporates many clarifications, includes support for remote metadata objects and remote child manifests, and enhances the use of child manifests. Earlier versions of IMS CP focused almost exclusively on exchanging simple standalone packages (i.e. ZIP files). IMS CP 1.2 continues to support that approach, but also broadens the exchange of content to exchanging logical packages rather than only physical ones. Another difference is that earlier versions specify as default metadata standard IMS LRM 1.3 while IMS CP 1.2 does not recommend or specify any metadata format. IMS CP 1.2 was designed for backwards compatibility with earlier versions. XML instances of IMS CP that validate against the IMS CP 1.1.4 schema also validate against the IMS CP 1.2 schema. New software components conforming to IMS CP 1.2 are expected to be able to process older IMS content packages as designed.

2.2.3.3 SCORM (Sharable Content Object Reference Model)

SCORM is comprised of a collection of technical standards and specifications which define a standardized way to package web-based resources, integrate and launch those resources in LMSs, establish communication between the resources and LMSs and specify their sequencing and navigation [110]. Today, it is the most used content packaging e-Learning standard [148] and it is supported in most of the major LMSs. Although SCORM is focused on LMSs, it can be implemented by other e-Learning systems. SCORM was created by ADL with the first implementable version launched in 2001. SCORM has evolved through the years and as a consequence nowadays there are several different implementable versions [149]. The most widely adopted version is SCORM 1.2 [147], which was launched in 2001. The latest and recommended version is SCORM 2004 4th Edition [110], which was launched in 2009 and it is also widely used. On the ADL website can be found all books, documentation and resources of SCORM 1.2 [147] and SCORM 2004 4th Edition [110]. This section provides a summary of SCORM 2004 4th Edition (hereafter SCORM 2004 for short) and its key differences with SCORM 1.2. The specifications of SCORM 2004 are classified into three different books: “Content Aggregation Model” (CAM), “Run-Time Environment” (RTE) and “Sequencing and Navigation” (SN). Next, a summary of each of these books is provided.

2.2.3.3.1 SCORM 2004 Content Aggregation Model

The SCORM 2004 CAM book specifies how to package web-based resources through SCORM Content Packaging, an extension of the IMS CP 1.1.4 specification [113]. SCORM Content Packaging describes how to apply IMS CP within the context of SCORM and define additional requirements to integrate other specifications and ensure interoperability. Two application profiles are defined: “Resource Content Package” and “Content Aggregation Content Package”. The first one defines a mechanism for packaging resources without organization. The resulting packages are not intended for presentation to a learner. Instead, they are intended exclusively for moving resources from one system to another. The second profile specifies how to build packages that allow delivering the packaged content to end users, typically through an LMS. These packages are similar to the simple standalone packages defined in IMS CP and explained in the previous section. They consist of ZIP files that contain a manifest file in XML format that strictly adheres to IMS CP 1.1.4 and all the local resources. Remote resources, if any, are referenced in the manifest file. In practice, these are the packages that are used almost always. This thesis always refers to this type of SCORM package.

According to SCORM CAM, a resource can be a SCO (Shareable Content Object) or an asset. A SCO is a resource that will use the SCORM API to interact with the SCORM RTE when it is launched and while it is running in order to communicate with the VLE (typically an LMS) into which it has been integrated and launched. A SCO is required to adhere to the requirements defined in the SCORM RTE book. An asset is a resource that is used in a learning activity but does not use the SCORM API. Only resources of type “webcontent” are allowed. In addition to SCOs and assets, SCORM CAM defines other components: activities, content organizations and content aggregations. Activities are conceptual components that may be described as meaningful units of instruction. In practice, an activity may be a learning resource (a SCO or an asset) or it may be composed of several sub-activities. Content organizations are defined as IMS CP organizations and have their same function. An organization contains items, where each of these items can reference a resource or contain sub-items. Thereby, content organizations are used to describe different hierarchies of activities that exploit the learning resources. An activity may be defined as an item that references a resource, as a collection of items or as an organization. Finally, a content aggregation component refers to the whole SCORM package.

The SCORM 2004 CAM book specifies how to use IEEE LOM metadata to describe the different components and how to include those metadata in XML format in a SCORM package. Although other metadata standards can be used, SCORM strongly recommends the use of IEEE LOM 1.0 [119]. A relevant difference with respect to the IMS content packages is that SCORM packages may not include the metadata inline in the manifest but in other files contained in the ZIP file and referenced in the manifest.

Lastly, the SCORM 2004 CAM book also describes how to build sequencing information in XML and how to place that information in the manifest file. Sequencing refers to the order in which resources will be presented to the learner. An intended sequencing is defined as part of a content organization, by structuring activities in relation to one another and by specifying sequencing rules and behaviours. Sequencing information is defined based on the IMS SS 1.0 specification [117]. If a SCORM package does not include any sequencing information, the implied default behaviour is to allow learners to freely choose any resource. More details on sequencing information are provided in the SCORM SN book.

2.2.3.3.2 SCORM 2004 Run-Time Environment

The SCORM 2004 RTE book defines how the web-based resources have to be launched in LMSs and the way of doing the communication between SCOs and LMSs using the SCORM API and the SCORM RTE Data Model.

The launch process described in this book defines a common way for LMSs to start the web-based resources in the learners’ web browsers. This process also defines procedures and responsibilities for the establishment of communication between the LMSs and the launched SCOs. LMSs are responsible at all times of determining which resource should be delivered to a learner based on the navigation events and taking into account the defined sequence information and the learner performance in previously experienced resources. LMSs must launch the resources using their URLs. If a resource is an asset, LMSs only track the fact that it has been launched. Once an asset has been launched, it will be considered "completed" and "satisfied" for purposes of further sequencing evaluations. If a resource is a SCO, LMSs must also track the data reported by the SCO, which are typically generated based on the learners' interactions, and determine its completion and success status. Each uninterrupted period of time during which a learner is accessing a resource is called "learner session". Each tracked effort by a learner to satisfy the requirements of a learning activity that provides a resource is called "learner attempt". An attempt may span one or more learner sessions and may be suspended between learner sessions.

The SCORM API enables standardized communication of data between SCOs and a run-time service typically provided by an LMS via a JavaScript API. It is based on the standard "1484.11.2-2003 - IEEE Standard for Learning Technology - ECMAScript Application Programming Interface for Content to Runtime Services Communication". The SCORM API provides a set of defined functions that SCOs can use in order to retrieve data from an LMS as well as to send and store data in it. All communication between an LMS and a SCO must be initiated by the SCO. The functions exposed by the SCORM API are divided into three categories: session, data-transfer and support. Session functions are used to mark the beginning and end of a communication session. Data-transfer functions allow exchanging values between a SCO and an LMS. Support functions provide auxiliary communications such as error handling. LMSs must launch the SCOs in web browser windows that provide an instance of the SCORM API as a DOM [150] object accessible via JavaScript. This API instance must be provided by the LMSs and must implement and expose the functions of the SCORM API. It is the responsibility of the SCOs to recursively search the parent and/or opener window hierarchy until the API instance is found. SCOs are also required to initialize and terminate the communication. To find and use the API instance provided by an LMS as well as to handle the communication, the SCOs (which basically are web applications) use JavaScript. In this thesis, the API instance expected to be provided by an LMS is termed "SCORM API" and the JavaScript component of the SCOs in charge of finding and managing the SCORM API is termed "SCORM API Wrapper". Web applications can use a SCORM API Wrapper to communicate with a SCORM compliant system through the SCORM API.

The SCORM RTE Data Model defines a set of information about SCOs that can be tracked by an LMS and how to represent, store and process this information. It is based on the standard "1484.11.1-2004 - IEEE Standard for Learning Technology--Data Model for Content Object Communication". The data elements defined by the SCORM RTE Data Model are required to be supported by LMSs but are optional for use by SCOs. The data model should not be extended. LMSs also must maintain the state of SCOs' data elements across learner sessions.

Various information about a SCO can be tracked by an LMS using the defined data elements, including among others:

- *Completion status*. Indicates whether the learner has completed the SCO.
- *Success status*. Indicates whether the learner has mastered or passed the SCO.
- *Progress Measure*. A measure of the progress the learner has made towards completing the SCO.
- *Score*. The learner score or grade for the SCO.
- *Time*. The amount of time the learner has spent on the SCO in the current learner session and in the current learner attempt.
- *Interactions*. Data about various types of interactions the learner had with the SCO.
- *Exit*. Indicates how or why the learner left the SCO.

On the other hand, a SCO can obtain various information from an LMS including:

- *Entry*. Indicates whether the learner has previously accessed the SCO.
- *Launch data*. Specific data for the SCO that it can use for initialization.
- *Mode*. Indicates the mode in which the SCO should be presented to the learner. SCORM defines three modes: "browse", "normal" and "review".
- *Learner profile*. Information about the learner including its identifier in the LMS, its name and its preferences associated with the use of the SCO.
- *Maximum Time*. Amount of time the learner is allowed to use the SCO in an attempt. The action that the SCO should do when this time is exceeded can also be obtained.
- *Suspend data*. A learner attempt can be suspended and resumed later. SCOs can store data between learner sessions and use these data to resume a learner attempt.

Some of the SCORM RTE Data Model elements impact each other or are used in coordination with others. For instance, if a completion threshold is defined, the completion status stored and reported by an LMS will be determined based on the progress value reported by the SCO. If the reported progress value is higher or equal than the completion threshold, completion status will be "completed", otherwise, it will be "incomplete". Something similar occurs with the success status and the score when a score threshold (called passing score) is defined.

The SCORM 2004 RTE book also specifies how to include additional information in the SCORM packages to describe how LMSs are intended to process them. Values of several data elements defined in the SCORM RTE Data Model can be set in the manifest XML file using new elements that extends the IMS CP specification.

2.2.3.3.3 SCORM 2004 Sequencing and Navigation

Firstly, the SCORM 2004 SN book describes the SCORM Sequencing Definition Model, an information model derived from the IMS SS 1.0 specification [117] that defines a set of elements that may be used to define sequencing information. This sequencing information can be applied to learning activities in order to define various sequencing strategies.

Secondly, the book describes the required behaviours and functionality that an LMS must implement for processing sequencing information at run-time in order to sequence SCORM resources. More specifically, it describes how SCORM resources are identified for delivery based on defined sequencing information, sequencing behaviours and results of learners' interactions with previously launched resources.

The SCORM 2004 SN book also describes how navigation events can be triggered (by learners, SCOs or LMSs) and processed resulting in the identification of resources for delivery. Learners can indicate their desired navigation requests using a set of user interface devices provided typically by an LMS but that can also be provided by a SCORM resource or by both. LMSs are required to provide a user interface that allows learners to trigger navigation events. The SCORM Navigation Model defines a minimal presentation model that allows a SCORM resource to indicate the user interface devices it provides in order to prevent LMSs to provide redundant ones. The design of the user interface presented to the learner, including issues such as look and feel, style and placement of navigation controls, is outside the scope of SCORM.

2.2.3.3.4 Major differences between SCORM 2004 and SCORM 1.2

One of the major changes from SCORM 1.2 to SCORM 2004 was the inclusion of content sequencing capabilities based on IMS SS. Regarding metadata, SCORM 1.2 defines application profiles based on older versions of IMS LRM [136] and IEEE LOM drafts while SCORM 2004 relies directly on IEEE LOM 1.0. Another difference is that the RTE functionality of SCORM 1.2 is based on AICC CMI while the SCORM 2004 RTE relies on IEEE standards as indicated above. Therefore, although there are similarities, the API and the elements of the RTE Data Model differ between SCORM versions. Lastly, there are significant differences in the content packaging. SCORM 2004 relies on IMS CP 1.1.4 instead of IMS CP 1.1.2 as SCORM 1.2 does. Besides, in SCORM 2004 several changes were made to content packaging mainly due to the introduction of the sequencing and navigation and the new standards.

2.2.3.3.5 SCORM Conformance

ADL provides a document that defines the requirements that LMSs, SCOs and SCORM packages must adhere to in order to be recognized as SCORM 2004 compliant. ADL also provides a software application called "SCORM Test Suite" for testing LMSs, SCOs and SCORM packages. There is one SCORM Test Suite for SCORM 1.2, which latest version is "SCORM Version 1.2 Conformance Test Suite 1.2.7", and other one for SCORM 2004, which latest version is "SCORM 2004 4th Edition Test Suite 1.1.1". According to ADL, the only criteria that a product need to meet for claiming conformance to a specific version of SCORM is to pass the tests within the corresponding SCORM Test Suite. Furthermore, ADL also offers a sample RTE, examples of SCORM packages and SCORM API Wrappers for SCORM 1.2 and SCORM 2004.

2.2.3.4 xAPI (Experience API)

The xAPI, also called Experience API and formerly known as Tin Can API, is a new e-Learning specification which aims to collect data about learning experiences in a consistent format [111]. The xAPI allows applications to record activities carried out by people during learner experiences (e.g. interactions with content, tools, systems and other people). In order to record an activity, applications send secure statements in the form of "Noun, verb, object" to a Learning Record Store (LRS), which can exist on its own or be hosted in a VLE. Learning Resource Stores can communicate and share data with one another, allowing to follow people from one Learning Resource Store to another. The xAPI is based on REST principles and data are transferred via HTTP in JSON format. The tracked experiences do not have to start and end in a specific VLE, they can start and end wherever the learner is. Besides, xAPI is not tied to any technology so many different technologies and devices can be used to send statements. For example, xAPI allows to track an experience in which a learner starts playing with an educational game in a smartphone and ends interacting with a VLE in a computer.

The xAPI was developed by ADL and Rustici Software with the goal of overcoming all the limitations of SCORM [110]. This is why, although xAPI is not a new version of SCORM, it is considered its evolution. The xAPI allows capturing everything SCORM can but provides much more flexibility and freedom. It is worth pointing out that the packaging and launch of the content is outside the scope of xAPI. Nevertheless, Rustici Software wrote an additional specification for defining how to package and launch xAPI content [151], which has been widely adopted by pretty much every authoring tool and LMS that supports xAPI packaging. Besides, a profile called cmi5 [152] that defines how to launch xAPI content in LMSs was built based on this specification. Although xAPI is expected to be a predominant standard in the future, it is still under development and has not been broadly adopted yet. The latest released version is xAPI 1.0.3, which was published in 2016.

2.2.3.5 cmi5

cmi5 is a profile for using the xAPI with traditional LMSs [152]. It is specifically designed for the use case where the learner launches xAPI content from an LMS user interface. It was built on the specification for launching xAPI content released by Rustici Software [151]. It adds additional features and rules. Concretely, cmi5 defines specific interoperability rules for the following areas: content launch, reporting, authentication, session management and course structure. Rustici Software recommends designing products that use cmi5 if it is supported and fall back to its launch specification if not. Although the cmi5 project was originally started by AICC in 2010, it was transferred to ADL when AICC was dissolved in 2014. Currently, cmi5 is being looked after by ADL. The latest version, entitled "cmi5 Specification Profile for xAPI, Quartz - 1st Edition", was released in June 2016.

2.2.3.6 IMS LTI (Learning Tools Interoperability)

The IMS LTI specification defines a standard and secure way to integrate rich web-based learning applications (often remotely hosted and provided through third-party services) in online learning systems such as LMSs [114]. LTI aims to allow e-Learning systems to securely launch and communicate with web-based, externally hosted applications (e.g. a chat or a virtual lab) and run them as if they were an integrated part of the system. In LTI, the systems that deliver these applications are called Tool Providers (TPs) and the systems that integrate them are called Tool Consumers (TCs). TCs are responsible of authenticating and authorizing learners and of providing data about the learners and their context to the TPs.

The first version is LTI 1.0 (formerly referred to as Basic LTI), which was released by IMS in 2010. Its major drawback is that the communication between a TC and a TP is lost after launch. Thus, an application can receive contextual information but cannot send tracking data to the TC. LTI 1.1 partially alleviated this issue by enabling applications to return grades to the TCs and allowing these grades to be included in the grade books of the TCs. The latest version is LTI 2.0 and was released in 2014. A major rewrite of LTI 1.1 was done to produce it. Nevertheless, LTI 2.0 continues to support all LTI 1.1 functionality and it is fully backwards compatible. LTI 2.0 provides some common services and also an architecture for REST web services that allows the definition of new services without affecting the core standard. It supports tool settings, more sophisticated outcomes reporting, and bidirectional communication between TCs and TPs. LTI 2.0 uses two types of message flows. When a TC communicates with a TP, messages are sent through the user's web browser. The second type is where a TP calls a service of a TC. In this case, messages are sent in JSON-LD format through direct connections between the TC and TP servers using HTTP. The OAuth (Open Authorization) 1.0a protocol is used to secure message interactions between TCs and TPs. Other version termed LTI 1.2 was co-developed with LTI 2.0. This version is a hybrid of LTI 1 and LTI 2 that was produced with the intention to provide a transition step to LTI 2.

2.2.3.7 IMS QTI (Question and Test Interoperability)

The IMS QTI specification describes a data model for the representation of question and test data and their corresponding results reports [115]. The data model is described abstractly but an XML binding is provided. IMS QTI was designed to provide a standardized content format for storing and exchanging questions and tests regardless of the authoring tool used to create them and for reporting test results in a consistent manner. It enables the exchange of questions, tests and results reports through XML files between authoring tools, question banks, VLEs and other e-Learning systems. IMS QTI is the most used e-Learning standard for representing tests [148]. The latest major version is IMS QTI 2.2, which was released in 2015. An update of the documents of this version was published in July 2016 as the IMS QTI 2.2.1 specification.

IMS QTI 2.2 considers three main elements: tests, sections and items. According to IMS QTI 2.2, a test (also referred to as assessment) consists of one or more parts, each part consists of one or more sections and each section consists of one or more subsections and/or items. A test must have at least one part, a part must have at least one section and a section must have at least one item or other section. An item is defined as a set of interactions collected together with any supporting material and an optional set of rules for converting the learner's response/s into assessment outcomes. Typically, an item represents just one question with one point of interaction (e.g. a multiple choice question). These items are termed “simple items”. IMS QTI 2.2 supports the following interactions: choice, inline choice, order, associate, match, gap match, text entry, extended text entry, hottext, hotspot, select point, graphic order, graphic associate, graphic match gap, position object, slider, media, drawing and upload. Thereby, it allows representing in XML files practically any type of question including among others: multiple choice, multiple response, true/false, sorting, matching, short answer, open-ended, fill in the blanks and hotspot. Custom interactions can be also defined. IMS QTI 2.2 allows specifying several settings for questions and tests such as the scoring method, feedback, hints, number of allowed attempts, time limit, branch rules, choices and items shuffling. It provides many other features such as adaptive items, random values, HTML5 tags, CSS stylesheets, MathML and the support of several types of resources including text, images and HTML5 audio and video elements. Besides, it has been designed to support application profiles. Any IMS QTI test, section and/or item or combination can be exchanged as a ZIP file (termed IMS QTI package) according to a profile of IMS CP 1.2 [113]. IMS QTI 2.2 also provides a profile that extends IEEE LOM [119] for describing items, tests and question banks with QTI specific metadata. Finally, IMS QTI 2.2 also defines a data model for reporting test results data and another data model for reporting statistical information about the usage of IMS QTI items.

2.2.3.8 Moodle XML

Moodle [79] is one of the most popular LMSs. Moodle XML is a Moodle-specific format for importing and exporting questions through XML files to be used with the quiz module of Moodle [153]. Although Moodle XML is not a de jure standard, it has been accepted as a de facto standard by some e-Learning systems like Miriada X [90]. It is much simpler than IMS QTI [115]. The latest version is the one defined by Moodle 3.3 which was released in 2017. The documentation is available at [153]. A Moodle XML file contains a quiz with one or more questions. Moodle XML allows representing in XML the following types of questions: multiple choice, multiple response, true/false, short answer, numerical response, matching and essay. It supports some features such as feedback, choices shuffling, score weighting and images. In Moodle XML there are no metadata or packages, the questions are interchanged between systems using directly XML files.

2.2.3.9 IMS CC (Common Cartridge)

IMS CC is a set of open standards that aims to enable interoperability between web-based resources and systems [116]. It defines a standard way of representing and packaging e-Learning content for use in online learning systems and how these systems can launch and exchange data with external applications. IMS CC 1.3 was released in 2013 and defines:

- A format to exchange e-Learning resources and their metadata between systems using content packages called "common cartridges". This format is defined through a profile of IMS CP 1.2 [113] and hence common cartridges adhere to IMS CP 1.2.
- A profile of the IEEE LOM metadata standard [119] for describing the content in the cartridges. All LOM metadata fields are supported. This profile also provides a mapping between the terms of the Dublin Core Metadata Element Set [120] and IEEE LOM.
- A profile of IMS QTI 1.2.1 [115] for representing questions and tests in XML format.
- A profile of IMS LTI 1.0 [114] to allow LMSs to launch and exchange data with external applications. These applications are included through IMS LTI links. An IMS LTI link is defined as a resource in the manifest XML file that contains all the data needed by an LMS to create a link to the application. Applications can receive contextual information about the learner and the LMS but they cannot report any data to the LMS. In IMS CC, content authorization can be provided by using IMS LTI links.
- Support for several types of resources including web content resources, web links, IMS LTI links, IMS QTI questions and tests, discussion topics, and IMS IWB [154], IMS APIP [155] and EPUB 3 [156] files.

On 2015, IMS released IMS Thin CC 1.0, a profile that consists of a greatly reduced set of the full IMS CC 1.2 and 1.3 specifications. It only supports two resources: web links and IMS LTI links. More details about IMS CC and a comparison with SCORM can be found at [157].

2.2.4 Educational Design Standards

2.2.4.1 IMS SS (Simple Sequencing)

IMS SS defines a data model for representing the intended sequencing behaviour of an authored learning experience so that any e-Learning system can sequence learning resources in a consistent way [117]. It also defines the behaviours and functionality that these systems must implement for sequencing the resources. IMS SS enables to define the order in which resources are to be presented to the learners and the conditions under which a resource is selected, delivered or skipped during presentation. It incorporates rules for defining the branching of instruction through resources according to the results of the learners' interactions. The intended sequencing behaviours can be defined manually or using authoring systems. IMS SS also defines an XML binding for its data model and how to include these data in the manifest XML file of an IMS content package [113] by extending the organization component. IMS SS 1.0 was released in 2003 and, at the time of writing, no other versions have been published.

2.2.4.2 IMS LD (Learning Design)

IMS LD is a specification that defines a generic and flexible information model to describe and represent learning designs, where these learning designs are defined as “descriptions of a method enabling learners to attain certain learning objectives by performing certain learning activities in a certain order in the context of a certain learning environment” [158]. It also describes a set of behaviours that systems must implement to process these learning designs. An XML binding is provided to represent the learning designs in XML. IMS LD allows including in an e-Learning resource standardized data describing the learning design or methodology for which it was designed. These data can be used to adapt or interpret the resource under different situations. A learning design is specified as a group of “persons”, each with a “role” (learner or staff), that performs a time ordered series of “activities” in order to achieve stated “learning objectives”, within the context of an “environment” consisting of “Learning Objects” (defined as web resources) and/or “services”. A learning design specifies one or more “plays” (often only one), each play contains a number of “acts” that will be run in sequence, and each act has a set of “role-parts” which will run together in parallel. Each role-part indicates the activities that should be carried out by a role in an act. An activity can have their own learning objectives and usually references an environment which contains the web resources and/or services to be used in that activity. IMS LD also specifies how to integrate a learning design in an IMS content package [113] as another type of organization. IMS LRM [136] and IEEE LOM [119] metadata can be used to describe the learning designs. IMS LD 1.0 was released in 2003 by IMS and, at the time of writing, no other versions have been published.

2.2.5 Learner Information Standards

2.2.5.1 IMS LIP (Learner Information Package)

IMS LIP is a specification that describes a data model, an XML binding and best practices for the representation, storage and exchange of learner information [159]. It supports the exchange of learner information among LMSs, student information systems and other e-Learning systems. The mechanisms used to exchange learner information are outside the scope of the specification. IMS LIP aims to describe those characteristics of a learner needed for the general purposes of recording and managing learning related history, goals and achievements, engaging a learner in learning experiences, and discovering learning opportunities for learners. IMS LIP represents learner information separated into the following 11 categories: identification (biographic and demographic data); goal (learning, career and other objectives and aspirations); qualifications, certifications and licenses; activity (formal and informal learning activities and work experience); transcript (summary of academic achievement); interest (hobbies and recreational activities); competency (skills and knowledge); affiliation (membership of professional organizations); accessibility (language capabilities, disabilities, eligibilities and cognitive, technical and physical learning preferences); securitykey (passwords assigned to the learner for transactions); relationship (relationships between the other data structures). IMS LIP uses IMS CP [113] to package and exchange learner information. It allows to include in a same package one or more LIP XML instances, each of them representing a learner. The latest version is IMS LIP 1.0.1 and was released by IMS in 2005. IMS also developed the specification IMS ACCLIP [160] that extends IMS LIP with a means to define learner accessibility preferences and accommodations.

2.2.5.2 IEEE PAPI Learner (Public And Private Information for Learners)

IEEE PAPI Learner is a specification formed by multiple parts that describes how to represent learner information in order to allow its creation, storing, retrieving and use by e-Learning systems, individuals and other entities [161]. It represents a learner according to six types of information: contact, relationships, security (credentials), preferences, performance (including learner's history, current work and future objectives), and portfolio (a representative collection of a learner's works and references to them intended for illustration and justification of his/her achievements and abilities). Besides, new information types can be included. An XML binding is also described. A comparison and mapping between IEEE PAPI Learner and IMS LIP [159] can be found at [162]. Although several drafts of IEEE PAPI Learner were produced, it was never approved as an official standard.

2.2.5.3 IMS RDCEO (Reusable Definition of Competency and Educational Objectives)

IMS RDCEO is a specification that defines an information model for representing, describing and exchanging competencies [163]. It uses the term competency in a very general sense encompassing skills, knowledge, tasks, educational objectives and learning outcomes. Common uses of IMS RDCEO include defining competencies of learners and educational objectives of learning resources. IMS RDCEO allows to include metadata in the competencies and suggests to use IEEE LOM [119]. A binding is described for representing competencies in XML. IMS RDCEO does not address how competencies should be assessed, certified or used. The only version is IMS RDCEO 1.0, which was approved by IMS in 2002.

2.2.5.4 CAM (Contextualized Attention Metadata)

CAM is a schema that allows to represent and store user interactions with online learning environments [164]. CAM records can be used to provide understanding about learners' activity as well as to enable the discovery of popularity, usage burst and trends of learning resources and applications. CAM does not define or suggest bindings for these records. The main element of CAM is the event, which describes one user action and also has related entities (at least one representing the user who performs the action), contextual information (e.g. the item over which the action is performed or the application used by the user) and data about the user session. CAM 1.5 is the latest version of the schema and was released in 2011.

2.2.5.5 IMS Caliper Analytics

IMS Caliper Analytics is a new standard for collecting, representing and reporting rich data about learning interactions [165]. It aims to provide a means for collecting, representing and reporting measures of learning activity in a standardized and consistent way facilitating the development of learning analytics features in online learning environments. At the time of writing, the only version is IMS Caliper Analytics 1.0, which was released by IMS in 2015. It defines data elements called metric profiles for representing and grouping learning activity data gathered across multiple learning environments. There is a base metric profile, but other metric profiles are defined for different types of learning activities. Each metric profile can contain three types of information: entities, actions and events. Each event contains in turn at least an actor, an action, an object and a timestamp. Data are specified in JSON-LD format. The standard also defines a Sensor API for capturing and reporting the learning activity data. Lastly, guidelines about how to integrate IMS Caliper Analytics with IMS LTI [114] are provided.

2.2.6 Architecture and Service Standards

2.2.6.1 OAI-PMH (Open Archives Initiative Protocol for Metadata Harvesting)

OAI-PMH is a protocol for harvesting resource metadata from repositories in such a way that value-added services can be built using metadata from several repositories [166]. This section describes the latest version: OAI-PMH 2.0, which was released in 2002. OAI-PMH considers two classes of participants:

- *Data Providers*. Repositories that support OAI-PMH as a means of exposing structured metadata of resources.
- *Service Providers*. Systems called harvesters that harvest metadata from repositories via OAI-PMH and use those metadata as a basis for building value-added services.

Repositories must be able to provide metadata instances in XML format conforming to Simple Dublin Core [120]. Optionally, repositories may also provide metadata in other standards such as IEEE LOM [119]. In OAI-PMH, metadata instances are termed “items” and the XML representations of the metadata instances according to a specific metadata format are termed “records”. Repositories are required to assign unique identifiers to items. Each record is identified unambiguously by the combination of the identifier of the item from which the record is generated, its metadata format and its datestamp. Records are comprised of three parts:

- *Header*. It contains the item identifier, the datestamp of the record and properties necessary for selective harvesting.
- *Metadata*. This part contains the metadata and indicates their format and XML schema.
- *About*. Contains optional data about the metadata part of the record. It is intended to allow repositories to define specific data (e.g. copyright and provenance statements).

OAI-PMH supports selective harvesting allowing harvesters to limit harvest requests to portions of the metadata available from repositories. Two types of harvesting criteria are supported. On the one hand, harvesters may use datestamps to harvest only those records that were created or modified within a specified date range. Repositories are required to support this harvesting criterion and to update the datestamp of the records when changes occur. On the other hand, repositories may group items into sets for allowing harvesters to harvest only records from items belonging to a specific set. The datestamps and set membership harvesting criteria may be combined in a same harvest request. OAI-PMH uses HTTP as transport protocol and XML for data representation. It defines a total of six requests or verbs:

- *GetRecord*. This verb is used to retrieve a single metadata record from a repository.
- *Identify*. It is used to retrieve information about a repository such as the name, the version of OAI-PMH supported or setting parameters.
- *ListMetadataFormats*. It is used to retrieve the metadata formats available in a repository.
- *ListSets*. It is used to retrieve the sets available in a repository.
- *ListRecords*. This verb is used to harvest records from a repository. Optional arguments enable selective harvesting of records.
- *ListIdentifiers*. This verb is an abbreviated form of ListRecords that retrieves only headers rather than full records (which contain three parts: header, metadata and about).

OAI-PMH has been widely adopted by Learning Object Repositories and digital archives. Although it is mainly used to disseminate metadata, it is also used to harvest resources [167].

2.2.6.2 IMS DRI (Digital Repositories Interoperability)

IMS DRI is a specification whose purpose is to provide recommendations for the interoperation of the most common functions of digital repositories in such a way that these recommendations enable the services that implement them to provide a common interface [168]. IMS DRI 1.0, released in 2003 by IMS, is the latest and only version of the specification. It considers the following interactions between resource utilizers and repositories:

- *Search/Expose*. A resource utilizer search for resource metadata in repositories.
- *Gather/Expose*. A resource utilizer requests and aggregates metadata from repositories.
- *Alert/Expose*. It is intended to allow a resource utilizer to subscribe to specified changes in repositories. The alert function is not addressed in IMS DRI 1.0.
- *Request/Deliver*. A resource utilizer requests a repository access to a resource.
- *Submit/Store*. A resource utilizer moves a resource to a repository.

2.2.6.3 SQI (Simple Query Interface)

SQI is an API for querying Learning Object Repositories in an interoperable way [169], [170]. It is neutral in terms of query languages and results format. SQI supports synchronous and asynchronous queries and allows both stateful and stateless implementations. It is based on a session management concept in order to separate authentication issues from query management. The API methods are classified in four categories: session management, query parameter configuration, synchronous query interface and asynchronous query interface. A detailed description of the methods is provided in the SQI specification [169]. When SQI is used, the source needs to create a connection with the repository. Once a session has been established, the repository awaits the submission of a search request. Several parameters of the interface at the repository can be configured such as the query language and format.

2.2.6.4 PLQL (ProLearn Query Language)

PLQL is a standardized query language for querying Learning Object Repositories [171]. It supports two query paradigms: approximate search, used for locating Learning Objects by means of keyword-based search, and exact search, used for selecting Learning Objects by means of queries on their metadata. PLQL has been designed with the goal of effectively supporting search over IEEE LOM [119], Dublin Core [120] and MPEG-7 metadata. However, it does not assume or require these metadata standards. PLQL aims to be the query language used with SQI [169]. It defines three conformance query levels and four conformance query result levels allowing repositories to implement only a subset of the PLQL functionalities.

2.2.6.5 SPI (Simple Publishing Interface)

SPI is a protocol for publishing Learning Objects and their metadata to repositories [172], [173]. It supports four operations: submit a resource to a repository (by value or by reference), delete a resource from a repository, submit a metadata instance to a repository and delete a metadata instance from a repository. There is no operation to update a resource or a metadata instance. Thereby, SPI allows publishing only metadata, only content or content linked to metadata.

2.2.6.6 IMS LIS (Learning Information Services)

The IMS LIS specification defines how systems manage the exchange of data that describe people, groups, memberships, courses and outcomes within the context of learning [174]. The latest version is IMS LIS 2.0.1 and was released by IMS in 2013. IMS LIS 2.0 defines an architectural model with six services. It describes the data model of the six services and how they are orchestrated to provide the full range of composite services. An implementation is not required to support each and every service and operation. On 2013, IMS published IMS CPS [175], a profile of IMS LIS that defines how systems manage the exchange of information used for the planning and scheduling of courses, the optimal use of facilities within an institution and the corresponding timetables for people within the institution. On 2017, IMS released IMS OneRoster 1.1 [174], a specification based on IMS LIS focused on the schools’ needs to exchange roster information, course materials and grades.

2.3 Learning Objects

2.3.1 Definition

Significant discussion has been devoted to establishing a unifying definition of Learning Objects across the last years without reaching a consensus [2]. Some of the proposed definitions of Learning Objects are presented in Table 2.4 below.

Table 2.4: Learning Object Definitions

Author	Definition
Wiley (2000) [1]	A Learning Object is any digital resource that can be reused to support learning.
IEEE LTSC (2002) [119]	A Learning Object is any entity, digital or non-digital, that may be used for learning, education, or training.
Dalziel (2002) [176]	A Learning Object is an aggregation of one or more digital assets, incorporating meta-data, which represent an educationally meaningful stand-alone unit.
Rehak and Mason (2003) [177]	A Learning Object is a digitized entity which can be used, reused or referenced during technology supported learning.
Polsani (2003) [178]	A Learning Object is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts.
McGreal (2004) [179]	A Learning Object can be defined as any reusable digital resource that is encapsulated in a lesson or assemblage of lessons grouped in units, modules, courses, and even programmes. A lesson can be defined as a piece of instruction, normally including a learning purpose or purposes.
Wisconsin Online Resource Center (2005) [180]	Learning Objects are small, independent chunks of knowledge or interaction stored in a database that can be presented as units of instruction or information. On average, Learning Objects take a learner from 2 to 15 minutes to review and complete. They are based on a clear instructional strategy and intended to cause learning through internal processing and/or action. They are self-contained, interactive, reusable, able to be aggregated and tagged with metadata.
Kay and Knaack (2005) [181]	Learning Objects are reusable, interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners.
McDonald (2006) [182]	A Learning Object is the result of applying a finite set of rules to a simpler Learning Object, in order to construct some meaning, activity or purpose which is used for learning. The degenerate case of Learning Object is a digital element. Therefore, a Learning Object is reusable, is as big as it needs to be in order to construct some meaning, activity or purpose, and must be used for learning.

One of the most cited definitions is the one proposed by the IEEE LTSC in the IEEE LOM standard [119], which states that a Learning Object is “any entity, digital or non-digital, that may be used for learning, education, or training”. This definition has been strongly criticized as being overly broad [178]. In fact, under this definition almost anything can be considered a Learning Object. A narrower definition, that is also frequently referenced, is the one proposed by Wiley [1] which defines a Learning Object as “any digital resource that can be reused to support learning”. Although this definition restricts Learning Objects to learning resources and excludes non-digital resources, it also has been considered too broad by some researchers [178].

Most definitions agree that Learning Objects are digital resources [1], [176], [177], [179]–[182], reusable [1], [177]–[182], and that can be used for education [1], [119], [176]–[182]. Besides, there is a considerable agreement that Learning Objects are self-contained [176], [178], [180]. Some definitions explicitly state that Learning Objects are tagged with metadata [176], [180] or point out that they are built by aggregation [176] or able to be aggregated [180]. In some cases, definitions restrict what can be considered a Learning Object based on other characteristics such as size [180] or interactivity [180], [181].

This thesis defines Learning Objects as **"reusable digital resources tagged with metadata that are self-contained and that can be used for education"**. This definition captures the characteristics that appear more frequently in the Learning Object definitions. It states that Learning Objects are digital learning resources, reusable and self-contained. It also remarks that Learning Objects have metadata. The proposed definition does not impose restrictions on size and considers that a Learning Object is as big as it needs to be in order to provide a meaningful self-contained digital learning resource. However, the potential of a learning resource for reuse increases as its size decreases, and therefore Learning Objects should be sufficiently large to be of educational value but also be small enough to be effectively reused [183]. In general, Learning Objects are expected to be small in terms of the time needed by learners to complete them. Typically, they are intended to be completed by a learner in a single uninterrupted period of time of less than one or two hours. Examples of Learning Objects might include a document or piece of text, a picture, a video, a question, a test, a slideshow, a web page or web application, a simulation tool, an educational game or a combination of these resources.

The fundamental idea behind Learning Objects is that educational content can be broken down into small chunks that can be independently created, combined and reused in various contexts and e-Learning systems [1]. The key difference between Learning Objects and other types of digital learning resources (or e-Learning resources) is that Learning Objects are designed to facilitate reuse of content. The main aim of Learning Objects is to improve reusability in order to minimize production cost, save time and enhance the quality of educational resources. In this context, reusability concerns the capacity of Learning Objects to be used or exploited repeatedly in different e-Learning systems and instructional contexts. A Learning Object can be reused in four different ways:

- *Reuse*. Use the Learning Object as is, without modification.
- *Revise*. Create a new Learning Object by altering or adapting the original one.
- *Remix*. Combine the Learning Object (original or revised) with others to create a new one.
- *Redistribute*. Share the Learning Object (original, revised or remixed) with others.

These forms of content reuse are described in the "4Rs" framework developed by Wiley [184], which identifies four rights that clarify distinctions of what a resource permits by its license.

In order to achieve reusability, Learning Objects are expected to use e-Learning standards. Besides, Learning Objects should have metadata describing the learning resource including information such as the title, description, location, ratings, keywords, language or creation date. Metadata facilitate the search, evaluation, acquisition and use of Learning Objects [26]. The most used metadata standards for Learning Objects are IEEE LOM [119] and Dublin Core [120]. Section 2.2 describes the main e-Learning standards used by Learning Objects in order to standardize different aspects including metadata, content integration, content packaging, sequencing, learner profiles, learner interaction data and services.

Ideally, Learning Objects can be combined among them to build more complex ones forming a hierarchy where the different levels of the hierarchy are called aggregation or granularity levels. Learning Object models (also referred to as Learning Object content or component models) define these levels of granularity and specify how the components can be aggregated as well as the properties of these components [185]. There are many Learning Object models since different e-Learning systems and specifications often specify their own. Descriptions of some Learning Object models can be found at [185], [186]. The Learning Objects that can be combined to form bigger ones and that can be decomposed into smaller ones are said to be granular. Granularity should not be seen as a requirement for e-Learning resources to be considered Learning Objects but as a desirable feature. The process where a Learning Object is assembled by integrating and combining other ones is referred to as authoring by aggregation [187]. As a consequence of this capacity to be combined and decomposed, Learning Objects are sometimes seen as the building blocks of e-Learning resources [188].

2.3.2 Learning Object Life Cycle

The work exposed in this thesis encompasses the design, development and evaluation of various solutions to address and overcome several of the main barriers hampering the use and adoption of Learning Objects along the different stages of their life cycle. Therefore, a clear definition of the stages of the Learning Object life cycle is crucial. Several studies have analyzed the Learning Object life cycle [176], [189]–[193], and have made efforts to identify and define its different stages. This section first reviews these previous approaches to define the Learning Object life cycle and then describes the Learning Object life cycle considered in this thesis.

Probably the most frequently quoted definition of the Learning Object life cycle is the one proposed by Collins and Strijker [189], which considers six distinct stages that are performed one after the other (see Figure 2.1 below):

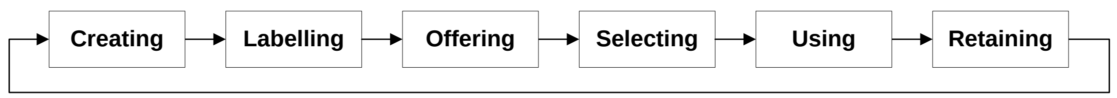

Figure 2.1: Learning Object life cycle proposed by Collins and Strijker [189]

1. *Creating*. The Learning Object is created or obtained.
2. *Labelling*. The Learning Object is tagged with metadata.
3. *Offering*. The Learning Object is offered to an audience for selection and use typically through a repository. The publication and distribution take place in this stage.
4. *Selecting*. The Learning Object is found and selected from repositories or other systems.
5. *Using*. The Learning Object is used directly or it is edited to use an adapted version.
6. *Retaining*. The Learning Object is deleted or revised.

This Learning Object life cycle was enhanced by Cardinaels [190] (see Figure 2.2), which addressed some of its shortcomings. Firstly, the creating stage (where the Learning Object could be created or obtained) was split in two stages: obtaining and authoring. The obtaining stage includes different substeps such as searching, selecting, rights management and downloading. The authoring stage is where the Learning Object is created from scratch or by modifying an existing one. Secondly, instead of considering the labelling as a single event before the Learning Object is offered, this proposal represents the labelling stage spread across all the other stages indicating that the metadata of a Learning Object can be constantly updated during its life. It also remarks that other stages use metadata. Finally, two new stages are defined:

- *Repurposing*. The Learning Object is slightly modified to make it suitable for the other stages. It includes activities such as aggregation and disaggregation.
- *Integration*. The Learning Object is integrated into the learning context in order to enable the learners to use it.

This proposal notably enhances the one proposed by Collins and Strijker [189] by separating the obtaining and authoring stages, by considering the labelling as a pervasive process, and by introducing the integration stage indicating that Learning Objects need to be integrated into VLEs or other systems before they can be used. However, it also has some shortcomings. It starts the life cycle with the obtaining stage assuming the Learning Object is already created. First stage should be authoring because nothing can be done with a Learning Object before its creation. Besides, the quality evaluation of the Learning Object and the user feedback are not considered in the life cycle, even though they are of crucial importance.

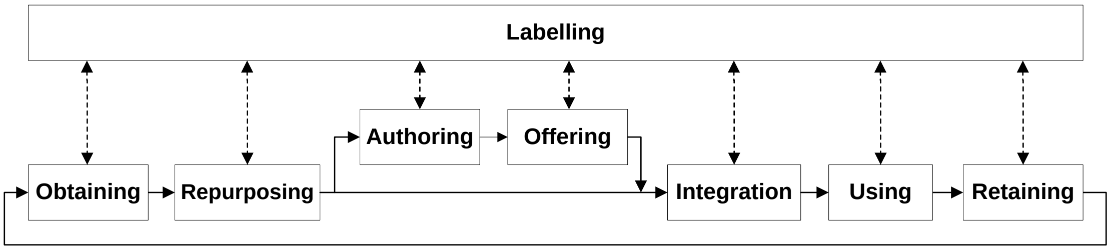

Figure 2.2: Learning Object life cycle proposed by Cardinaels [190]

A Learning Object life cycle that takes into account the quality management was proposed by Van Assche and Vuorikari [191] (see Figure 2.3). Several stages defined in the previous life cycles appear with different names (Authoring is renamed to Create, Labelling to Describe, Offering to Publish, and Repurposing to Repurpose and Reuse). Searching is moved from obtaining to a new stage called discovery, which considers additional ways of distributing Learning Objects such as recommender systems. Besides, other new stages are included:

- *Approve*. The Learning Object is approved for publication after a quality assurance process such as a peer review, an expert evaluation or a decision of the staff.
- *Evaluate*. The Learning Object is evaluated for selection by users.
- *Resolution.* The permission to obtain the Learning Object is granted or denied to the user. Digital rights management is addressed in this stage.
- *Retract*. The publisher of a Learning Object retracts it.
- *Local delete.* The Learning Object is locally deleted by a user.

Although this proposal makes an important contribution by introducing stages related to quality management, it still has important gaps. Quality assurance processes such as peer review are only considered before publication. This limitation should be removed because there are repositories with quality control policies that allow Learning Objects to be evaluated after publication. Other gap is that user evaluation is only considered as a preliminary step for selecting Learning Objects and that user feedback is not taken into account. Another important gap is that labelling is considered a single event instead of a pervasive process. Lastly, the inclusion of results from the quality assurance processes into the metadata is not contemplated.

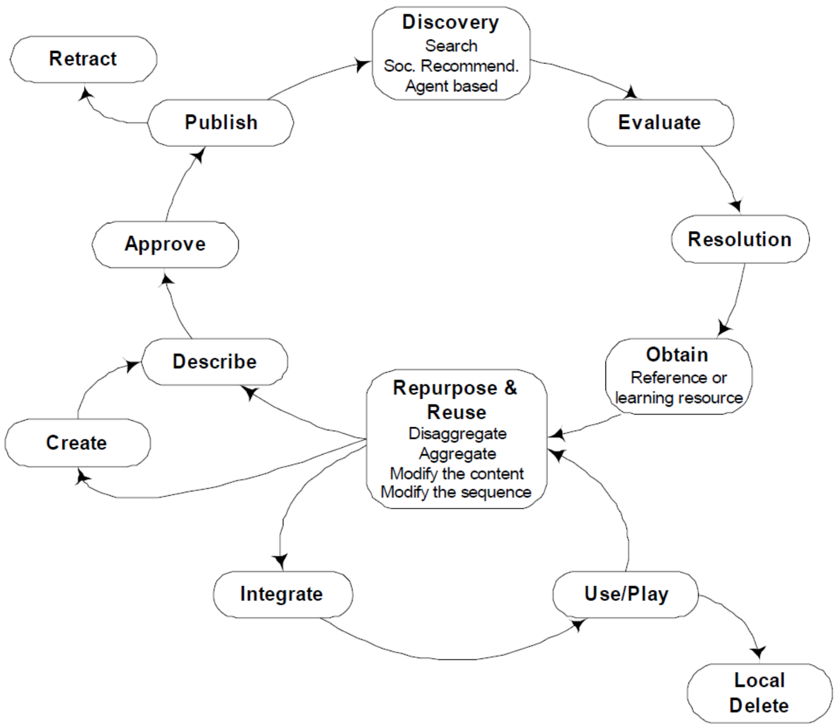

Figure 2.3: Learning Object life cycle proposed by Van Assche and Vuorikari [191]

User feedback (e.g. comments, ratings) is incorporated in the Learning Object life cycle defined by Sampson and Zervas [192] represented in Figure 2.4. This life cycle is similar to the previous one but has some relevant differences. For instance, it considers that before creating a new Learning Object a search of related Learning Objects should be carried out to reuse them. Other important differences are the inclusion of a feedback stage after the use stage, and the definition of the repurpose and reuse stage with more detail representing three sub-functions: disaggregate, adapt and aggregate. This proposal considers usage feedback from users but the other gaps present in the proposal of Van Assche and Vuorikari [191] remain. Besides, the representation of the life cycle is much more complex than the previous proposals.

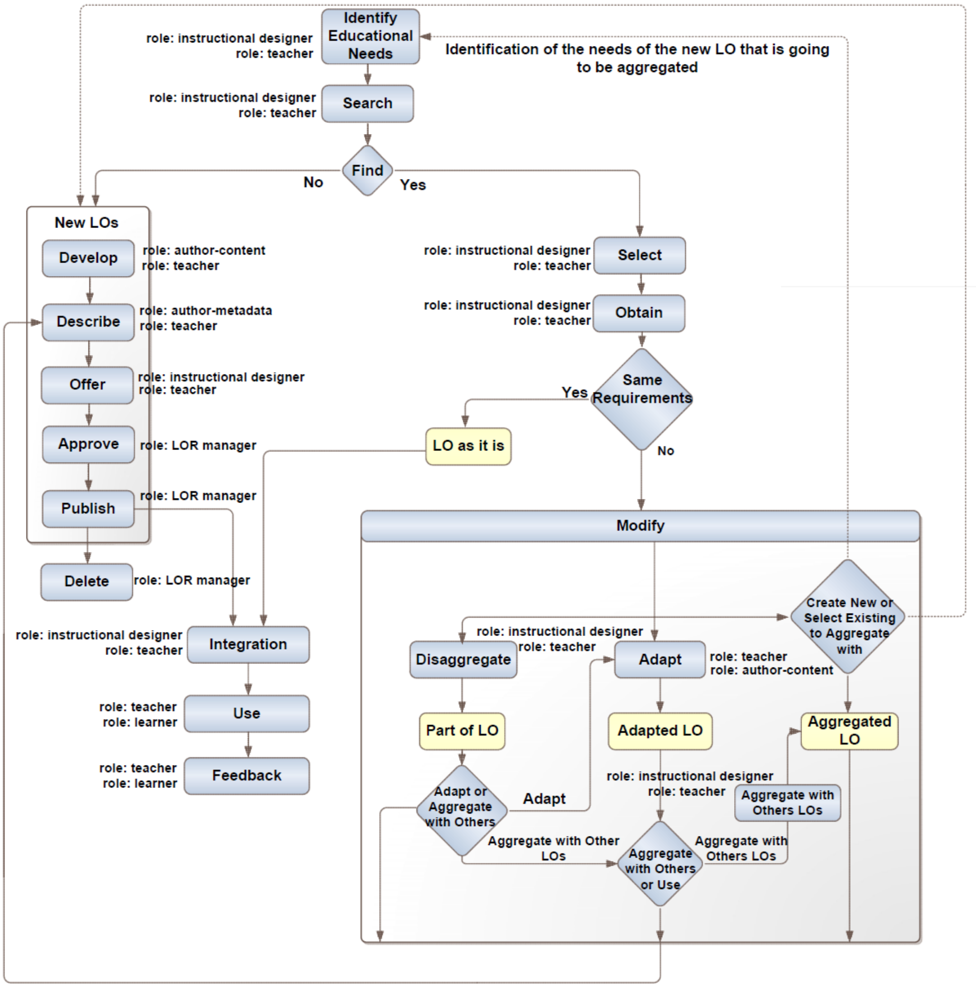

Figure 2.4: Learning Object life cycle proposed by Sampson and Zervas [192]

There are other works that have studied the Learning Object life cycle [176], [193], but none of them has defined it as completely as the previously exposed proposals. Dalziel [176] proposed a life cycle considering six stages: creation, storage, search and retrieval, delivery, use and modification. Two additional actions related to rights management were considered: the teacher should review and accept the conditions of the license of the Learning Object, and the students should accept an end-user license agreement. Finally, Rensing et al. [193] exposed a very simple life cycle composed of four stages: authoring, provision, learning and re-authoring.

The Learning Object life cycle proposed and considered in this thesis is shown in Figure 2.5.

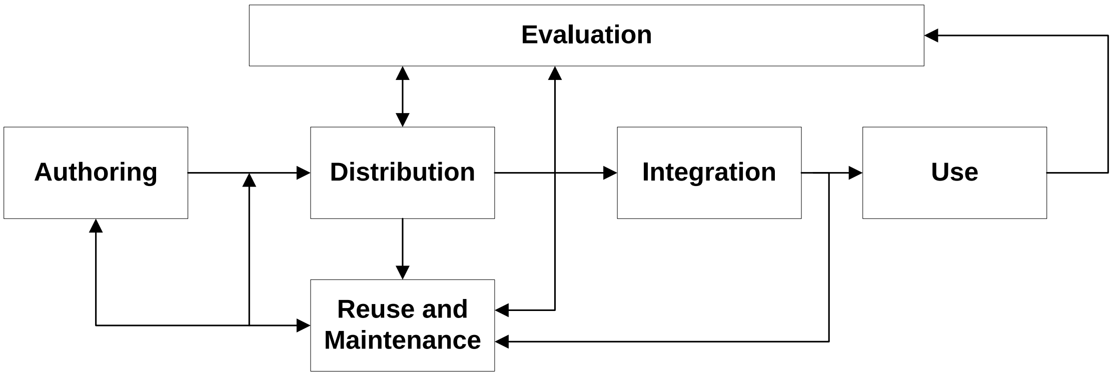

Figure 2.5: Learning Object life cycle proposed by Gordillo

The aim of this life cycle is to overcome the shortcomings of the previous proposals and provide a clear and straightforward representation. It considers the following six stages:

- *Authoring*. This is the initial stage where the Learning Object is created from scratch or by editing, disaggregating and/or aggregating other Learning Objects.
- *Distribution*. Once a Learning Object has been created, it can be distributed. This stage encompasses the following steps:
    1. *Submission.* The Learning Object is submitted to a distribution system.
    2. *Storage.* The Learning Object is stored in the distribution system.
    3. *Approval.* The distribution system decides if the Learning Object should be distributed to the intended audience. It may opt to make the decision based on quality evaluations or to approve all submitted Learning Objects. If the Learning Object is approved continues to the next step, otherwise it is forwarded to the reuse and maintenance stage where it can be revised or deleted.
    4. *Publication.* The Learning Object is made available to the intended audience under its corresponding license and terms of use. This might range from publishing the Learning Object to the entire world up to making it available to a single user. This step includes the distribution of the Learning Object through different systems such as web portals, search services and recommender systems.
    5. *Discovery.* The existence of the Learning Object is noticed.
    6. *Selection.* The Learning Object is selected.
    7. *Obtaining.* The Learning Object is obtained via a file, a URL or in other way.
- *Integration.* The Learning Object, once obtained, is integrated into a VLE, authoring tool or other system in order to enable its use by learners or to enable any other type of reuse.
- *Use*. The Learning Object is used by learners.
- *Reuse and Maintenance*. The Learning Object is updated or reused in one of the following ways: as is by submitting it to other distribution systems, to create a new Learning Object by its modification, adaptation and/or disaggregation, or to create a new

Learning Object by its combination with others. This stage also represents when the Learning Object is deleted, retracted or stops being distributed for any other reason.

- *Evaluation.* The Learning Object is evaluated by human users or software applications. Evaluations can be provided in distinct forms: ratings, rubrics, accept/deny statements, comments, etc. They can occur in different moments along the life cycle:
    a. *During the distribution stage, in the approval step.* Repositories might have quality control policies that require Learning Objects to be evaluated and accepted before publication.
    b. *After the distribution stage.* Repositories also might opt to allow users to freely publish resources without pre-publication reviews and evaluate these resources after publication. In these cases Learning Objects are published and begin to be distributed immediately after being submitted to the system.
    c. *After the use stage.* Users can evaluate the Learning Object and give feedback after using it. Evaluations can also be performed based on user interactions.

  The results of the evaluations can be used in the stages of distribution (for instance to enhance a search service or a recommender system using the user ratings) and reuse and maintenance (for instance to provide authors with usage information about their Learning Objects to facilitate them the enhancement of these Learning Objects).

In this life cycle labelling and metadata usage are not represented as a stage but are considered as actions that can be performed in all stages. In the authoring stage, authors describe the Learning Object with metadata. If other Learning Objects are used in the creation process, their metadata can be used. In the distribution stage, distribution systems can use metadata in their quality control and distribution processes as well as include additional data such as the number of visits or downloads. Metadata can greatly help VLEs and other systems to appropriately integrate Learning Objects during the integration stage. Besides, these systems can include more data such as access and error logs. In the use stage, learner interaction data can be obtained and stored in the metadata. Evaluations of Learning Objects can also be stored in the metadata providing quality scores and feedback. Metadata can also be accessed in the evaluation stage to verify their conformance and rate their quality. Finally, in the reuse and maintenance stage metadata can be read, updated or deleted.

The systems and models implemented and presented along this thesis are associated with distinct stages of this Learning Object life cycle. The authoring tool described in chapter 4 supports the stages of authoring and reuse and maintenance, the e-Learning platform (chapter 3) and the recommendation model (chapter 7) primarily tackle the distribution stage, the evaluation system and the quality metrics (chapters 5 and 6) are used in the evaluation stage, and the models described in chapter 8 mainly deal with the integration stage. Moreover, the use stage is also tackled in chapter 9 which studies the use of Learning Objects in various contexts.

2.3.3 Open Educational Resources and Learning Objects

The term OER (Open Educational Resources) was first defined in 2002 at a UNESCO conference as “the open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes” [194]. Nowadays, the most used definition (and the one used in this thesis) is: “OER are digitised materials offered freely and openly for educators, students and self-learners to use and re-use for teaching, learning and research” [195], [196]. Nonetheless, further refinement of this definition is needed in order to clarify what is meant by open. Distinct definitions of OER and open can be found in the literature [197]. For instance, Wiley states that a resource should be considered open as long as its license provides users with free and perpetual rights to retain, reuse, revise, remix and redistribute it [198]. The problem of this definition of open is that it excludes resources published under some of the most popular open licenses. This thesis considers open all resources that can be freely used and distributed by the users, even if conditions and restrictions are imposed for their use and distribution.

Creative Commons licenses [199] play a crucial role in the OER movement allowing authors to retain copyright while granting permission to others to use, copy, distribute or make derivative works of their resources under certain conditions [200]. They are by far the most used licenses for OER [184], [196], [197]. Creative Common licenses are formed by combining four conditions: Attribution (BY) which requires giving credit to the author, NonCommercial (NC) which prohibits commercial use, ShareAlike (SA) which requires derivative works to be distributed under the same licence as the original, and NoDerivatives (ND) which prohibits the creation of derivative works. Thereby, a total of six Creative Commons licenses are specified: BY, BY-SA, BY-ND, BY-NC, BY-NC-SA and BY-NC-ND. Besides, the CC0 license is offered by Creative Commons to release material into the public domain.

OER research clusters into four categories: models of sharing OER, models of producing OER, benefits associated with OER and challenges of OER [197]. OER are typically created in the form of Learning Objects and shared through Learning Object Repositories. Thereby, they can be reused, revised, remixed and redistributed in the same ways as Learning Objects. There are two primary models for producing OER: the institutional production model where materials created by experts and used in formal learning are adapted into a format appropriate for open sharing, and the commons-based peer production model in which materials are created by groups and communities of motivated individuals. Among the most frequently cited benefits of OER for education are the radical reduction of costs without detriment to learning effectiveness, the encouragement of improvement and localization of content, and the capacity to offer equal access to knowledge for all [201]. Main challenges of OER are among others: authoring and reuse, reward systems, distribution, quality assurance, sustainability and business models, incompatible policies and copyright issues [39], [53], [195]–[197], [200]–[202].

OER raise many similar issues to those that have surrounded Learning Objects [38]. In fact, the question of to what extent OER are merely open Learning Objects has arisen [2]. A comparison between both concepts is provided in [38]. OER and Learning Objects have the same main aim: to improve reusability and sharing of educational resources. However, while OER focus on ensuring open access and distribution through open licensing and promoting sharing of resources through widespread community involvement, Learning Objects focus on technical issues such as granularity, interoperability, metadata and e-Learning standards. Not all OER are Learning Objects and vice versa, but all open Learning Objects are OER. Learning Objects seem to be the best path forward for OER because if OER are created as open Learning Objects their reuse and sharing potential can be maximized. So, Learning Objects can help OER to overcome several of their main challenges (e.g. authoring, reuse and distribution). Furthermore, quality control mechanisms for open Learning Objects can be also valid for OER. Nonetheless, in order to create, distribute and manage OER following the Learning Object paradigm, new systems and tools are needed [51]. Taking all these into account, it can be stated that this thesis also contributes to the authoring, distribution, evaluation and integration of OER.

2.3.4 Use of Learning Objects in Educational Environments

This section provides a brief overview of recent studies that have examined the acceptance and instructional effectiveness in terms of student engagement and academic performance of Learning Objects across different educational environments.

A comparison of the effectiveness of a TEL environment with Learning Objects with a traditional teaching environment was carried out by Derya and Yıldırım [3]. A total of 137 sixth grade students from 4 classes in a public primary school participated in this study. Two classes were assigned to an experimental group in which instruction was delivered with Learning Objects, and the other two classes were assigned to a control group, in which Learning Objects were not used and instruction was mainly teacher-directed. The study lasted 24 lesson hours within 8 weeks. A total of 52 Learning Objects were created (from scratch or by reusing others) for the study using an authoring tool and content collected from teachers' lecture notes, course textbooks, the Internet and Learning Object Repositories. These 52 Learning Objects were finally aggregated to form 9 Learning Objects about different social studies topics. Results indicated that achievement of students who used Learning Objects was significantly higher than the achievement of students taught by the traditional approach. Results also showed that students found the Learning Objects very engaging, beneficial for their learning and easy to use.

Another study that examined the use of Learning Objects in primary education was conducted by Cameron and Bennett [4], who analyzed the use by students of two classes from a public primary school of several Learning Objects obtained from a repository. In one class, the teacher chose a student-centred strategy based on collaboration and peer learning. The teacher of the other class used a combination of direct teaching and modelling, followed by open-ended project-based activities. In both cases, students were engaged and enthusiastic during the lessons in which Learning Objects were used, but there were differences in the extent to which learning outcomes were achieved. The study suggested that the teacher and the used learning methodology play a critical role in the effectiveness of Learning Objects.

Two studies authored by Freebody [5], [6] reported on an evaluation of the use of Learning Objects in a wide number of schools. The evaluations drew on two data sources: surveys and case studies. Surveys were provided online to students and teachers, and the case studies included interviews and observations. In total, in the two studies, 4,199 students and 783 teachers completed surveys about the Learning Objects they had used in class. Case studies were conducted in 23 schools (9 primary schools, 9 secondary schools, 4 K-12 schools and 1 K-8 school). Learning Objects were used in a wide variety of ways to teach various subjects including mathematics, science and literacy. Results of the studies indicated that there were strongly positive responses to the use of the Learning Objects from students and teachers with respect to perceived benefits to both learning outcomes and engagement in learning. Results also pointed out that there are major variations in awareness and usage of Learning Objects in schools, and also in the extent to which Learning Objects are integrated into learning programs.

Lorenzo-Quiles, Vílchez-Fernández and Herrera-Torres [7] compared the effectiveness of an learning-centred program based on the use of Learning Objects versus a teaching-centred program supported through the use of a textbook as the only pedagogical material. The study involved 58 seventh grade students from a public secondary school, which were distributed into 2 groups. A total of six Learning Objects were used by the experimental group, each of them including four didactic units about music with digital activities, worksheets and audiovisual content. Results showed that students that used the Learning Objects obtained greater benefit and academic achievement than the other students.

Kay [8] explored the use of web-based Learning Objects in secondary school classrooms. The sample of the study was composed of 333 students (aged 15 to 17 years) and 8 teachers. A total of 12 Learning Objects (3 for mathematics and 9 for science) were used by the teachers following pre-designed lesson plans. Students completed a pre-test and post-test based on the content of the Learning Objects used in class. Results showed that teachers, in general, agreed that Learning Objects had a positive impact on student learning, were of good quality and were engaging for students. Students slightly agreed on these same features. Student performance increased between 28% and 53% when Learning Objects were used. Based on the results of the study, Kay stated that Learning Objects address two barriers for teachers to use technology in the classroom: having limited computer skills and excessive time required to learn new software. Other similar studies carried out by Kay and Knaack [9]–[12] that evaluated the use of Learning Objects in secondary schools found consistent results.

An evaluation of students' perceptions and usage of Learning Objects in a higher education environment was carried out in [13]. The sample of the study was 312 undergraduate students who were enrolled in a digital systems course. Relevant Learning Objects were retrieved from various well-known Learning Object Repositories and linked to the course syllabus. Some Learning Objects were animations and simulations and others were text-based resources created as web pages. During 14 weeks, students used the Learning Objects as supplementary resources for the course. On average, each week students used about 10 to 20 Learning Objects and spent about 3 to 5 hours on them. Results indicated that, on the whole, students had a positive attitude towards Learning Objects. The study also found that Learning Objects obtained higher perceived usefulness compared with traditional techniques such as lectures and textbooks.

Other study investigated the effect of Learning Objects on the achievement of students in a university English course [14]. The study involved 118 students distributed in 3 groups. In the first group, students received traditional education in the classroom. The second group received traditional web-based distance education. Lastly, the third group received web-based distance education supported with Learning Objects. A total of 70 Learning Objects including audios, videos, animations, slideshows and quizzes were integrated into the university's LMS. Some of the Learning Objects were created from scratch and others by converting existing materials. For six weeks, all 3 groups used text-based materials, and the third group also used the 70 Learning Objects. Findings indicated that web-based distance language learning supported by Learning Objects was more effective in terms of student achievement than web-based learning supported by text-based materials and face to face learning.

More studies can be found in the literature reporting on consistent findings of the use of Learning Objects in primary education [15]–[17], secondary education [15], [16], [18] and higher education [19]–[23]. It is also worth pointing out that some studies did not found significant difference between the performance of students taught using Learning Objects and those students taught with traditional methods [203]–[206]. Nevertheless, in general, these studies found that using Learning Objects is at least as effective as traditional learning. For instance, Nurmi and Jaakkola [203] reported results from three studies that compared the effectiveness of learning environments where Learning Objects had been used with traditional classroom environments. Only in one study the students that had used Learning Objects significantly outperformed those in the traditional setting. No statistically significant differences on student performance were found in the other two studies. It was concluded that learning performance gains and success are dependent not just on the Learning Objects themselves, but also on how they are used and on the environment into which they are integrated.

Several studies have explored the factors that influence acceptance and instructional effectiveness of Learning Objects [29]–[37]. Lau and Woods [29] found that users' acceptance of Learning Objects was significantly influenced by the perceived usefulness and to a lesser extent by the perceived usability. A subsequent study confirmed these results and identified the pedagogical, technical and content quality of Learning Objects as important predictors of perceived usefulness and perceived usability [30].

Kay [31] found that subject area, learner grade level, learning methodology and the experienced technological problems can significantly influence learner attitudes towards Learning Objects and learning performance. In other study, Kay [32] confirmed some of these results and also found that higher computer and subject area comfort ratings were significantly correlated with more positive learner attitudes about Learning Objects, and that learning performance was significantly higher for learners who used structured (vs. open-ended) Learning Objects. Gender was not significantly correlated with learner attitudes or performance. These findings are consistent with those observed by previous research [33]. In a later study, Kay [34] found that Learning Objects with a direct instruction architecture were more preferred by students and more effective than those with a constructive-base architecture. Lastly, other studies have found that the effectiveness of Learning Objects depended on the students' ability in the subject being taught [17] and the technology used in their development [35].

A study that examined the use of Learning Objects in two different settings showed that students' achievements were different depending on the learning methodology employed [36]. Marcus-Quinn and McGarr [37] explored the different ways in which teachers use Learning Objects in school classrooms. They identified the following types of use of Learning Objects: use by teachers as support materials for face-to-face teaching in the classroom, use as electronic textbooks, use by students independently or in small groups to complete tasks at their own pace, and use in VLEs to deliver asynchronous learning online. Regarding instructional design, [207] suggested some best practices for effectively using Learning Objects.

In summary, the results from research on Learning Objects provide strong evidence that Learning Objects are widely accepted and can engage learners, help them learn and increase academic performance. However, several factors can significantly influence their success. On the one hand, success depends on characteristics of the Learning Objects such as their content quality, subject area, usability and the instructional design. On the other hand, success also depends on characteristics of the context of use including the learning methodology followed and the characteristics of the learners (e.g. age, ability and subject area comfort). Therefore, in order to be successful and achieve better results than traditional methods, Learning Objects need to have high quality and be used following a learning methodology suitable for the educational environment into which they are going to be integrated and used.

In addition to increasing engagement, motivation and academic performance, other benefits of Learning Objects have been pointed out such as enhancing reusability, facilitating the integration of ICT in the classroom, enabling students to work at their own pace, helping to introduce new concepts, facilitating the use of new learning methodologies and environments, fostering learner-centred approaches, and stimulating independent learning. Learning Objects can also provide more detailed tracking of user interactions with learning content. Besides, open Learning Objects have the potential to provide successful learning experiences at low cost.

Learning Objects can be used in different educational environments in a wide variety of ways including: in the classroom as support materials for face-to-face teaching, as electronic textbooks, in VLEs to deliver learning in blended and online courses including MOOCs, to provide learning activities and assignments (graded or not), to conduct learner-centred activities, as self-learning material, and to deliver e-Learning resources with more detailed tracking.

Although several studies have investigated the use of Learning Objects in different settings, further research is needed, especially to evaluate the use of Learning Objects in traditional online courses and novel educational environments such as MOOCs and OER repositories, as well as in combination with distinct learning methodologies.

2.3.5 Reuse of Learning Objects

Several studies cited in the previous section describe successful learning experiences in which the used Learning Objects were directly retrieved from Learning Object Repositories or authored by reusing other Learning Objects [3]–[6], [13]–[15], [205]. All these experiences provide evidence of the benefits of reusing Learning Objects. This section reviews a few studies that have addressed Learning Object reuse.

Elliot and Sweeney [24] reported a case study in which an online inquiry project was developed by reusing existing Learning Objects. These Learning Objects were obtained mainly from Learning Object Repositories, and then evaluated, adapted and integrated. A total of 37 were reused, 36 of which required adaptations. Besides, two new Learning Objects had to be created. Results of the study estimated that it would take a threefold increase in time to develop the project with newly created Learning Objects as compared to the reuse approach. The study concludes by suggesting that considerable savings can be made by reusing Learning Objects.

Zervas and Sampson [25] analyzed the reuse of 719 Learning Objects created by 112 teachers during a series of workshops and a later three-month period. After the workshops, the teachers created 132 courses. Results found that 35% of the Learning Objects were reused in these courses. The study also found a significant positive correlation between the number of times of reuse and the metadata completeness. Thereby, it can be stated that metadata significantly influences Learning Object reuse.

Ochoa [26] conducted a quantitative analysis of reuse in the ARIADNE repository [124] which showed that 11.5% of the Learning Objects were reused for authoring new ones. This same study showed that 22.6% of the Learning Objects available in the Connexions repository [208], [209] were reused to form collections. A similar study analyzed the reuse in the LRE repository [133] and found that 7% of the Learning Objects were reused in collections [27]. The reuse rate increased to 19% when Learning Objects with lower granularity were excluded. In [28], authors explored Learning Object authoring and reuse in Connexions, and found that 12% of the derived modules had been published by authors different than the original. However, these results must be treated with caution due to the small sample size.

Summarizing, the few studies that have explored Learning Object reuse in Learning Object Repositories suggest that the ratios of Learning Objects reused for creating new ones are around 12% and that the ratios of Learning Objects reused in collections vary from 5% to 25%. Further research is required to provide more understanding and evidence of Learning Object reuse.

2.4 Learning Object Repositories

Learning Object Repositories (LORs) are web-based digital libraries used for storing, distributing, discovering and retrieving e-Learning resources. They play a crucial role in the large-scale distribution of Learning Objects since they fully support the distribution stage of the Learning Object life cycle. LORs may provide Learning Objects as well as other digital educational resources not created in the form of Learning Objects [2]. A LOR provides access to both e-Learning resources and their metadata, either by storing them physically together or by presenting a combined repository to the outside world, while the resources and the metadata are actually stored separately [49]. There are four types of LOR architecture [210]:

- *Centralized content and centralized metadata*. Repositories that store e-Learning resources and their metadata in a single centralized server.
- *Centralized content and distributed metadata*. Repositories that store e-Learning resources in a centralized server while metadata are stored in distributed servers.
- *Distributed content and centralized metadata.* Repositories that store metadata in a centralized server and provide links to e-Learning resources stored in other repositories.
- *Distributed content and distributed metadata.* Repositories that have a fully distributed architecture composed by multiple content and metadata repositories.

Nowadays, the two most used architectures are “centralized content and centralized metadata” and “distributed content and centralized metadata”.

LORs can also be classified into three types based on the locality of the resources [50]:

- *Content-based LORs*: provide resources which are exclusively stored in their system.
- *Link-based LORs*: act as link aggregators by providing links to e-Learning resources stored and provided by other systems.
- *Hybrid LORs:* provide e-Learning resources stored in their system and links to e-Learning resources stored and provided by other systems.

McGreal [50] identified and categorized according to this classification 60 different LORs: 27 (45%) were classified as content-based, 20 (33%) as link-based and 13 (22%) as hybrid.

LORs offer access to a wide variety of e-Learning resources: images, videos, documents, web applications, applets, flash objects, simulations, games, lessons and even courses [50]. An analysis of 29 LORs that had more than 900,000 resources found that 6% of them were images, 79% were documents, 13% were multimedia resources and the remaining 2% were other types of resources [211]. The proportion of resources of each type was vastly different depending on the repository. LORs provide resources in various languages, subject areas, and for different audiences [48]. LORs that hold content in a specific subject area are categorized as "targeted" while those hosting content in a wide variety of subject areas are categorized as "generic" [50].

Many LORs have been developed over the last years as a consequence of the increasing awareness, use and adoption of Learning Objects. More than 100 different LORs have been identified by various surveys and studies conducted in recent years [47]–[50]. Several of these LORs no longer exist and this fact points out that sustainability is an ongoing challenge. In this regard, Downes [202] reviewed several models for sustainable LORs. As some LORs become defunct, new ones are established [2]. Table 2.5 shows some examples of LORs operational at the time of writing. Two of them, ViSH and EducaInternet, have been developed in the scope of this thesis and are described in later chapters.

Table 2.5: Learning Object Repositories

Name	URL	Type
Agrega	http://agrega.educacion.es	Content-based (distributed)
Curriki	http://curriki.org	Hybrid
EducaInternet	http://educainternet.es	Hybrid (mostly content-based)
Europeana	http://europeana.eu	Link-based
Go-Lab	http://golabz.eu	Hybrid
LRE	http://lreforschools.eun.org	Link-based
MERLOT	http://merlot.org	Hybrid (mostly link-based)
MIT Open Courseware	http://ocw.mit.edu	Content-based
NSDL	http://nsdl.oercommons.org	Link-based
ODS Portal	http://www.opendiscoveryspace.eu	Hybrid (mostly link-based)
OER Commons	http://oercommons.org	Hybrid (mostly link-based)
OpenStax CNX (formerly Connexions)	http://cnx.org	Content-based
ViSH	http://vishub.org	Hybrid (mostly content-based)
Wisconsin Online Resource Centre	http://wisc-online.com	Content-based

Ochoa and Duval [212] conducted a quantitative analysis of 39 LORs, 24 of which were content-based and 15 were link-based. Content-based LORs had an average size (defined as the number of resources present in the repository) of around 4,000 while the average size of the link-based LORs was around 20,000. Link-based LORs have bigger size than content-based LORs because submitting links require less effort from users than submitting own materials. Results also revealed that most of the content was stored in few big repositories. This finding is consistent with [211]. Among the 59 LORs identified by [48], 76% offered less than 10,000 resources, 19% between 10,000 and 50,000, and only 5% offered more than 50,000.

Ochoa and Duval [212] also showed that the average growth rate measured in resources added per day was around 1.4 for content-based LORs and 11.0 for link-based LORs. Results suggested that LORs grow approximately linearly over time, but with two different growth rates: one initial and then one mature. In most cases, growth rate increased with maturity. A more recent analysis indicated that resources were being stored in a flood pattern (straight up lines) in some LORs as well as in a flow pattern (slow ascendant lines) in others [211].

Lastly, [212] also analyzed how contributors growth and publish resources in LORs. The amount of contributors per LOR ranged between 100 and 1,500. On average, LORs added a new contributor each 4.5 days. Results showed that the number of contributors grew linearly in most LORs, but exponential growths were observed in some cases. Each contributor published, on average, around 14 resources. However, findings revealed that LORs were affected by the Pareto principle (20/80 rule): the 20% of the users created around the 80% of the resources. More quantitative analyses of LORs could help to obtain better understanding of the requirements, gaps and opportunities of the LORs.

Some works have studied the features offered by the different LORs that have been developed over the last years [46]–[50]. Sampson and Zervas [46] proposed a list of features that LORs should have in order to meet the demands of the educational communities. A later study analyzed the adoption level of these features by 49 major LORs [47]. A wide range of features were identified: storage of resources and links to external resources (present in 69% of the analyzed LORs), storage of metadata (69%), browse (100%), search (100%), federated search (37%), ranking metrics (31%), recommendations (14%), viewing of resources (71%), viewing of metadata (96%), download of resources (90%), download of metadata (16%), metadata validation (47%), personal accounts (88%), bookmarks (47%), ratings and comments (59%), social networks (37%), RSS feeds (29%), social tagging (27%), forums (29%), blogs (14%) and wikis (2%). On average, LORs had implemented 51% of the proposed features. Only around 10% of the LORs had implemented more than 70% of the features. Findings of [47] also revealed weak positive correlations of the adoption level of features by LORs with the average number of resources created per year and the average number of registered users per year.

The presence of some of these features was also analyzed by Tzikopoulos, Manouselis and Vuorikari [48], which examined 59 LORs. The presence was as follows: viewing of metadata (71%), browse a catalogue (58%), search (73%), personal accounts (44%), bookmarks (12%) and forums (3%). Besides, new features were identified: contacting LOR staff (81%), online advisory (41%), use of educational tools (27%), purchase (8%) and multilingual support (8%). Another feature that was identified was federated search, which allows the search of resources in multiple repositories. Moreover, some features were proposed for future LORs such as recommendations, tracking systems and integration with LMSs [213], [214]. Results also showed that 95% of the LORs had some specific policy about resource submission, from which

48% concerned submissions by the LOR staff and 52% submissions by the LOR users. Among the 42 LORs that made available the corresponding information, only 64% followed some quality control policy, and only 43% had some resource evaluation or review policy. It was suggested that Learning Object quality and evaluation services would become more of the focus of the LOR development.

Two more features were identified by [49]: advanced search and peer review. Other features that LORs may have are harvesting and provision of metadata (often relying on OAI-PMH [166]) and maintenance functionalities [50]. Some LORs also provide authoring tools to allow their communities to create and share Learning Objects [215]. More requirements were identified by [216], who explored which features of LORs are more important for teachers. Furthermore, the support of e-Learning standards, especially the most widely used and adopted such as SCORM 1.2 [147], SCORM 2004 4th Edition [110], IMS CP [113], IMS QTI [115] and IEEE LOM [119], is of vital importance for a LOR in order to effectively support the whole Learning Object life cycle. Finally, more features are required for LORs aiming to manage open Learning Objects (i.e. OER) including sharing functionalities, collaborative tools and open licensing [51]. These systems also should provide sustainable evaluation models capable of providing quality assurance for large quantities of resources [39]. Although several works have identified many features of LORs, further research is needed to evaluate their effective use.

Regarding metadata, [48] found that the 54% of the 59 LORs analyzed used IEEE LOM compatible metadata (29% LOM [119] and 25% LOM profiles or IMS LRM [136]), 22% used Dublin Core [120], and the rest did not use any metadata standard. An analysis of 8 LORs that used LOM metadata and 11 LORs that used Dublin Core metadata was conducted by [211]. Metadata were collected from more than 600,000 e-Learning resources. Title was found in almost all resources. In the Dublin Core LORs, description, format and subject were found, respectively, in around 44%, 19% and 47% of the resources. In LOM LORs, description, format and keywords were found, respectively, in around 99%, 52% and 69% of the resources. Aside learning resource type (31%) and context (20%), no other LOM educational elements were found in more than 15% of the resources. A similar study analyzed more than 600,000 LOM metadata instances provided by 7 different LORs [217]. Title, resource identifier and metadata instance identifier were found in almost all instances. Other LOM elements such as description, language, location and copyright were found in more than 80% of the instances. Contributors (both of the resource and the metadata instance), learning resource type, cost and description on conditions of use were found in more than 60% of the cases. Keywords, metadata language, format, purpose of classification and taxon path appeared more than 50% of the times. The other elements were used less than 50% of the times. Among the educational elements, 4 out of 11 (learning resource type, intended end user role, typical age range and context) were used more than 40% of the times, 3 elements (language, interactivity level and interactivity type) were used more than 10%, and the remaining 4 elements (description, difficulty, semantic density and typical learning time) were used less than 10% of the times. It was stated that although these values were lower than desirable, they provide proof that LOM is used in the real world to capture educational information about e-Learning resources. Lastly, the metadata instances were validated using the loose schema validation approach, and errors were found in 30% of them. This fact points out a clear need for LORs to develop metadata evaluation services.

Many works have referred to the difficulty that users have in locating suitable Learning Objects in the different LORs available on the Web. For instance, in [43] a group of 31 teachers reported that finding an appropriate Learning Object took them less than 30 minutes 41% of the times, between 30 and 60 minutes 24% of the times, and over an hour the remaining 22% of the times. Over 40% of these teachers reported that the search process was time consuming and occasionally frustrating. An empirical study on usability problems of search tools of LORs concluded that these tools were hard to use [44]. Recently, other study explored the different search features offered by some LORs and identified some gaps and potential solutions [45]. In order to face the problem of finding suitable Learning Objects, LORs can adopt some measures besides the development of easy to use search tools [44], such as the use of ranking metrics for sorting the search results according to their relevance or quality [218]–[221], and the use of quality control mechanisms [39] and recommender systems [42]. Nonetheless, the fact that this problem continues to exist brings out the limitations of current systems for searching and distributing Learning Objects and indicates that further work is required.

Cervone [222] provided an overview of the issues related to LOR development and suggested that LORs should implement social features, offer various discovery approaches, use educational metadata and support major e-Learning standards. Besides, resources of the LORs should be designed for reuse (i.e. in the form of Learning Objects), developed using standards such as HTML5, and provided free of copyright restrictions or governed by Creative Commons licenses. More suggestions for developing successful LORs can be found at [207].

Not much work has been done in developing software for building LORs. There are some systems such as DSpace [223] and Fedora [224] which allows creating generic digital libraries and archives, but there are hardly any systems for building specialized repositories for managing Learning Objects. One example of these systems is DOOR [225], which allows to create LORs for storing, searching and retrieving content in the form of Learning Objects from a tree-shape catalogue. The project seems abandoned, since the last version was released in 2008. Another example is the software that runs OpenStax CNX (formerly Connexions) [208], [209], which has been released as open source [226]. The features offered by the LORs that can be created with the current systems for building LORs are quite limited and insufficient for supporting the whole Learning Object life cycle in an effective way. Therefore, further work is required in order to provide better software, preferably open source, for building LORs.

2.5 Authoring Tools

An e-Learning authoring tool can be defined as “a software application that enables authors to create complete e-Learning resources by integrating and linking together different objects and custom content generated by them”. Most authoring tools also make possible to edit existing resources. These systems are usually designed for users with basic computer skills although some of them also allow the use of programming languages. Their main goals are to save cost and effort. There is no standard classification system for authoring tools although there has been some attempts such as [227], which proposed a taxonomy for classifying these systems into three major groups: content development tools, multimedia tools and auxiliary tools.

There are several works in the literature that have examined the different characteristics of authoring tools (e.g. [228]). The most important characteristic of an authoring tool is the type of resource or output that can be created with it. Authoring tools have been primarily used in education for creating Learning Objects and e-Learning resources in general [229]–[247]. Nevertheless, authoring tools have been also used for other purposes such as authoring educational metadata [25], [248], developing IEEE LOM application profiles [249], creating learning designs [236], planning courses [250] and collaborative learning scenarios [251], [252], generating exams [253], adding virtual content into printed educational materials [230], or simulating digital circuits [254]. This review focuses on Learning Object authoring tools, that is, e-Learning authoring tools aimed to create Learning Objects.

Learning Object authoring tools allow educators to create effective Learning Objects with little effort and low cost without requiring them any programming knowledge or strong computer skills. A trained author can achieve a ratio of around 4 hours of authoring to produce 1 hour of instruction using an authoring tool and importing existing materials, while the creation of the same type of resource without using the tool is estimated to take between 300 and 1,000 hours per hour of instruction [229]. Therefore, the development of suitable Learning Object authoring tools facilitates the low cost development of high quality reusable content. These tools can help to remove two major barriers to the use and adoption of Learning Objects: the limited availability of suitable Learning Objects and the need to customize these resources to adapt them to specific contexts. Limited availability of suitable content and courseware has been identified as a reason for the limited use of technology in education [37]. The low availability of topic specific Learning Objects is another obstacle [13]. Moreover, a recent survey conducted by the OER Research Hub project, which gathered more than 600 responses from educators, revealed that around 86% of them adapted educational resources to suit their needs [52]. This indicates a need for educators to effectively adapt e-Learning resources. Learning Object authoring tools can help to overcome all these barriers by allowing educators to create their own Learning Objects and modify the ones they find. These tools support the authoring stage of the

Learning Object life cycle as well as the reuse and maintenance stage because they allow the edition, disaggregation and aggregation of Learning Objects.

Relevant characteristics of Learning Object authoring tools, besides the type of learning resource that can be created, are among others: platform support, media and files type support, content customization, automated programming, ease of use, creative freedom, adherence to e-Learning standards (which are used by tools mainly for integrating the produced Learning Objects into VLEs as well as for importing resources), metadata authoring, reusability of the created resources, extensibility, cost and license. According to [255], these tools must meet the following requirements:

- Offer levels of usability that allow educators to create Learning Objects after a short training or by self-teaching even if they have little computer skills.
- Produce Learning Objects with good quality and in conformity with SCORM [110].
- Provide an appropriate level of integration with Learning Object Repositories and VLEs to facilitate the reuse of the created Learning Objects.
- Be distributed under an open source license allowing their customization.

Some studies have confirmed that Learning Objects created with authoring tools are able to improve learning outcomes and enhance student engagement [3], [229]–[231]. Derya and Yıldırım [3] found that students who used Learning Objects created with an authoring tool were highly engaged and had significantly higher achievement than those taught in a traditional setting (see section 2.3.4 for details). Ainsworth and Fleming [229] presented and evaluated an authoring tool to create Learning Objects by customizing and enriching existing courseware. Results showed that the Learning Objects created with the tool were more effective in terms of student achievement than the courseware they were based on. Cubillo, Martin, Castro and Boticki [230] developed an authoring tool to create augmented reality Learning Objects by combining multimedia resources, descriptions and questions. For the evaluation, a Learning Object was created using the tool and a video. Results indicated that students who used the Learning Object created with the tool scored higher than those who used the video. Lastly, Gaeta et al. [231] presented an authoring tool for creating storytelling Learning Objects and showed that these resources were more engaging and effective than expositive materials.

Learning Object authoring tools have been also adopted by Learning Object Repositories since educational communities can use them for creating corpora of resources [215], [242]. Moreover, these tools have been also used with the main aim of stimulating learning by doing and enhancing learner skills such as creativity, critical thinking and problem solving [256].

Many Learning Object authoring tools have been developed over the last years. Most of them are proprietary software but there are also open source alternatives. Table 2.6 shows some examples of these tools. The ViSH Editor authoring tool has been developed in the scope of this thesis and is described in chapter 4.

Table 2.6: Learning Object Authoring Tools

Name	URL	Open Source	Output
Adobe Captivate	http://adobe.com/products/captivate	✗	Various (presentations, quizzes, screencasts, software demonstrations and simulations, etc.)
Articulate Presenter	http://articulate.com/products/presenter.php	✗	Interactive presentations
Articulate Quizmaker	http://articulate.com/products/quizmaker.php	✗	Quizzes
CourseLab	http://courselab.com	✗	Various (animations, presentations, quizzes, etc.)
Educaplay	http://www.educaplay.com	✗	Various (quizzes, crosswords, word search puzzles, videoquizzes, presentations, etc.)
eXeLearning	http://exelearning.net	✓	Navigable web pages with text, multimedia resources and interactive activities.
GLO Maker	http://github.com/glomaker	✓	Interactive presentations
Hot Potatoes	http://hotpot.uvic.ca	✗	Multiple choice, short answer, jumbled-sentence, crossword, matching and gap-fill exercises.
JClic	http://clic.xtec.cat/en	✓	Various (puzzles, crosswords, quizzes, etc.)
Microsoft LCDS	http://microsoft.com/en-us/learning/lcds-tool.aspx	✗	Various (activities, quizzes, animations, etc.)
RELOAD Editor	http://www.reload.ac.uk/new/editor.html	✓	Web-based resources packaged according to IMS CP 1.1.4, SCORM 1.2 or SCORM 2004.
RELOAD Learning Design Editor	http://www.reload.ac.uk/new/ldeditor.html	✓	Units of learning comprised of web-based resources that adhere to IMS LD 1.0
ViSH Editor	http://vishub.org	✓	Interactive presentations
Xerte	http://www.xerte.org.uk	✓	Navigable web pages with text, multimedia resources and interactive activities.

There are a few works on evaluation of open source Learning Object authoring tools. In [255], six authoring tools (CourseLab, eXeLearning, Hot Potatoes, Microsoft LCDS, MyUdutu and Xerte) for creating Learning Objects were evaluated according to two criteria: usability and quality of the produced Learning Objects. Usability evaluation was carried out using Nielsen's heuristics while the quality of the Learning Objects was measured by comparing them with a reference Learning Object. The study concluded that both proprietary and open source authoring tools can be used for producing good quality Learning Objects. Other study presented an usability evaluation of three authoring tools: CourseLab, GLO Maker and Microsoft LCDS [257]. A user testing in which 6 users performed 16 tasks with each tool was conducted. Results showed that users from different content development experience were able to used easily GLO Maker and Microsoft LCDS to create Learning Objects, while CourseLab was found hard to use. Task success rates were around 65% for CourseLab, 91% for GLO Maker and 96% for Microsoft LCDS. Lastly, the results of a study in which 33 students used eXeLearning to create 10 Learning Objects showed that most students found the tool easy to use and that they had good opinion about the created Learning Objects [240].

Further research is required to determine if educators actually can use Learning Object authoring tools to create effective and reusable Learning Objects easily and the characteristics that should be taken into account in the design and implementation of such tools.

2.6 Learning Object Evaluation

There is a huge and rapidly growing amount of Learning Objects available for learners and educators on the Web through Learning Object Repositories. This fact has raised an increasing need for systematically evaluating and measuring the quality of Learning Objects in order to establish quality control mechanisms. The lack of effective quality control mechanisms in Learning Object Repositories is a major barrier hindering the uptake and usage of Learning Objects, especially for OER [258]. A recent survey showed that the lack of quality control is a barrier for teachers to use resources made by others [53]. In this same survey, most teachers agreed that features to review and evaluate resources could be helpful to increase reuse. However, it seems that many repositories are not making efforts to provide such features. A survey of 59 Learning Object Repositories only identified 27 that followed some quality control policy, and 23 that had some resource evaluation or review policy [48].

The approaches used by Learning Object Repositories to control content quality can be classified mainly in three types [195]: reputation-based approaches, peer review, and community-based mechanisms. In the first case, the brand or reputation of an institution is used to persuade the user that the resources offered by the repository are of good quality. When using peer review, one or more accredited reviewers evaluate the quality of the resources submitted to the repository. Based on these evaluations, an administrator can decide whether the resources should be accepted for publication or not. Lastly, community-based mechanisms consist of using the interactions of the end users (explicit or implicit) in order to determine the quality of the resources offered by the repository. Examples of community-based quality mechanisms include user evaluations, ratings and comments, as well as peer reviews fully managed by the community. Some repositories also use the number of times that resources have been visited, downloaded or bookmarked as quality indicators. Many repositories of open Learning Objects (i.e. OER repositories) have adopted community-based quality mechanisms to achieve sustainable solutions for quality assurance [39]. However, these mechanisms alone cannot assure quality if there are no communities to back them up. In this regard, an encouraging fact is that teachers, in general, are willing to contribute by ranking and commenting resources, or even by becoming accredited reviewers [53]. Clements, Pawlowski and Manouselis [39] recommended developers of Learning Object Repositories to take a mixed approach for quality assurance by combining peer review and community-based quality control mechanisms. Finally, it is worth noting that Learning Object Repositories may use other types of quality control mechanisms. For instance, [259] presented an approach for Learning Object Repositories to automatically classify web-based Learning Objects between good and not good using only intrinsic features of the Learning Objects such as their number of links, words, images, videos, scripts or files for downloading.

A plethora of evaluation models for Learning Objects have been developed by repositories, institutions and researchers. The most relevant are shown in Table 2.7, but more can be found at [260], [261]. Learning Object evaluation models encompass any evaluation instrument, method, rubric or set of criteria which has the purpose of evaluating the quality of Learning Objects. These models allow evaluating and, in some cases, measuring Learning Object quality.

Table 2.7: Learning Object Evaluation Models

Name	Intended Audience	Criteria				Evaluation		Metrics	Output
		Pedagogical	Usability	Reusability	Metadata	Qualitative	Quantitative		
Assessment Guide of UCI [262]	Authors Reviewers	✓	✓	✓	✓	✓	✓	✓	Vocabulary value
COdA [263]	Authors Reviewers End users	✓	✓	✓	✓	✓	✓	✗	Evaluation
HEODAR [264], [265]	Reviewers	✓	✓	✗	✗	✓	✓	✓	Evaluation and Score
LOAM [266]	All users	✓	✗	✓	✗	✗	✓	✗	Evaluation
LOEI [267]	Reviewers	✓	✓	✓	✗	✓	✓	✓	Evaluation and Score
LOEM [268]	Reviewers	✓	✓	✗	✗	✗	✓	✗	Evaluation
LOES-S [269]	Learners	✓	✓	✗	✗	✓	✓	✗	Evaluation
LOES-T [270]	Teachers	✓	✓	✗	✗	✓	✓	✗	Evaluation
LOQES [271], [272]	Software systems	✗	✗	✓	✓	✗	✓	✓	Score
LORI [273]	Reviewers	✓	✓	✓	✓	✓	✓	✓	Evaluation and Score
LRE User Review [133]	End users	✗	✗	✗	✗	✓	✓	✗	Evaluation and Score
MECOA [274]	Learners Educators Experts	✓	✓	✗	✗	✓	✗	✗	Evaluation
MERLOT Peer Review [275], [276]	Reviewers	✓	✓	✗	✗	✓	✓	✓	Evaluation and Score
MERLOT User Review [275], [276]	End users	✗	✗	✗	✗	✓	✓	✗	Evaluation and Score
Reusability Evaluation Model [277], [278]	Reviewers Software systems	✗	✗	✓	✗	✗	✓	✓	Evaluation and Score
SUS [279]	All users	✗	✓	✗	✗	✗	✓	✓	Score
UNE 71362 [261], [280]	Authors Reviewers End users	✓	✓	✓	✓	✓	✓	✓	Evaluation and Score
WBLT-S [9], [281]	Learners	✓	✓	✗	✗	✓	✓	✗	Evaluation
WBLT-T [9], [281]	Teachers	✓	✓	✗	✗	✓	✓	✗	Evaluation

The main characteristics of Learning Object evaluation models are the following:

- *Intended Audience.* Evaluation models might target different audiences such as authors, reviewers, experts, educators, learners, teachers or end users. There are also models intended to be used by any user. An evaluation model may not require human intervention and be used by software systems to perform quality evaluations.
- *Criteria.* Evaluation models consider different set of criteria for evaluating the quality of Learning Objects. A model might evaluate Learning Objects from a pedagogical perspective but also other aspects such as their usability, reusability, metadata quality or

any combination of these criteria. Thereby, evaluation models constitute different views of the quality of Learning Objects that might complement one another [220].

- *Type of evaluation.* A model may consider providing qualitative evaluations (e.g. comments or text reviews) and/or quantitative evaluations (i.e. numerical ratings) both for the different criteria and for the Learning Object as a whole.
- *Metrics.* A model may define quality metrics to calculate overall quality scores (typically based on numerical ratings) for the evaluated Learning Objects. A quality metric is characterized by the criteria it takes into account, the process it uses to calculate the quality score, and the scale in which the final numerical value is yielded.
- *Output.* The application of an evaluation model may result in one of the following outputs or in a combination of several of them.
  a. *Evaluation*: A list of numerical ratings and/or qualitative evaluations (comments or text reviews) for each criterion. A comment or text review on the Learning Object as a whole may also be included.
  b. *Score*: A numerical value, generally calculated according to a metric based on the evaluations, which represents the overall quality score of the Learning Object and allows its comparison with other Learning Objects evaluated.
  c. *Vocabulary value*: a text value belonging to a specific list (e.g. “accepted”, “certified” or “very suitable”). This value may or may not be determined based on an overall quality score.

These models may be also characterized based on the context in which they are expected to be applied. A model may be designed to be used in a specific country or region (e.g. Spain), in a certain educational setting (e.g. higher education) or in a particular subject area (e.g. health). Nonetheless, most evaluation models are generic in terms of context. Based on the amount of criteria considered, models can be categorized as single-criteria or multi-criteria. The scales used for the ratings are another relevant characteristic.

Evaluation models can be used to evaluate a Learning Object in different moments of its life cycle (as defined in section 2.3.2): during the distribution stage (in the approval step), after the distribution stage and after the use stage. Authors can also use an evaluation model to conduct self-evaluations as part of the authoring process. Since a model may have been designed to be applied in a particular stage, this is another characteristic. Thereby, evaluation models can be used to conduct different types of evaluations including self-evaluations (for authors), peer and collaborative reviews (reviewers, experts, and educators), automatic evaluations and validations (software systems), and end user evaluations (learners, teachers and other end users).

LORI (Learning Object Review Instrument) is likely the most widely used evaluation model for Learning Objects. The latest version is LORI 1.5 [273], which considers the following nine criteria: content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, reusability, and standards compliance. For each criterion, reviewers can enter comments and ratings on a 5-point scale. Reviewers can skip criteria that they are unable to assess or that they do not feel qualified enough to rate by selecting the “Not applicable” option instead of a numerical rating. This can also be done for criteria that are judged not relevant to the Learning Object. LORI 1.5 also defines an overall quality metric that consists of the average rating of all criteria. A convergent participation model is recommended to use LORI for collaborative evaluation [282], [283]. In this model, small teams of reviewers are formed from participants representing relevant knowledge sets (e.g. subject matter experts or e-Learning professionals). First, each member of the team evaluates the Learning Objects individually. Then, all members meet, usually via videoconference, to compare and discuss their evaluations and establish a final team evaluation. LORI was tested in a study that showed that it can be used to reliably assess some aspects of Learning Objects [284]. Other study found that LORI evaluations could be not sufficient to predict learning outcomes of students in some scenarios [285].

COdA is an evaluation model based on LORI and focused on higher education [263]. Authors, users and external reviewers alike can use COdA to evaluate Learning Objects by rating them according to the following 10 criteria: objectives and didactical coherence, content quality, capacity to generate learning, adaptability and interactivity, motivation, format and design, usability, accessibility, reusability and interoperability. As in LORI, each criterion is rated on a 5-point scale and admits comments. Reviewers can also skip criteria by selecting the “Not applicable” option. Results derived from evaluations of COdA motivated the development of a scoring rubric [263], [286]. At the time of writing, the COdA scoring rubric is being used by AENOR (Spanish Association for Standardization and Certification) as the basis for the development of a future standard for the quality evaluation of e-Learning resources. The name of the proposal is UNE 71362 [261], [280], and it is expected to be published in 2017. A recent paper presented an evaluation tool that had implemented a version of the standard [280]. According to this paper, UNE 71362 will consider the following 15 criteria: teaching description, content quality, capacity to generate learning, adaptability, interactivity, motivation, format and design, reusability, portability, robustness, learning scenario structure, navigation, operability, audiovisual content accessibility, and textual content accessibility. Each criterion is comprised of several items. Each item is given 0 score is if it not fulfilled and 1 if it is fully fulfilled. Intermediate scores and the “Not applicable” option are also considered. Each time an item is rated, the reviewer must justify the score. The overall quality score is obtained as the quotient between the sum of the scores obtained by the applicable items and the number of applicable items. The output of the model is this overall score plus comments.

LOEI (Learning Object Evaluation Instrument) was developed based on LORI, guidelines and specifications of Learning Object Repositories, and special concerns of the

K-12 environment [267]. It considers 15 criteria divided into the following 5 categories: integrity, usability, learning, design, and values. Reviewers rate each criterion using a 4-point scale and can enter comments. Overall quality score is calculated by averaging all ratings.

HEODAR is an evaluation model that allow reviewers to evaluate Learning Objects according to pedagogical and usability criteria [264], [265]. Pedagogical criteria are divided into two categories: psycho-pedagogical and didactic-curricular, and usability criteria are divided into other two categories: interface design and navigation design. These categories are in turn divided into subcategories. In total, the latest version considers 61 criteria. Each of them is rated according to a 5-point scale. Reviewers have the chance to select the D/N (don't know) value for a criterion as well as to provide comments. Overall quality score is calculated by averaging all ratings. The HEODAR tool described in [264] also proposed other metric that consists of the average of all ratings multiplied by the percentage of evaluators that have evaluated the Learning Object with respect to the total number of evaluators. The results of a study that evaluated HEODAR showed a high reliability of the evaluation model [287].

LOEM (Learning Object Evaluation Metric) allows reviewers to evaluate Learning Objects according to four distinct constructs: interactivity, design, engagement and usability [268]. A total of 17 criteria are considered. Reviewers rate each of these 17 criteria on a 3-point scale. The score of each constructor is calculated by adding the ratings of its criteria. However, LOEM does not specify how to calculate overall quality scores. LOEM was tested in middle and secondary schools and the results showed that it is a reliable, valid and effective approach for Learning Object evaluation [268].

MECOA allows learners, educators and experts to evaluate Learning Objects from a pedagogical perspective based on six quality indicators: content, representation, competence, self-management, signification and creativity [274]. Each of these indicators is comprised of several criteria. In total, MECOA considers 22 criteria. Each criterion is evaluated using linguistic labels (textual values from a controlled vocabulary). Overall comments are also allowed. MECOA does not provide any kind of score or quantitative evaluation.

LOAM (Learning Object Attribute Metric) supports the evaluation of Learning Objects with respect to a set of pedagogical criteria that are mapped to the environment, roles and activities as defined in the IMS Learning Design specification [266]. It considers the following criteria: interactivity, objective, integration, context, media richness, pre-requisites, support, feedback, self-direction, navigation, assessment and alignment. Each criterion is rated on a 5-point scale.

The University of Information Sciences in Cuba defined an evaluation model for use by authors and reviewers alike that aims to determine the quality of Learning Objects [262]. This model considers three aspects: formative (15 criteria), design and presentation (9 criteria), and technological (11 criteria). Each of these 35 criteria is rated on a 0-3 scale. The model defines metrics to calculate scores for each of the aspects and another one to calculate the overall quality score. The model also defines how to determine the quality of Learning Objects on a qualitative scale using these scores. Four possible values are considered in the qualitative scale: “Very suitable”, “Suitable”, “Not very suitable” and “Unsuitable”.

MERLOT is a Learning Object Repository that has a peer review process to evaluate the quality of the submitted resources [275], [276]. On MERLOT, reviewers evaluate the resources with comments and ratings on a 5-point scale according to three criteria: content quality, potential effectiveness as a teaching tool, and usability. The overall quality metric defined as the equally weighted mean of the three criteria is used to provide quality-based sorting of the search results. Furthermore, the end users of MERLOT can evaluate published resources by giving a single 1-5 star rating and a comment. This same single-criteria evaluation model is also used in the LRE repository [133] for the end user evaluations.

WBLT-S (WBLT Evaluation Scale for Students) allows assessing the effectiveness of Learning Objects from a learner’s perspective [9], [281]. WBLT stands for Web-Based Learning Tool and is a term used as a synonym of Learning Object. This model is a refinement of a previous one called LOES-S [269]. WBLT-S is intended to be applied by learners that have used Learning Objects in order to evaluate them according to three constructs: design, learning and engagement. A total of 13 criteria are considered. Learners rate each of these criteria on a 5 or 7-point scale. Besides, they can add comments about what they like and do not like about the Learning Objects. WBLT-T (WBLT Evaluation Scale for Teachers) aims to assess the effectiveness of Learning Objects from a teacher’s perspective [9], [281]. It is a refinement of LOES-T [270]. WBLT-T is intended to be used by teachers that have employed Learning Objects in their lectures in order to evaluate them according to three constructs: design, learning and engagement. A total of 11 criteria are considered. Teachers rate each of these criteria on a 5 or 7-point scale. Besides, they can add comments about their teaching experience. In WBLT-S and WBLT-T, the score of each constructor is calculated by adding the ratings of its criteria. However, these models do not define an overall quality metric. WBLT-S and WBLT-T have been tested in middle and secondary schools and results suggest that they are reliable and valid models to evaluate Learning Object quality [281].

The System Usability Scale (SUS) is a simple and reliable 10-item Likert scale giving a global view of subjective evaluations of systems usability [279]. It can be used to evaluate and measure the usability of any tool or system. Thus, it can be used for evaluating the usability of Learning Objects. SUS is intended to be used by the users after they have had an opportunity to use the system (or Learning Object) being evaluated, but before any discussion takes place. Each of the 10 items (i.e. criteria) of SUS should be answered by users on a 5-point Likert scale. Half of the items are positively worded and half are negatively worded. SUS defines a metric to yield an overall score on a 0-100 scale representing a composite measure of the overall usability of the system being evaluated.

Sanz-Rodríguez, Dodero and Sánchez-Alonso [277] proposed an evaluation model to measure aspects that influence Learning Object reusability using IEEE LOM [119] metadata. A total of four criteria are considered: cohesion, size, technological portability and educational portability. Each criterion is rated using a 5-point scale [278]. Although authors stated that scores for these criteria could be calculated automatically using LOM metadata for those Learning Objects with complete and correct metadata, no equations or processes were defined to do so. Therefore, human review is required. Three overall reusability metrics were proposed in order to aggregate the scores of the four criteria: one consists of a weighted arithmetic mean, other is based on the Choquet's integral and the other one consists of obtaining the overall reusability score using multiple linear regression analysis. An experiment showed that reusability scores obtained using these overall reusability metrics were significantly correlated with those obtained from LORI evaluations. The better results were obtained by the metric based on multiple linear regression analysis. The experiment also showed that the scores yielded by this metric significantly correlated with the number of times that Learning Objects were reused in personal collections in the MERLOT repository.

Besides the quality metrics defined by some of the above evaluation models, more metrics have been developed to evaluate various aspects of Learning Objects such as metadata quality [26], [288], popularity [219], [221], effectiveness [289], [290] or cost of reuse [192].

Vidal, Segura, Campos and Sánchez-Alonso [288] proposed a set of quality metrics for Learning Object metadata in order to evaluate metadata standardization, completeness, correctness, understandability, coherence and congruence. Some of these metrics can be calculated automatically by software systems while others require expert evaluations.

Ochoa [26] proposed a set of standard-agnostic metrics to measure the quality of Learning Object metadata instances in terms of completeness, accuracy, conformance to expectations (usefulness to find, identify and select the Learning Object), consistency (adherence to the metadata standard), coherence, findability, cognitive accessibility, timeliness and provenance. These metrics can be calculated automatically by software systems fast enough to be applied to each metadata instance at creation or update time. The metadata quality metrics were evaluated in three studies which yielded four major conclusions: some metrics correlated well with human reviews while others seemed to be completely orthogonal, human reviewers have difficulties to evaluate metadata quality appropriately, there are metadata characteristics that human reviewers are not able to evaluate, and the proposed metrics can be used by Learning Object Repositories to filter low quality metadata instances.

An evaluation model called LOQES was proposed to automatically evaluate Learning Objects in terms of various parameters including metadata quality and reusability [271], [272]. Metadata quality evaluation is based on the metadata quality metrics proposed by Ochoa [26] while reusability evaluation is based on the reusability metrics proposed by Sanz-Rodríguez, Dodero and Sánchez-Alonso [277], [278]. Although the idea of combining different existing metrics is interesting, no implementation or evaluation of the model is described. Future works should go beyond proposals and should implement and evaluate this type of models.

Other important metrics are the ranking metrics [218]–[221], which can be used by search services of Learning Object Repositories to sort the Learning Objects retrieved from the searches based on their relevance. According to [218], there are three main ranking strategies:

- *Ranking based on human review.* Some Learning Object Repositories sort their search results based on the average scores obtained from the quality evaluations conducted by reviewers and/or end users according to Learning Object evaluation models. This is the case of repositories such as MERLOT [275], [276] and eLera [283].
- *Ranking based on text similarity.* This strategy consists of ranking the Learning Objects based on the similarities between the text in the metadata and the search query terms.
- *Ranking based on user profile.* This strategy consists of using the user profile to personalize the search results. It typically uses similarity metrics (e.g. [219], [221]) to calculate similarities between Learning Objects or users as well as between Learning Objects and users. This type of similarity metrics are also used in recommender systems. Section 2.8 gives an overview of Learning Object recommender systems.

Besides, there are other two popular ranking strategies:

- *Ranking based on popularity*. It consists of ranking the Learning Objects based on popularity indicators such as the number of times that (or the frequencies with which) the Learning Objects are visited, downloaded, bookmarked, shared, etc. Therefore, this strategy completely relies on popularity metrics (e.g. [219], [221]).
- *Hybrid Ranking*. It is possible to create compound metrics by combining other metrics. Thus, ranking metrics can combine distinct indicators such as similarity to the search query terms, pedagogical quality measured through expert reviews, similarity with the user profile or popularity indicators. Examples of ranking metrics for Learning Objects based on integration of different indicators can be found at [218]–[220].

Ochoa and Duval [218] proposed a set of ranking metrics to estimate the topical, personal and situational relevance dimensions, which can be used to sort Learning Objects based on usage and contextual information. Authors stated that the different metrics should be combined to produce a unique ranking value in order to be useful, and presented different mechanisms to do this combination. The evaluation of the ranking metrics showed that they provide statistically significant improvement compared to a ranking based on pure text-based approach. The study concluded that ranking metrics could be used to improve current Learning Object Repositories.

In [219], several metrics for Learning Objects were proposed. First, some popularity metrics for Learning Objects were defined based on download frequency and timescales. Then, a quality metric was defined by incorporating end user evaluations in a popularity metric. Moreover, a metric for obtaining similarity between Learning Objects was defined based on cosine similarity and LOM metadata. Lastly, a ranking metric was defined by combining the previous metrics.

A set of metrics based on contextual attention metadata gathered from different tools used in the Learning Object life cycle were proposed by Ochoa and Duval [221]. A total of 11 metrics were proposed: 1 quality metric, 5 popularity metrics, 1 ranking metric and 4 similarity metrics.

The variety of environments in which Learning Objects can be used suggests that no single evaluation model is sufficient. Besides, given that the context in which a Learning Object is used can significantly influence learner attitudes and performance [31]–[33], [36], [291], quality evaluations and metrics should take into account context. According to [292], three phases need to be considered to evaluate and rank a set of Learning Objects using multi-criteria decision analysis: to decide a proper set of criteria, to assign weights that show criteria's relative importance, and to process and interpret numerical values which decide on the rank of each Learning Object as compared to total preference. Besides, if qualitative criteria are considered, an additional step is needed to transform these decisions into numerical values. Therefore, effective Learning Object evaluation models should define a set of criteria, weights for these criteria, and a metric to calculate overall quality scores.

Several software tools have been developed to evaluate the quality of Learning Objects following an evaluation model. Examples of these tools can be found for different evaluation models including tools that have implemented LORI [283], [293], UNE 71362 [280], HEODAR [264], MECOA [274] and LOAM [294], [295]. Besides, Learning Object Repositories such as MERLOT [275] or LRE [133] provide tools for evaluating their resources according to their models. A limitation of these tools is that they only support one evaluation model. Moreover, there is an increasing need for Learning Object Repositories to provide standard evaluation tools closely integrated with the Learning Object life cycle [296]. Another need is the development of an interoperable metadata model that enables to represent, store, manage, share and reuse evaluations of Learning Objects. Vuorikari, Manouselis and Duval [260] addressed this need and presented several scenarios to show how these metadata could benefit end users.

In summary, Learning Object evaluation and quality metrics can be used in Learning Object Repositories for implementing quality control mechanisms, filtering low quality Learning Objects, automatically validating metadata, enhancing search services by providing better ranking metrics, and allowing recommender systems to provide enhanced recommendations. However, not much work has been reported on these topics. Thus, future research should investigate how Learning Object evaluation models and quality metrics can be effectively used for the benefit of end users as well as which features should have evaluation systems in order to provide systematic evaluation of Learning Objects and generation of quality scores.

2.7 Learning Analytics

Learning analytics can be defined as “the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs” [297]. Learning analytics is a novel and growing research field related to educational data mining. Nonetheless, there are notable differences between the two fields in terms of scope and purpose. While educational data mining is concerned with developing methods to analyze the different types of educational data and using these methods to better understand learners and learning [298], learning analytics also tackles the interpretation and contextualization of those data in order to enhance learning. The learning analytics cycle is comprised of four steps [299]:

1. *Learners’ interactions*. The learners interact with e-Learning systems (typically VLEs) and e-Learning resources. Different types of interactions can be distinguished. For instance, Moore [300] classified learners’ interactions into three types: learner-content, learner-instructor and learner-learner. Other interactions that should be taken into account are those that learners have with the interface of software systems [301].
2. *Capture of data*. Data about the learners and their interactions are captured. In this regard, an important benefit of Learning Objects is that they can provide more detailed tracking of data about the learners’ interactions with learning content.
3. *Generation of analytics*. Data captured in step 2 are processed into analytics in order to provide some insight into the learning process.
4. *Interventions*. Lastly, the analytics are used to drive one or more interventions that have some effect on learners. The cycle can be considered complete even where the interventions do not reach the learners who originally generated the data.

Learning analytics systems need to address these four steps in order to be effective. These systems can improve their effectiveness in three different ways: by speeding up the realization of the intervention (e.g. by providing real-time feedback), by enlarging the scale of the intervention (e.g. by providing feedback to a larger number of stakeholders), and by improving the quality of the intervention itself (e.g. by providing more useful feedback) [299].

The use cases and benefits of learning analytics are numerous and varied [302]. For example, learning analytics can be used to predict student academic performance [97]–[101], predict student satisfaction [98], improve decision-making processes in academic institutions [98], monitor student activity [303], reduce attrition through early detection of students at risk of dropping out or failure and automatically generating alerts [99]–[101], diagnose collaboration between students [304], allow teachers to enhance the effectiveness of their courses by providing feedback about the different e-Learning resources, activities and tools used by the students [289], [303], measure effectiveness of Learning Objects [289], [290], define learner profiles [305], rank and recommend Learning Objects [221], and generate personalized sequences of Learning Objects for each student [305].

The techniques used in learning analytics are very diverse. Some of the most common are classification, clustering, association, decision trees, correlation, linear regression, social network analysis and web analytics. More information about techniques used in learning analytics can be found at [41], [101], [298].

The relationship between students' interactions with VLEs (typically LMSs) and their academic performance is an issue that has been frequently addressed in studies on learning analytics [97]–[103]. These studies usually aim to determine which of the interaction data may be pedagogically significant. Most of them analyze the interactions between students and an LMS like Moodle [79] in the context of blended courses or traditional distance learning courses. Examples of interaction data analyzed include, among others, logins, connection time, time spent on learning resources or assignments, messages read and posted in forums, accessed resources, accomplished activities, number of attempts, usage of specific functionalities (e.g. chat) and frequency of clicks. Besides interaction data, learning analytics systems can take into account other data sources such as students' demographic information and grades.

Although many studies have addressed learners' interactions with VLEs, there has been scarce research on learners' low-level interactions with Learning Objects. In this regard, [306] analyzed 1,335 sessions of students with interactive Learning Objects in order to identify a set of significant predictors of learning. Results found that interaction data such as the number of clicks and the time students spend on Learning Objects are significant indicators of learning. In [307], data from 494 students who had interacted with Learning Objects for several months were collected and used to predict their scores on a test. Results showed that learners' interaction data such as the time taken to answer questions, the number of hint requests and the number of attempts were negatively correlated with test scores, while total time spent on Learning Objects was positively correlated. Other relevant work is [289], which presents a generic methodology to determine the effectiveness of students when interacting with e-Learning resources in online courses. This methodology was applied to four particular SPOCs for calculating the effectiveness of videos and self-graded exercises. Effectiveness of videos was calculated as a function of the percentage of video watched by the students while effectiveness of exercises was calculated as a function of the number of times they were solved by the students. Lastly, other work proposed a set of metrics based on an adaptation of Google Analytics to evaluate the effectiveness of Learning Objects taking into account various interaction data such as the number of visits, time spent, achievement of learning goals, and percentage of exits without completing a goal [290].

Several learning analytics tools have been developed for LMSs (especially for Moodle) as well as for Learning Object Repositories. Descriptions of some of these tools can be found in [41]. Typical features offered by learning analytics tools include dashboards, monitoring of learning process, and generation of reports, graphical representations, statistics, alerts and recommendations both for teachers and students.

Significant challenges have been raised during the implementation of learning analytics in e-Learning systems. These challenges encompass needs for open platforms to integrate heterogeneous learning analytics techniques, open software and open educational technologies for learning analytics such as standards and APIs, and a clear set of ethical guidelines [41]. Some progress has been made with respect to the development of standards for learning analytics. The standards IMS LIP [159] and IEEE PAPI Learner [161] allow to represent learner profiles, and CAM [164] and IMS Caliper Analytics [165] allow to represent data about learner interactions. Furthermore, xAPI [111] allows applications to record interactions using a standardized API. Section 2.2 includes a description of all these e-Learning standards.

2.8 Recommender Systems

Recommender Systems (RSs) are software tools that provide suggestions for items likely to be of use to a user [308], [309]. “Item” is the general term used to denote what a RS recommends to users. In a TEL environment, items might be Learning Objects, educational activities, courses or peers relevant to the users’ interests. Thus, RSs can be used in the distribution stage of the life cycle of Learning Objects to facilitate their discovery. A RS can be distinguished from an information retrieval system by the semantics of its user interaction: while a result from a RS is understood as a recommendation (an option worthy of consideration), a result from an information retrieval system is interpreted as a match to a user’s query [309]. Recommendations usually consist of a ranked list of items. In performing this ranking, RSs try to predict what the most suitable items are based on the user’s preferences and constraints [308]. Therefore, RSs need to collect user’s preferences, which might be explicitly expressed (e.g. ratings) or might need to be inferred by interpreting the actions of the user (e.g. the access to a page that shows details of a Learning Object may be considered as an implicit interest for that Learning Object). In order to generate the recommendations, RSs typically calculate a score for each candidate item that represents the predicted utility or relevance of that item to the user. Thereby, the decision of what items to recommend is made based on the comparison of these scores.

Different types of RSs can be distinguished based on the techniques used to generate the recommendations [308], [309]. These recommendation techniques differ from each other mainly on the knowledge sources and the recommendation algorithms used. Each of them has its own strengths and shortcomings. The main types of RSs are:

- *Content-based.* The system learns to recommend items that are similar to the ones that the user liked or found interesting in the past. Recommendations are generated based on the features associated with the items and the ratings and/or actions of the user.

- *Collaborative filtering.* These systems generate item recommendations using only information about ratings or usage from different users. Two main approaches can be distinguished: user-based and item-based. User-based collaborative filtering recommends to the user items that other users with similar tastes liked or found interesting in the past. The similarity in taste of two users is calculated based on the similarity in the rating or usage of the users. Item-based collaborative filtering provides recommendations to a user based on the similarity between items calculated using the ratings or usage of the user and of other users for those items.
- *Demographic.* This type of systems recommends items based on the demographic profile of the user. Thus, recommendations are generated based on demographic information such as language, country, age, gender, etc.
- *Knowledge-based.* Knowledge-based recommenders suggest items to the users based on inferences about their needs and preferences. To achieve this, they usually use specific domain knowledge about how certain item features meet users' needs and preferences.
- *Community-based (social).* These systems provide recommendations of items based on the preferences of the user's friends and contacts. For this purpose, they use information about the social relations of the users and the preferences of their contacts. These systems are also known as "social recommender systems".
- *Hybrid.* Hybrid RSs are those that combine two or more techniques to generate the recommendations. Their aim is to achieve some synergy between the combined techniques in order to provide better recommendations. Hybrid RSs usually try to overcome the shortcomings of one or more techniques by using the strengths of other ones. Although not common, these systems can combine multiple different RSs of the same type (e.g. two different content-based RSs). Different types of hybrid RSs have been identified based on the type of combination used [309], [310]:
    a. *Weighted.* The scores of the different recommenders are combined numerically to produce a single recommendation.
    b. *Switching.* The system chooses among recommenders depending on the current situation and uses the selected one.
    c. *Mixed.* Recommendations from different recommenders are presented together.
    d. *Cascade.* The recommenders are given strict priority in such a way that those with lower priority break ties in the scoring of those with higher priority.
    e. *Feature combination.* Features derived from different knowledge sources are combined together and given to a single recommendation algorithm.
    f. *Feature augmentation.* One recommender is used to compute a feature or set of features which is then used in the input of another recommender.
    g. *Meta-level.* A model learned by one recommender is used as input for another.

A large variety of properties and problems of RSs are described in [311]. One of the most well-known problems in RSs is the cold-start problem, which concerns the issue that a system does not have sufficient information to handle new items or new users.

Context is an important source of information that can be used by RSs to provide recommendations. One of the most cited definitions of context is the one provided by Dey [312] that defines context as “any information that can be used to characterize the situation of an entity”, where entity is defined as “a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves”. Those RSs that incorporate contextual information into the recommendation process are called “context-aware recommender systems” [313], [314]. These systems recommend items to users taking into account contextual information such as time, location, current activity or device used. In TEL environments, RSs also usually take into account learning resources that are relevant to the user [314]. A typical case is recommending Learning Objects similar to those the user is viewing. Verbert et al. [314] proposed to classify context information that is relevant to context-aware TEL RSs according to eight categories: computing, location, time, physical conditions, activity, resource, user, and social relations. This contextual information can be obtained explicitly or implicitly, either directly or by analyzing users’ interactions.

RSs can also be classified as proactive or reactive. Proactive RSs differ from reactive RSs in that they automatically provide (or push) recommendations to the users, without explicit requests or actions from them.

A recent review conducted by Drachsler, Verbert, Santos and Manouselis [42] identified, analyzed and classified 82 TEL RSs. These RSs were classified according to supported tasks, user model, domain model, recommendation techniques, architecture and proactivity. Results showed that, in the field of TEL, RSs are used mainly to help learners and educators to find appropriate e-Learning resources, and to a lesser extent, to recommend sequences of resources, peers, courses and learning activities.

Some works on RSs for Learning Object Repositories have been published over the recent years. Al-Khalifa [315] described an item-based collaborative filtering RS for an Arabic Learning Object Repository. Cechinel, Sicilia, Sánchez-Alonso and García-Barriocanal [316] evaluated suggestions of e-Learning resources generated by different collaborative filtering recommendation algorithms using a database gathered from the MERLOT repository [275]. Ochoa and Duval [221] proposed a set of metrics for recommending Learning Objects based on IEEE LOM [119] and contextual attention metadata. Sergis and Sampson [317] proposed a RS for providing Learning Object recommendations to teachers based on their user profiles automatically elicited from their interactions within the Learning Object Repositories. More specifically, user profiles are elicited using histories of rating, bookmarking, Learning Object access and Learning Object creation. The RS was evaluated using datasets retrieved from three

Learning Object Repositories: ODS portal [131], [132], Discover the COSMOS [318] and OSR [319]. Gallego, Barra, Rodríguez and Huecas [320] proposed a theoretical model for generating proactive context-aware recommendations in the ViSH repository [56] by using social, user-based collaborative filtering and context-aware recommendation techniques. A subsequent study determined some parameters of this theoretical model [321]. Clough, Otegi, Agirre and Hall [322] described a model for generating non-personalized recommendations (i.e. generated without taking the user into account) of e-Learning resources from Europeana [57] using collaborative and content-based recommendation techniques. More recently, Otegi, Agirre and Clough [323] investigated the use of personalized PageRank algorithms to generate recommendations of Europeana resources. Gallego, Barra, Gordillo an Huecas [324] presented a model to generate proactive context-aware recommendations of e-Learning resources in Learning Object authoring tools. Fraihat and Shambour [325] presented a reactive semantic RS to assist learners in searching Learning Objects. Zapata, Menéndez, Prieto and Romero [326] presented DELPHOS, another reactive RS to assist learners in searching Learning Objects within a Learning Object Repository, which was implemented as a weighted hybrid RS that combines collaborative, content-based and demographic recommendation techniques. In a more recent work, the same authors described an implementation in DEPLHOS of a collaborative methodology for searching, selecting, rating and recommending Learning Objects [327]. Another related work is the one of Ruiz-Iniesta, Jiménez-Díaz and Gómez-Albarran [328], that proposed a knowledge-based recommendation model for OER repositories which was used to enhance OER search. In order to provide recommendations, the model uses a domain ontology, user queries, descriptions of the OER tagged with LOM metadata, and contextual information about the users: their level of knowledge on the different concepts defined in the ontology. In other work, the same authors described a hybrid recommendation model for Learning Object Repositories that exploits Learning Object metadata, learner profiles (navigation history and achieved goals) and rating scores that learners assign to Learning Objects [329]. More Learning Object recommender systems and algorithms are described in [42], [330].

Many evaluations of RSs have been conducted focusing on the accuracy of the algorithms. However, there is evidence that many other factors need to be considered for evaluating RSs since user satisfaction and perceived usefulness do not always correlate with high recommender accuracy [331], [332]. Shani and Gunawardana [311] described different methods and metrics to evaluate various properties of RSs including accuracy, utility, coverage, diversity, serendipity and scalability. Besides measure the performance of the RSs from a technical point of view, these systems should be evaluated from the user perspective. For this reason, several user-centred methods have been developed for evaluating RSs [332], [333]. Furthermore, TEL RSs can be evaluated considering also educational aspects. A recent survey of 265 TEL RSs provides an overview of the diverse methods that have been applied to evaluate these RSs [334].

2.9 Integration of Learning Objects

The integration stage of the Learning Object life cycle refers to the stage in which a Learning Object is integrated into a VLE, authoring tool or any other software system in order to enable its use by learners or to enable any other type of reuse. The existence of this stage indicates that Learning Objects need to be integrated into a system before they can be used (or reused).

Various e-Learning standards have been developed to integrate Learning Objects into LMSs and other e-Learning systems. Examples of these standards are IMS CP [113], SCORM [110], xAPI [111], IMS CC [116], IMS QTI [115], IMS LTI [114], IEEE LOM [119] and OAI-PMH [166], [167]. All these standards and some more are described in section 2.2.

Although e-Learning standards play a crucial role in facilitating the integration of Learning Objects, they are not enough by themselves to enable a successful integration of Learning Objects into all the different systems and contexts in which they can be used. On the one hand, it is necessary to develop tools, technologies and methodologies that exploit the affordances of the e-Learning standards [335]. On the other hand, the integration of Learning Objects into novel contexts or into contexts in which educational technology is not typically present requires analyzing the particular characteristics and constraints of those contexts and developing suitable integration approaches. Unfortunately, not much work has been done on these topics. This section reviews some related work on integration of e-Learning applications and Learning Objects in different systems and contexts.

Alario-Hoyos and Wilson [336] analyzed the main features of four alternatives to integrate external learning tools into VLEs: IMS LTI, IMS Basic LTI, Apache Wookie and GLUE! [337]. More proposals that have addressed the integration of external tools into VLEs can be consulted in [338]. Arapi, Moumoutzis and Christodoulakis [339] presented ASIDE, an architecture that conforms to IMS DRI [168] and that aims to support interoperability between e-Learning applications and digital repositories. Garaizar and Reips [340] presented a social network software system that was used to create a simulated social network where users can learn about privacy and social engineering in a practical and safe way. This work is an example of how social networks can be used for learning if suitable applications are integrated into them. The integration of online laboratories into e-Learning systems has been addressed in some works. Orduña et al. [341] described an architecture for integrating remote and virtual laboratories into e-Learning systems. Ruano, Cano, Gámez and Gómez [342] presented a set of procedures and resources to facilitate the integration of web laboratories developed with Java or JavaScript into LMSs using SCORM, including a Java package that facilitates Java applications to access and use the SCORM API, and a JavaScript library that works as a SCORM API Wrapper. In other work, Ruano, Gámez, Dormido and Gómez [343] proposed a generic methodology for developing online laboratories for learning that can be integrated into LMSs.

In addition to works on integration of e-Learning applications, there are several works in the literature on integration of Learning Objects into different systems and contexts. Verbert and Duval [186] presented ALOCOM, a generic Learning Object model for content interoperability that aims to facilitate the reuse of Learning Objects across different systems such as LMSs, Learning Object Repositories and authoring tools. Sullivan, Baum, Dyer and Braman [344] exposed an experience in which Learning Objects were integrated into a virtual world of Second Life. Gordillo, Gallego, Barra and Quemada [345] described a way of integrating Learning Objects into formal and informal mobile learning experiences based on the use of the cities as learning gamified platforms. Cubillo, Martin, Castro and Boticki [230] developed an authoring tool that allows to add Learning Objects into printed materials such as books and notes through tags. Other relevant work is the one of [346], which presented a solution for reusing SCORM resources from multiple repositories without making new copies of them, enabling this way multiple VLEs to access SCORM resources delivered from multiple repositories. The solution requires using an extension of IMS CP and including an application on the VLE server.

The peculiarities of the context of IDTV (interactive digital television) with respect to t-learning (a term coined to mean interactive learning based on TV) and the integration of Learning Objects have been studied by some researchers [347], [348]. De Souza, Zancanaro, dos Santos and Leomar [347] conducted a review on creation and adaptation of Learning Objects for the context of IDTV. Pazos-Arias et al. [348] presented ATLAS, a framework that supports the development and deployment of t-learning services exploiting the characteristic features of IDTV. An authoring tool to create Learning Objects for t-learning provided by the framework was also presented. ATLAS makes use of adaptations for IDTV of several e-Learning standards including SCORM, IMS QTI and LOM. Other related work is the one of Rey-López et al. [349], which introduced T-MAESTRO, an intelligent tutoring system that was incorporated into ATLAS to provide personalized t-learning experiences based on the use of adaptive Learning Objects for t-learning. Authors also developed and described an authoring tool that allows creating these adaptive Learning Objects using an extension of SCORM.

A few approaches have been developed addressing the authoring of Learning Objects through the integration, combination and/or disaggregation of other ones. In [350], authors proposed an extension of SCORM for supporting disaggregation and aggregation of Learning Objects and implemented a tool to evaluate the proposed extension. Based on the notion that the reusability potential of Learning Objects increases as their size decreases, [241] presented a process and a prototype for creating Learning Objects by decomposing Learning Objects into smaller ones. Another work on this topic can be found in [351], which presented an approach to assist authors to search Learning Objects and compose them in order to create new ones. Despite the work carried out so far, more efforts are needed to achieve an easy and effective assembling of Learning Objects by integrating and combining other Learning Objects.

The use of videoconferencing in the field of education is becoming increasingly popular due to the range of benefits it can offer [352]. Nowadays, there are many videoconferencing systems that can be used for synchronous e-Learning [353], [354]. Several benefits can be gained by integrating Learning Objects into videoconferencing services such as the sharing, co-viewing and synchronized co-browsing of Learning Objects at the same time that real-time communication is provided. An example of this integration can be found in Isabel [355], [356], a videoconferencing system which was used to deliver educational activities and share learning materials. Another example is the Bridgit videoconferencing system, which was used together with interactive whiteboards to share e-Learning resources across multiple classrooms [357].

The integration of Learning Objects into video games has attracted considerable attention. This is not surprising since this approach is a way of creating educational video games, and there is empirical evidence that playing with these games can lead to positive impacts in terms of motivation and learning outcomes [358], [359]. One of the main barriers hampering the introduction of video games in educational contexts is their huge development cost [360], [361]. For this reason, some authoring tools have been developed to allow teachers to create educational video games such as <e-Adventure> [361], e-Training DS [362], Game·Tel [363] and StoryTec [364], [365]. Many of these tools are aimed to create story-driven educational video games. Some of them use an approach based on game templates, in which authors can create educational video games through the configuration and customization of provided pre-made games. This approach often involves the integration of content and e-Learning resources into the game templates. An interesting work is the one of Minović, Milovanović and Starčević [366], who proposed a model for integrating Learning Objects into various multimedia platforms, and validated that model in the context of video games. The integration process consists of four steps. First, a Learning Object in the form of HTML page of a specific platform and its metadata are transformed into a platform specific XML file. After that, this file is transformed to a platform independent XML file. Then, the platform independent XML file is transformed to a new platform specific XML file suitable for the new context into which the Learning Object is going to be integrated. Lastly, the Learning Object is integrated into a target system using this file. For instance, for the validation the authors developed a game engine that interprets game platform specific XML files at runtime. Lastly, some works have also addressed the integration of educational video games into e-Learning systems (which is a distinct issue that integrating Learning Objects into video games). For example, [367] proposed to package educational games as Learning Objects in order to distribute these games to students through LMSs and track the students' performance in the game experience. Following this idea, [368] proposed three models to integrate educational games into VLEs based on the Learning Object approach and the use of e-Learning standards. Finally, [369] analyzed the possibilities of SCORM to integrate educational games into VLEs.

Chapter 3

An e-Learning Platform to Create and Distribute Learning Objects

Many Learning Object Repositories enriched with new features have been developed over the past years to store and distribute Open Educational Resources in the form of Learning Objects. However, not much work has been done to evaluate the use of these systems in order to study which features are worthy to be considered in their implementation, or to develop software for their creation. This chapter presents the results of the design, implementation, deployment and evaluation of ViSH, an e-Learning platform to create and distribute open Learning Objects. The evaluation of ViSH included user surveys, a usability test, a feature comparison and a quantitative analysis. The results of this evaluation show that ViSH is an effective system to create and distribute Learning Objects.

3.1 Introduction

The increasing recognition of the benefits of reusing and openly sharing e-Learning resources has led to the rise of the Open Educational Resources (OER) movement. The Learning Object paradigm seems to be the best path forward for OER since if these resources are created as open Learning Objects their discoverability, sharing and reuse potential can be maximized. For this reason, many Learning Object Repositories (LORs) have been developed over the past years in order to store and distribute OER in the form of Learning Objects. Several surveys and studies conducted in recent years have identified more than 100 different LORs [47]–[50]. Examples of popular LORs that distribute OER and are currently available are MERLOT [275], OpenStax CNX (formerly Connexions) [208], [209], LRE [133], the ODS portal [131], [132], and Europeana [57]. Nowadays, the number of LORs and the number of Learning Objects distributed through these repositories continue to grow.

Initially, LORs only allowed storing, searching and retrieving Learning Objects. However, educational communities continually demand new functionalities. In this regard, [46] proposed a list of more than 20 features that LORs should provide in order to meet the demands of the educational communities. The adoption level of these features by 49 major LORs was analyzed in a later study [47]. Moreover, the management of OER requires LORs to implement new features [51]. Furthermore, the support of e-Learning standards has gained importance since these standards are crucial for a LOR in order to effectively support the whole Learning Object life cycle. As a consequence of these facts, LORs have started to implement new features beyond storage, searching and retrieval of Learning Objects [46]–[50]. Examples of these features are, among others: authoring tools, advanced search, ranking metrics, quality control mechanisms, ratings and comments, personal accounts, collections, bookmarks, social networks, integration with LMSs, recommendations, and metadata harvesting. Some of these new features (e.g. ranking metrics, quality control mechanisms and recommendations) have the goal of facilitating the search of suitable Learning Objects in a LOR, a task that is generally difficult for users [43]–[45]. Contrarily, other features extend the functionality traditionally offered by the LORs. The implementation of these new features has led to the creation of enriched LORs: web-based e-Learning systems that are used not only for storing, distributing, discovering and retrieving e-Learning resources, but also for other purposes such as authoring and sharing OER in the form of Learning Objects. Nevertheless, not much work has been done to evaluate the effective use of these systems in order to study which features are worthy to be considered in their implementation. Some works have identified many features implemented in current LORs [46]–[50], but further research is needed to evaluate their effective use. Moreover, scarce quantitative analyses of LORs such as [211], [212] have been conducted so far. In this regard, Ochoa and Duval [212] made a call for more quantitative analyses of LORs. This type of studies could be of great help to obtain better understanding of the Learning Object life cycle and the requirements, gaps and opportunities for LORs. Lastly, in spite of the crucial role that LORs play in the large-scale distribution of OER, not much work has been done in developing software for building this kind of systems. On the one hand, there are some systems such as DSpace [223] and Fedora [224] which allows creating generic digital libraries and archives, but they are not appropriate for creating LORs since they lack of specific features to manage Learning Objects. On the other hand, hardly any systems have been developed for building specialized repositories for managing Learning Objects. Two examples of these systems are DOOR [225] and the software that runs OpenStax CNX (formerly Connexions) [208], [209] which has been released as open source [226]. Nevertheless, new systems for building LORs are needed because the features offered by the LORs that can be created with the existing systems are insufficient for supporting the whole Learning Object life cycle in an effective way.

This chapter presents the results of the design, implementation, deployment and evaluation of a web-based e-Learning platform called ViSH to create and distribute Learning Objects. ViSH consists of a LOR enriched with new features, which have been designed and implemented in order to satisfy the needs of the educational communities and support the whole Learning Object life cycle, including the management of open Learning Objects (i.e. OER). The software that runs the ViSH platform is open source and can be used for creating new platforms. Thereby, this work makes an important contribution by providing a software system for developing LORs. This chapter describes the main features of ViSH, and then provides an evaluation of the system. Several characteristics of ViSH were evaluated including user acceptance, perceived usefulness of the different features, and usability. A comparison of ViSH with other LORs in terms of features supported is also presented. Finally, a quantitative analysis of the ViSH platform was also conducted as part of the evaluation. Based on the evaluation of ViSH, this chapter aims to provide insights about which features should be considered in the implementation of systems aimed to create and distribute Learning Objects.

This chapter lays an important foundation for the following chapters of this thesis because, in addition to describing the ViSH e-Learning platform, it also introduces most of the systems presented in these chapters, which have been integrated into ViSH. More specifically, this chapter describes how and for what purpose are used in ViSH: the Learning Object authoring tool presented in chapter 4, the system for evaluating Learning Objects presented in chapter 5 (together with the quality metrics described in chapters 5 and 6), and the Learning Object recommender system for ViSH described in chapter 7. Besides, the description of the ViSH scenario contained in this chapter is also important since most of the solutions and systems proposed in this thesis have been evaluated in it.

The organization of the chapter is as follows. Next section shows the objectives and research questions of this thesis covered by this chapter. Section 3.3 describes ViSH in detail. Section 3.4 presents the results of the evaluation of the system. Finally, section 3.5 finishes with the conclusions of the chapter.

3.2 Objectives

This chapter addresses the following objective of the thesis:

- *Design, implement, deploy and evaluate an e-Learning platform to create and distribute Learning Objects. This e-Learning platform will integrate most of the systems implemented and presented along the thesis: a Learning Object authoring tool, a system to evaluate Learning Objects and a Learning Object recommender system. This goal also pursues to build a community of users on the platform that creates and openly shares educational resources with the entire world.*

Next section presents the results of the design, implementation and deployment of the ViSH e-Learning platform. The evaluation of the system is provided in section 3.4. This evaluation shows how effective has been ViSH in order to create and distribute Learning Objects, as well as to what extent it has succeeded in building a community of users that creates and shares OER in the form of Learning Objects with the entire world.

The chapter also covers the following research question of the thesis:

- *Which features need to be considered in the implementation of a system to create and distribute Learning Objects?*

The question is answered based on the results of the evaluation of the ViSH platform.

3.3 Description of ViSH

ViSH is a web-based e-Learning platform to create and distribute Learning Objects. It consists of a Learning Object Repository (LOR) enriched with new features such as authoring tools, a Learning Object evaluation system, a recommender system, a social network, collections, open licensing and integration with LMSs.

ViSH was originally developed for the GLOBAL excursion (Extended Curriculum for Science Infrastructure Online) project [54] funded by the European Commission under the Seventh Framework Programme. The initial requirements for the system were collected through the application of a participatory design process, which involved developers, scientists and teachers [55]. In this participatory design, the development team of ViSH and the future users engaged to work together, exchanged perspectives and defined a set of requirements. Taking into account that one of the main goals of the ViSH platform was to foster the authoring, distribution and sharing of OER, Learning Objects were identified and selected as the best approach for its implementation. During the GLOBAL excursion project, a first version of the ViSH platform was deployed and managed to establish a significant community of users. More information about the development and use of ViSH during the GLOBAL excursion project can be found in [370]–[374], as well as in chapter 9 of this thesis. After the project ended the development of ViSH has continued. A dialogue was established between the development team and the community of users of the ViSH platform. Based on this dialogue, many new features, enhancements and changes have been implemented over the last years. Thereby, the users of ViSH not only have used the platform, they have contributed to its design.

At present, the ViSH platform is publicly available at http://vishub.org. Figure 3.1 shows its frontpage. The platform has been operating for more than four years and is offered to the entire educational community for free. During these years, the ViSH platform has managed to establish a repository that provides a significant amount of Learning Objects and a relatively large community of users. The ViSH community has created and published many OER to teach and learn about various topics. New enhancements and features continued to be implemented in order to satisfy the demands of the community. Besides, ViSH has been and is used in several projects. Some of these projects are described in chapter 9 of this thesis. Furthermore, a transfer process has been initiated in order to offer ViSH as an institutional service of UPM (Universidad Politécnica de Madrid), which will ensure its long-term sustainability.

ViSH is open source and its source code is publicly available at http://github.com/ging/vish. Besides, a wiki is available at http://github.com/ging/vish/wiki, which contains various documentation of the project such as installation and deployment instructions, configuration guides, and API specifications. At the time of writing, ViSH 1.4 is the latest version released. This chapter describes this version of ViSH.

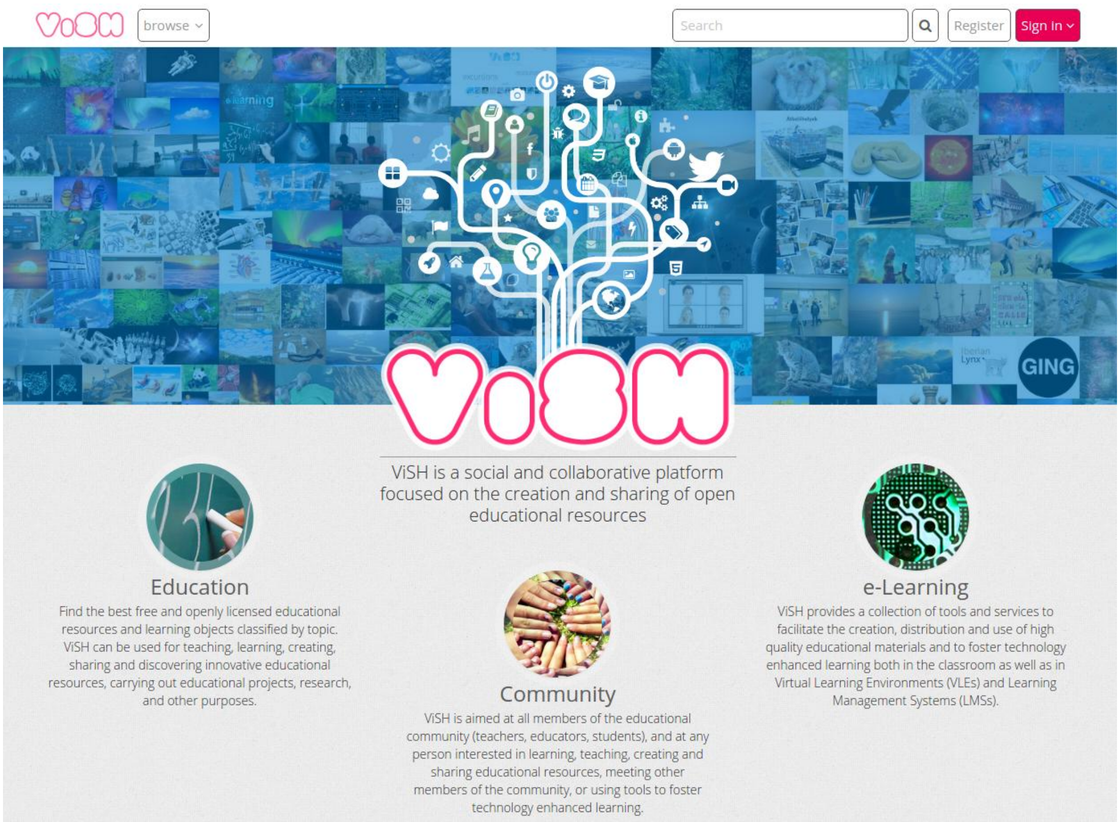

Figure 3.1: Frontpage of the ViSH platform

3.3.1 Architecture of the System

The main components of the architecture of the ViSH platform are represented in Figure 3.2, together with the main entities (users and software systems) involved in its operation.

The main features of ViSH are represented in its business layer. Next section describes each of these features in detail. All of them are provided directly by the ViSH server with the exception of the evaluation system, which is provided by using other system called LOEP (Learning Object Evaluation Platform). LOEP is an open source web-based platform that communicates with ViSH in order to provide it with systematic evaluation of Learning Objects and generation of quality scores. Chapter 5 of this thesis describes in detail the LOEP system.

The data layer shows the main data that are stored in the systems. ViSH stores information of registered users (including credentials, profiles and contacts in the social network), Learning Object metadata, Learning Objects created with the authoring tools offered in the platform, files (e.g. pictures, videos, text documents, e-Learning content packages, web applications, ...), links to external Learning Objects and websites, collections, quality scores of the evaluated Learning Objects, indicators of popularity of the Learning Objects (e.g. number of visits and downloads) as well as of the users (e.g. number of contacts), data about the interactions of the users, and learning analytics obtained from these interaction data. The evaluations of the Learning Objects and the data related to these evaluations (e.g. reviewers responsible of the evaluations and completion dates) are stored separately in the database of the LOEP system.

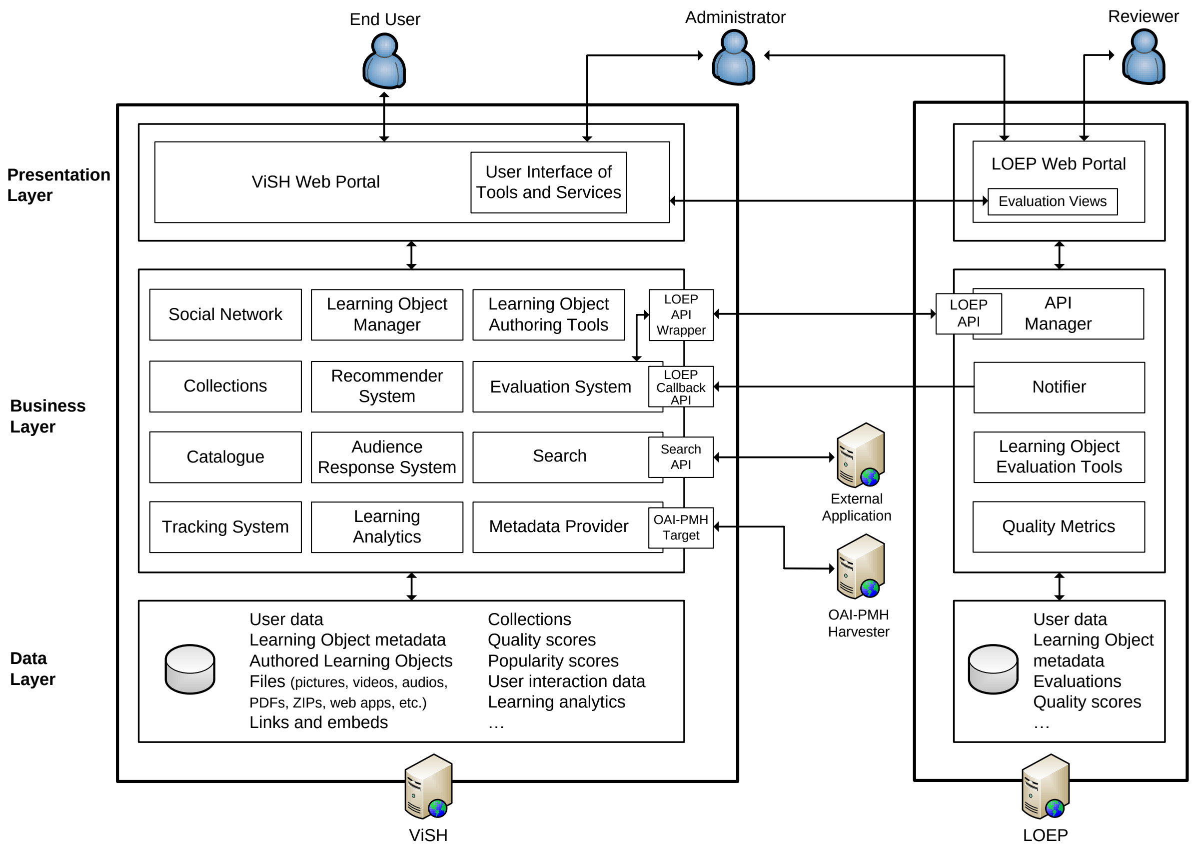

Figure 3.2: Architecture of the ViSH platform

ViSH has been developed using the Ruby on Rails web application framework. HTML5, JavaScript and CSS were used for developing the frontend (i.e. presentation layer). Regarding the data layer, two different database management systems can be used with ViSH: PostgreSQL and MySQL. The former is the one used in the ViSH instance deployed at http://vishub.org.

Different type of entities can interact with ViSH for different purposes:

- *End Users.* These users access ViSH using the web portal in order to use the features offered by the platform. Many features (e.g. search, access and download of Learning Objects) do not require the user to login, although others (e.g. creation and publication of Learning Objects) are only available for registered users. ViSH is targeted to different types of users including students, teachers and educators. In this regard, it is worth noting that ViSH is aimed at all educational levels and covers all subject areas. End users can use ViSH mainly for the following purposes:
    a. *Learn.* Users have access to a repository of OER in the form of Learning Objects. These Learning Objects can be discovered using search services, a catalogue, a recommender system or by browsing through the web portal. Besides, ViSH can also be integrated with the Moodle LMS [79] to offer courses.

   b. *Teach.* Teachers can use the Learning Objects published on ViSH for their teaching. They can use the Learning Objects directly in ViSH or integrate them into a VLE. Moreover, the Learning Objects created with authoring tools can be customized by the teachers in order to be adapted to their needs.
   c. *Create.* Teachers and educators can create their own Learning Objects by using the authoring tools offered by ViSH.
   d. *Share.* Users can share their resources with the entire world. On the one hand, users can upload resources and publish them. On the other hand, users can share the Learning Objects they have created in the platform.
   e. *Meet new people.* ViSH provides a social network where users can meet new members of the educational community.

- *Reviewers.* These users are accredited reviewers who evaluate the quality of the Learning Objects published on the ViSH platform through the LOEP system. Reviewers conduct the evaluations by accessing the web portal of LOEP and using the evaluation tools provided by this system.
- *Administrators.* Administrators are users with additional privileges to manage user accounts, resources, evaluations and, ultimately, the ViSH platform as a whole.
- *External applications.* Two different services are offered to external applications in order to allow them to use the ViSH platform:
   a. *Search API*. This API allows different types of applications such as other LORs, e-Learning authoring tools and LMSs to find and retrieve Learning Objects from ViSH.
   b. *OAI-PMH Target.* This service allows external systems to harvest Learning Object metadata from ViSH using the OAI-PMH [166] standard.

3.3.2 Features

3.3.2.1 Social Network

ViSH provides a social network that was developed based on Social Stream [375], a framework for building distributed social network websites. Thus, ViSH provides typical social networking features like personal accounts, user profile pages, following/follower relationships, activity timelines, comments, notifications and private messaging. Users can enrich their profile with personal information such as their full name, avatar (an image for representing the user within ViSH), organization, country, website, areas of interest (in the form of tags), and an “about me” section. The main use of the social network in ViSH is to enable members of the community to meet each other, exchange ideas, experiences and comments, and collaborate. Users can also follow other users to receive information about their activities (e.g. publication of new Learning Objects).

3.3.2.2 Learning Object Manager

This feature tackles the management of all the e-Learning resources stored in the ViSH repository, both the resources that are uploaded by users to the system and the Learning Objects that are created using the offered authoring tools.

ViSH allows users to upload to the platform three types of resources:

- *Files*. The current version supports the following types of files:
  - *Pictures*, in commonly used image file formats such as JPG, PNG and GIF.
  - *Audios and Videos.* Users can upload video files (in different formats such as AVI, MOV, WMV, WEBM and MP4) and audio files (in formats such as WAV, OGG and MP3). ViSH provides a media conversion service that converts these videos and audios to HTML5 compliant formats if necessary, making them accessible from any device with an HTML5 compliant browser.
  - *PDF files.*
  - *ZIP files.*
  - *Flash objects*, saved as SWF files.
  - *Text documents*, in DOC and DOCX formats.
  - *Presentations*, in PPT and PPTX formats.
  - *SCORM packages*, compliant with SCORM 1.2 [147] or SCORM 2004 [110].
  - *IMS content packages,* compliant with IMS CP 1.1.4 [113].
  - *Web applications.* In order to be recognized by ViSH, these web applications must be packaged in a ZIP file with an index.html file inside it.
  - *Generic files.* If a file whose format is not recognized by ViSH is uploaded, it will be stored as a generic file.
- *Links*. Users can submit links to any website. Thereby, users can share links to external Learning Objects, e-Learning tools, repositories, etc. The links can be visualized on ViSH by embedding the linked website or just by showing its URL.
- *Embeds.* Some repositories such as YouTube and Vimeo allow sharing their resources by using an embed code. ViSH recognizes embed codes from some of the major content providers in order to facilitate the sharing of their resources.

Users should specify metadata for the resources they upload or create. In the case of uploaded resources, metadata are specified through web forms. In the case of authored Learning Objects, metadata are managed by using the corresponding authoring tool. Uploaded resources are automatically published. Conversely, the Learning Objects created with authoring tools can be saved as drafts and published when the author deems it to be completed. Drafts can only be accessed by their owners (i.e. their authors). Once a resource has been published, users can edit its metadata as well as retract or remove the resource.

All resources can be described with the following metadata: title, description, keywords (in the form of tags), language, avatar (an image for representing the resource), recommended age range, and license (including original author and attribution required by the license if necessary). In order to publish a resource, users must provide at least the title and the required license information. In addition to these metadata, ViSH automatically includes more metadata such as owner, creation date, update date, resource type according to the ViSH classification, size (for uploaded files), and version of e-Learning standard (for SCORM and IMS packages). It is worth noting that these are the mandatory metadata fields that any resource stored in ViSH should support, but the tools and systems of ViSH are free to incorporate more metadata fields. For instance, the ViSH Editor authoring tool (described in next section) allows users to tag Learning Objects with more metadata fields such as educational context, difficulty, typical learning time, subject and educational objectives. Almost all of these metadata fields can be represented using the IEEE LOM [119] standard. In this regard, ViSH provides LOM metadata instances in XML format for all resources.

Regarding copyright, ViSH allows contributors to license their resources using Creative Commons licenses [199] (see section 2.3.3 for details) or as public domain. Contributors can also specify other open licenses not explicitly considered by the system. Thereby, contributors can retain copyright while granting permission to others to use, copy, distribute or make derivative works of their resources under certain conditions. ViSH also allows users to submit OER published by third parties indicating the corresponding author and the attribution required by the license. Once a resource has been published, its license cannot be changed. In this way, users who reuse an OER stored in the ViSH platform have a guarantee that it will remain open under the same conditions.

Each resource published on ViSH has its own page with a unique URL. Figure 3.3 shows an example of a page of a resource published on the ViSH platform. Next, each of the features offered in these pages are explained:

- *Viewing of content*. Users can view the resources directly in the web portal of ViSH through a web browser. This is possible for all resources except ZIP files, generic files (i.e. files in unrecognized format), and links whose linked website cannot be embedded.
- *Viewing of metadata*. Metadata of a resource can be viewed through the web portal and also as a LOM metadata instance in XML format.
- *Viewing of popularity indicators*. The page of a resource shows the number of times it has been visited and bookmarked.
- *Viewing of quality indicators*. The page of a resource can show results of quality evaluations provided by the ViSH evaluation system. Results of different evaluations (e.g. evaluations conducted by end users and reviewers according to different evaluation models) can be offered for a same resource. These results show through graphs the

different criteria evaluated and the numerical score of each criterion. At present, only results of evaluations from end users for one type of Learning Object are shown. Further details are included in the description of the evaluation system feature.

- *Download of content*. This feature is available for all files as well as for authored Learning Objects that can be exported as content packages (e.g. SCORM packages).
- *Download of metadata*. Download of LOM metadata in XML format is supported.
- *Sharing*. All resources can be shared through its unique URL. ViSH also allows sharing resources through social networks (Twitter, Facebook and Google Plus) and email. Besides, most resources that allow viewing of content can be shared by using an embed code, which allows to embed these resources in external websites (e.g. blogs).
- *Comments*. Registered users can comment on the published resources that allow this option.
- *Collections and bookmarks.* Registered users can save a resource in a personal collection, as well as bookmark a resource to add it to their favorites.
- *Recommendations.* On the page of each resource, a list of suggested resources generated by the ViSH recommender system is shown.
- *Reports.* Users can report inappropriate content and errors.

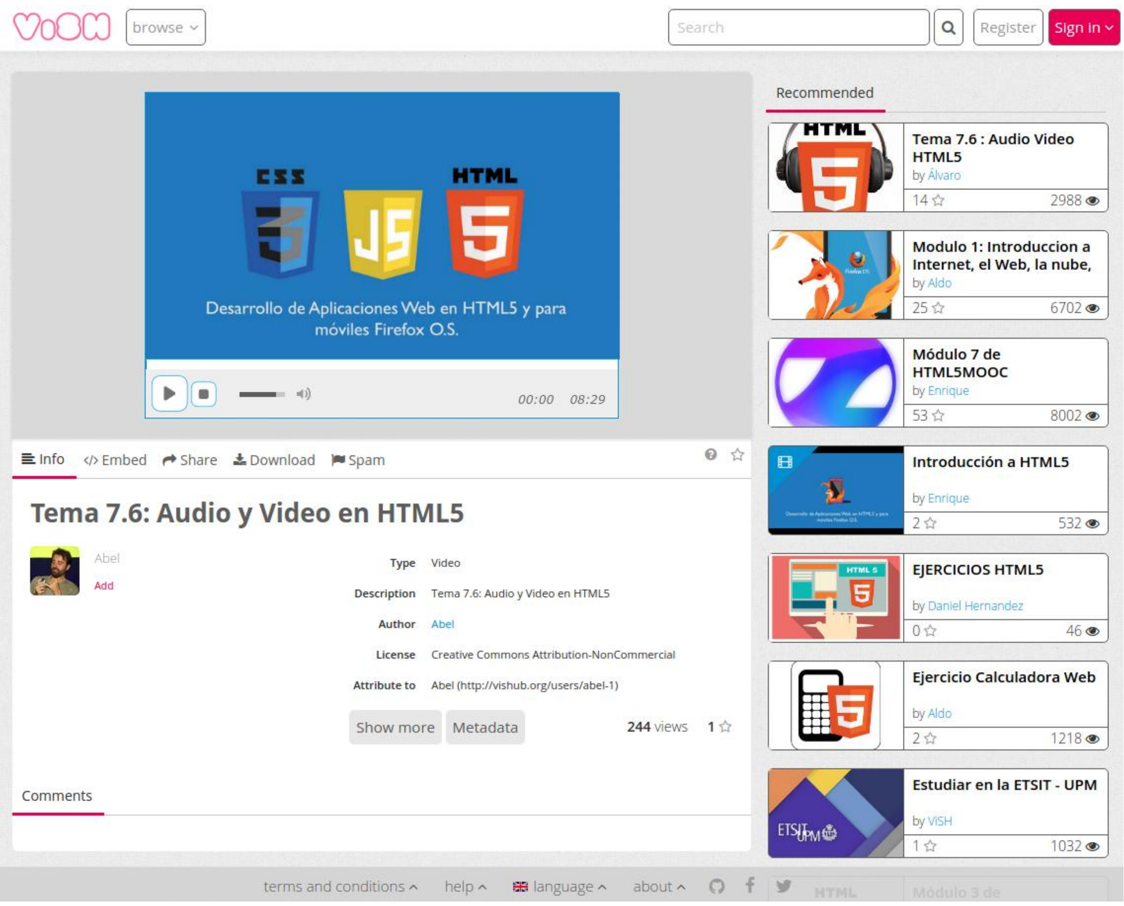

Figure 3.3: Resource published on the ViSH platform

3.3.2.3 Learning Object Authoring Tools

3.3.2.3.1 ViSH Editor

ViSH Editor is a web-based authoring tool available on the ViSH platform that allows registered users to create Interactive Presentations in the form of Learning Objects. These Interactive Presentations can integrate different types of resources including images, audios, videos, text, self-graded questions, SCORM and IMS content packages, and web applications. Questions can be created from scratch or they can be imported from IMS QTI [115] and Moodle XML [153]. Moreover, Interactive Presentations can integrate other interactive Learning Objects created with the tool such as Flashcards, Virtual Tours and Enriched Videos. ViSH Editor also allows authors to convert PDF slideshows into Interactive Presentations, which can be enriched later. Furthermore, authors can reuse resources and slides from Interactive Presentations published by other users on ViSH, as well as cloning them in order to create derivative works. The Interactive Presentations created with ViSH Editor can be exported to SCORM 1.2 and SCORM 2004 4th Edition. ViSH users can download from the web portal the Interactive Presentations published on ViSH as SCORM 1.2 and 2004 packages and integrate them into SCORM compliant VLEs such as Moodle. The metadata included in the SCORM packages are LOM compliant. The Interactive Presentations can be accessed from any device with an HTML5 compliant web browser without an installation being needed. A detailed description and evaluation of the ViSH Editor authoring tool is presented in the next chapter of this thesis.

ViSH Editor is the main authoring tool of the ViSH platform. The Interactive Presentations created with ViSH Editor, which are referred to as "Virtual Excursions" in the web portal, are the most important e-Learning resources offered by ViSH. For this reason some of the features are focused on these resources. Figure 3.4 shows two slides of an Interactive Presentation created with ViSH Editor and published on the ViSH platform. More examples of Learning Objects created with ViSH Editor can be found in [376].

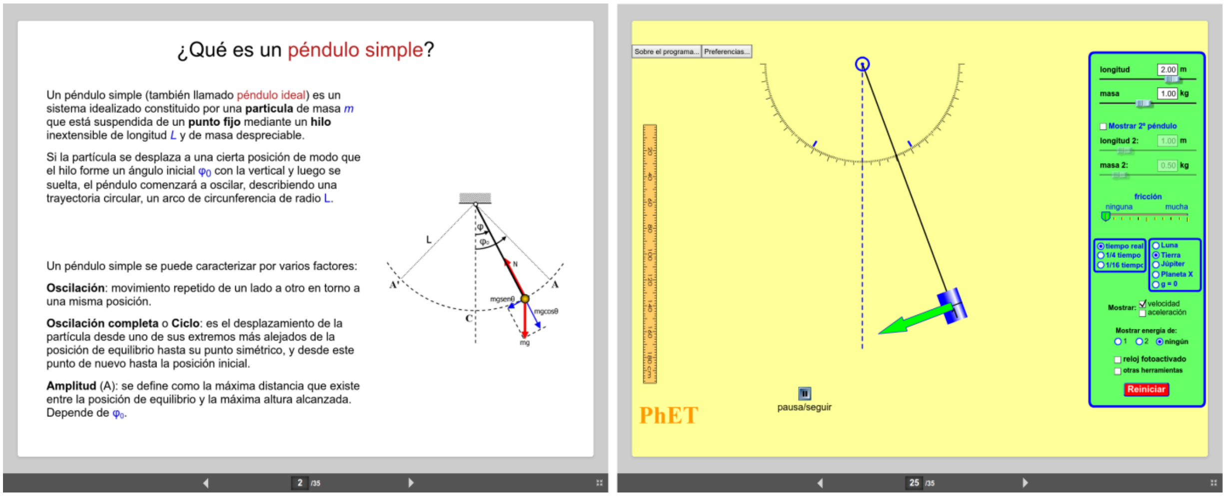

Figure 3.4: Interactive Presentation created with ViSH Editor

3.3.2.3.2 ViSH Lesson Editor

ViSH provides another authoring tool called ViSH Lesson Editor, which allows registered users to create lessons in the form of Learning Objects through the integration and combination of different elements. A lesson consists of a single web page in which all their elements are placed in sequence one after another. The current version of the authoring tool allows adding to a lesson the following types of elements:

- *Text*. Authors can add blocks of text to a lesson. Thereby, they can add an introduction to the lesson, statements of exercises, descriptions of activities, a bibliography, etc.
- *Resource*. Any public resource available on ViSH can be added to a lesson (except other lesson). Therefore, a lesson may include files (e.g. pictures, audios, videos, PDF and ZIP files, SCORM packages, web applications, ...), links, embeds and Learning Objects created with ViSH Editor (i.e. Interactive Presentations). Resources that allow viewing of content are embedded in the web page of the lesson while the others are included through links to their corresponding pages. Thereby, ViSH Lesson Editor allows authors to create lessons in the form of Learning Objects by integrating and combining the other resources available on ViSH.
- *Gallery of resources*. This element allows authors to group together a set of resources in a single component. Instead of displaying content, galleries of resources show the avatars of the resources and provide links to them. These elements may be useful to organize resources within a lesson or to provide additional materials.
- *Assignment*. Assignments allow end users to submit resources to a lesson. These resources are termed “contributions” and can be submitted by users in two ways:
    a. By uploading a file. Any file supported by ViSH is valid.
    b. By selecting a public resource (file, link, embed or Interactive Presentation) stored in ViSH and owned by the user.

  The owner (i.e. the author) of a lesson has access to a page that lists all its contributions.
- *Gallery of contributions*. This element can be added to a lesson in order to show to end users all the submitted contributions.

A lesson can include any number of elements of any type. Thus, authors are free to include all the elements they want and to specify their order in the sequence.

Lessons have a wide range of use cases. They may be used for the same purposes as the other Learning Objects, but they may also be used to conduct learning activities in which learners have to submit some content (e.g. experiences of learning by doing in which learners have to create Learning Objects), workshops or contests. Figure 3.5 shows an example of a lesson created with the ViSH Lesson Editor authoring tool that was used in a workshop on creating Learning Objects.

Figure 3.5: Lesson created with ViSH Lesson Editor

3.3.2.4 Collections and Bookmarks

On ViSH, registered users can create personal collections (named "categories" in the web portal) to organize their resources. Besides own resources, users can save in these collections public resources of ViSH owned by other users. Collections are similar to folders. On the one hand, users can create collections inside other collections forming a hierarchy in the form of a tree. On the other hand, users can place the items of a category in the order they want. By default, collections are hidden to other users in the sense that they are not indexed by search services, and they are only visible in the user profile page for the owners. However, a user may decide to make a collection completely visible. Thereby, users are able to not only publish and distribute individual resources, but also to publish and distribute collections of resources.

All users have a special collection named “My Favorites”. On the page of each resource, a button is provided to allow users to bookmark such a resource to automatically add it to their favorites (i.e. to automatically save the resource in the “My Favorites” collection of the user). Users can view and manage their favorites in their profile page.

3.3.2.5 Evaluation System

Mainly, the ViSH evaluation system provides support to:

- Allow the systematic evaluation of the quality of the published Learning Objects:
    a. From reviewers by using the LORI [273] evaluation model.
    b. From end users who are learners by using WBLT-S [9], [281].
    c. From end users who are teachers by using WBLT-T [9], [281].

  Reviewers should conduct the evaluations through the web portal of the LOEP system, while end users can evaluate Learning Objects directly on the ViSH web portal by using web forms provided by LOEP. Thus, the use of LOEP is transparent for end users.
- Allow the automatic evaluation and measurement of the metadata quality of the published Learning Objects. This is done by using a set of metadata quality metrics defined based on the metrics proposed by Ochoa [26]. Validation of the metadata is also supported.
- Generate quality scores based on the evaluations performed with the evaluation models LORI, WBLT-S and WBLT-T by using Learning Object quality metrics. The evaluation system also generates quality scores for metadata by using the metadata quality metrics. Lastly, overall quality scores for all evaluated Learning Objects are generated based on the above scores.
- Generate warnings when Learning Objects have quality scores below a threshold.
- Show in the web portal the results of the quality evaluations of the Learning Objects to the end users. These results show the evaluated criteria and the numerical score of each criterion through radar and bar graphs obtained from LOEP.

Unlike the other features, the ViSH evaluation system is not provided directly by the ViSH server, but by relying on the LOEP system. Chapter 5 of this thesis describes in detail LOEP and presents an evaluation of it. All evaluation models and metrics used to calculate the quality scores provided by LOEP to the ViSH evaluation system are also described in that chapter. This section focuses exclusively on the integration and use of LOEP in ViSH.

As shown in Figure 3.2, the communication between ViSH and LOEP is done through two APIs. On the one hand, LOEP provides a REST API that ViSH can use to register, update and remove Learning Objects in LOEP. The LOEP API can also be used by ViSH in order to embed in its web portal HTML pages from LOEP such as evaluation web forms and result graphs. The "LOEP API Wrapper" is a component that facilitates the use of the LOEP API, and that is used in ViSH to facilitate the evaluation system to send data to LOEP. On the other hand, ViSH provides a REST API (termed LOEP Callback API) that LOEP can use to send to ViSH the quality scores obtained by the registered Learning Objects. Regarding security, both APIs can be protected with HTTP basic authentication over HTTPS.

Several types of quality scores are provided by LOEP to ViSH. These quality scores can be then used by ViSH for different purposes. The current version of ViSH only registers in LOEP its main resources: the Learning Objects created with ViSH Editor (i.e. Interactive Presentations). Future versions will register all the resources of the repository. For each registered Learning Object, LOEP provides to ViSH the following quality scores:

- Average quality score given by reviewers (Q_R). This score is calculated based on the LORI evaluations according to the LORI WAM (Weighted Arithmetic Mean) CW metric.
- Average quality score given by learners (Q_L). This score is calculated based on the WBLT-S evaluations according to the WBLT-S AM (Arithmetic Mean) metric.
- Average quality score given by teachers (Q_T). This score is calculated based on the WBLT-T evaluations according to the WBLT-T AM metric.
- Metadata quality score (Q_M). This score is automatically calculated by LOEP by using the LOM Metadata Quality metric.
- Interaction quality score (Q_I). This score is automatically calculated by LOEP by using a predictive metric based on learning analytics termed "Interaction Quality", which estimates the quality of Learning Objects based on the interactions that learners have with them.

All these scores are provided as decimal numbers on a scale from 0 to 10. The metrics used to calculate these scores are defined and described in chapter 5 of this thesis. Furthermore, a detailed explanation and evaluation of the predictive metric used to calculate the interaction quality scores is included in chapter 6.

Based on these quality scores, the ViSH evaluation system generates an overall quality score (Q) for each Learning Object on a 0-1 scale. These overall quality scores are very important because they are used to enhance the search services, the recommender system and the catalogue of ViSH. Scores can also be used to generate warnings of low quality resources. Details about the use of the quality scores in ViSH are included in the following sections: default ranking metrics, search, catalogue, recommender system and administration.

If a Learning Object has not been evaluated, it receives a default overall quality score (Q) of 0.5 out of 1. Thereby, resources not evaluated have lower priority in terms of quality than those resources positively evaluated, but higher priority that those negatively evaluated. This fact implies, for example, that new resources will be more visible in the web portal than those resources that have received poor evaluations.

For Learning Objects that have been evaluated, the overall quality score (Q) is calculated on a 0-1 scale based on the quality scores given by reviewers (Q_R), learners (Q_L) and teachers (Q_T), according to the following equation:

$$Q(\{Q_R, Q_L, Q_T\}) = f(A) = \frac{1}{10} \times \frac{\sum_{q \in A} W_q \times q}{\sum_{q \in A} W_q}, \qquad Q \in [0,1] \tag{3.1}$$

where A is the largest subset of the finite set $\{Q_R, Q_L, Q_T\}$ that satisfies that all their scores exist for the Learning Object for which Q is calculated, and

$W_{Q_R} = 0.6$, $W_{Q_L} = 0.3$, and $W_{Q_T} = 0.1$

For instance, the overall score of a Learning Object evaluated only by reviewers will be calculated according to the following equation:

$$Q(\{Q_R, Q_L, Q_T\}) = f(\{Q_R\}) = \frac{1}{10} \times \left(\frac{W_{Q_R} \times Q_R}{W_{Q_R}}\right) = \frac{Q_R}{10} \tag{3.2}$$

If this Learning Object is then evaluated also by one or more learners, its overall score will be calculated as follows:

$$Q(\{Q_R, Q_L, Q_T\}) = f(\{Q_R, Q_L\}) = \frac{1}{10} \times \left(\frac{W_{Q_R} \times Q_R + W_{Q_L} \times Q_L}{W_{Q_R} + W_{Q_L}}\right) = \frac{1}{10} \times \left(\frac{0.6 \times Q_R + 0.3 \times Q_L}{0.6 + 0.3}\right) = \frac{1}{10} \times \left(\frac{2}{3} \times Q_R + \frac{1}{3} \times Q_L\right) \tag{3.3}$$

If a teacher evaluates this same Learning Object, its overall score will be now calculated in the following way:

$$Q(\{Q_R, Q_L, Q_T\}) = f(\{Q_R, Q_L, Q_T\}) = \frac{1}{10} \times (0.6 \times Q_R + 0.3 \times Q_L + 0.1 \times Q_T) \tag{3.4}$$

For example, a Learning Object that has obtained an average quality score of 6.5 from three accredited reviewers, an average quality score of 7.2 from several learners, and a quality score of 8 from one teacher, will have an overall quality score of:

$$Q(\{Q_R, Q_L, Q_T\})|_{\{Q_R, Q_L, Q_T\} = \{6.5, 7.2, 8\}} = \frac{0.6 \times 6.5 + 0.3 \times 7.2 + 0.1 \times 8}{10} = 0.686 \tag{3.5}$$

In this way, quality scores of Learning Objects are calculated according to different equations depending on the evaluation data available. A total of eight cases are considered for calculating Q depending on the availability of the quality scores Q_R, Q_L, and Q_T.

At present, metadata and interaction quality scores are only used for research purposes. Nevertheless, these scores can be very useful for future developments. On the one hand, metadata quality scores can be used to provide feedback to authors in order to facilitate them to enhance the metadata of their Learning Objects. These scores might also be used in the calculation of the overall quality scores. On the other hand, interaction quality scores can be used to estimate the quality of those Learning Objects that have not been evaluated, but that have enough interaction data to do so (see chapter 6 for further details).

3.3.2.6 Popularity Metrics

ViSH calculates popularity scores of all their objects (resources, collections and users) by using popularity metrics. All these popularity scores are calculated on a 0-1 scale. Two popularity metrics have been defined for resources: one for those resources that can be downloaded (and therefore for which the number of downloads can be counted), and another one for those resources that cannot be downloaded. Popularity scores of collections are calculated by using a different metric. Lastly, another metric has been defined to calculate the popularity of users.

The popularity score of a downloadable resource (e.g. a file or an Interactive Presentation) is calculated according to the following equation:

$$P(F_V, F_B, F_D) = W_{F_V} \times \frac{F_V}{MaxF_V} + W_{F_B} \times \frac{F_B}{MaxF_B} + W_{F_D} \times \frac{F_D}{MaxF_D}, \quad P \in [0,1] \tag{3.6}$$

where F_V, F_B and F_D are, respectively, the frequencies with which the resource has been visited, bookmarked and downloaded, $MaxF_V \geq 1$, $MaxF_B \geq 1$ and $MaxF_D \geq 1$ are, respectively, the maximum values of F_V, F_B and F_D obtained by a resource in the repository, and $W_{F_V} = 0.6$, $W_{F_B} = 0.3$, and $W_{F_D} = 0.1$

The frequencies F_V, F_B and F_D of a resource are calculated using the following equations:

$$F_V(N_V, T_R) = \frac{N_V}{MAX\left(\frac{T_R}{T_P}, 0.5\right)} \tag{3.7}$$

$$F_B(N_B, T_R) = \frac{N_B}{MAX\left(\frac{T_R}{T_P}, 0.5\right)} \tag{3.8}$$

$$F_D(N_D, T_R) = \frac{N_D}{MAX\left(\frac{T_R}{T_P}, 0.5\right)} \tag{3.9}$$

where N_V is the total number of times the resource has been visited,
N_B is the total number of times the resource has been bookmarked,
N_D is the total number of times the resource has been downloaded,
T_R is the time since the creation of the resource, and
T_P is a fixed period of time expressed in the same units as T_R
ViSH uses a default T_P of two months and represents time variables in seconds

The following equation is used to calculate the popularity score of a resource that cannot be downloaded (e.g. a link or a lesson):

$$P(F_V, F_B) = W_{F_V} \times \frac{F_V}{MaxF_V} + W_{F_B} \times \frac{F_B}{MaxF_B}, \quad P \in [0,1] \tag{3.10}$$

where $W_{F_V} = 0.7$ and $W_{F_B} = 0.3$

The popularity scores of collections are calculated taking into account only the visits (since collections cannot be downloaded or bookmarked) according to the following equation:

$$P(F_V) = \frac{F_V}{MaxF_V}, \qquad P \in [0,1]$$

where F_V is the frequency with which the collection has been visited calculated in the same way as Equation 3.7, and $MaxF_V \geq 1$ is the maximum value of F_V obtained by a collection (3.11)

Finally, the popularity score of a user is calculated by using this equation:

$$P(N_F, P_R) = W_{N_F} \times \frac{N_F}{MaxN_F} + W_{P_R} \times \frac{P_R}{MaxP_R}, \qquad P \in [0,1]$$

where N_F is the number of followers of the user in the social network, $MaxN_F \geq 1$ is the maximum value of N_F obtained by a user, P_R is the popularity score of the resources owned by the user, $MaxP_R \geq 1$ is the maximum value of P_R obtained by a user, and $W_{N_F} = 0.4$ and $W_{P_R} = 0.6$ (3.12)

The popularity score P_R of the resources owned by a user U is calculated according to the following equation:

$$P_R(U) = \sum_{r \in R} P(r)$$

where R is the set of resources owned by the user U, and $P(r)$ is the popularity score of the resource r according to Equation 3.6 or 3.10 depending on the type of resource (3.13)

By default, the current version of ViSH calculates P_R taking into account only the Interactive Presentations created by the user.

3.3.2.7 Default Ranking Metrics

ViSH defines default ranking metrics to sort the objects (resources, collections and users) in those situations in which users have not yet specified a criterion to do so. An example of these situations is when users begin to explore resources on the web portal. Since these metrics are built upon the popularity metrics defined in the above section, they can also be used as alternative popularity metrics. Basically, there are three default ranking metrics: one for resources, one for collections, and another one for users.

Resources are sorted by default according to the scores yielded by the following metric:

$$R_D(R) = W_P \times P(R) + W_Q \times Q(R), \qquad R_D \in [0,1]$$

where $P(R)$ is the popularity score of the resource R, $Q(R)$ is the quality score of the resource R, and $W_P = 0.7$ and $W_Q = 0.3$ (3.14)

The default ranking metric used to sort collections is defined as follows:

$$R_D(C) = W_P \times P(C) + W_Q \times Q(C), \quad R_D \in [0,1]$$
where $P(C)$ is the popularity score of the collection C,
$Q(C)$ is the quality score of the collection C, and
$W_P = 0.7$ and $W_Q = 0.3$ (3.15)

The quality score of a collection C is calculated according to the following equation:

$$Q(C) = \begin{cases} 0, & N = 0 \\ \frac{\sum_{i=1}^{N} Q(r_i)}{N}, & N > 0 \end{cases}, \quad Q \in [0,1]$$
where N is the total number of resources saved in the collection C, and
$Q(r_i)$ is the quality score of the i-th resource saved in the collection C (3.16)

Lastly, users are sorted by default based on their popularity as follows:

$$R_D(U) = P(U), \quad R_D \in [0,1]$$
where $P(U)$ is the popularity score of the user U (3.17)

3.3.2.8 Search

ViSH provides a search service that allows any user (registered or not) to search for public resources stored in the repository (files, links, embeds and Learning Objects created with the authoring tools of the platform), as well as search for collections of resources that users have made visible. Moreover, the ViSH search service also allows searching for users of the ViSH community (i.e. users registered in the system). The search service offered by ViSH uses a simple search approach, where users can search by inputting query terms. In this approach, the search engine compares the search query terms with the text contained in the metadata and returns all the objects that contain the same words. The search engine indexes title, description and keywords for resources, title and description for collections, and name and tags for users.

After performing a search, users can filter and sort the search results according to different criteria (see Figure 3.6). Users can filter the search results by object type (e.g. resource, collection or user), and then they can apply specific filters for each type of object. Resources can be filtered by type of resource according to the ViSH classification (e.g. Interactive Presentation, lesson, link, picture, video, SCORM package, ...), language, tags (i.e. keywords), and recommended age. Users can be filtered by language and tags (i.e. areas of interest). In addition to filters, different criteria are available to sort the search results. All types of object can be sorted by relevance to the search query, popularity (using the default ranking metrics defined above) and creation date (for users registration date is used as creation date). Collections and resources can also be sorted by update date and number of visits. Lastly, two more sorting criteria are available for resources: quality (using the quality metrics defined above) and number of favorites (i.e. number of times a resource has been bookmarked). If a user searches for objects of multiple types, only common criteria can be used for sorting.

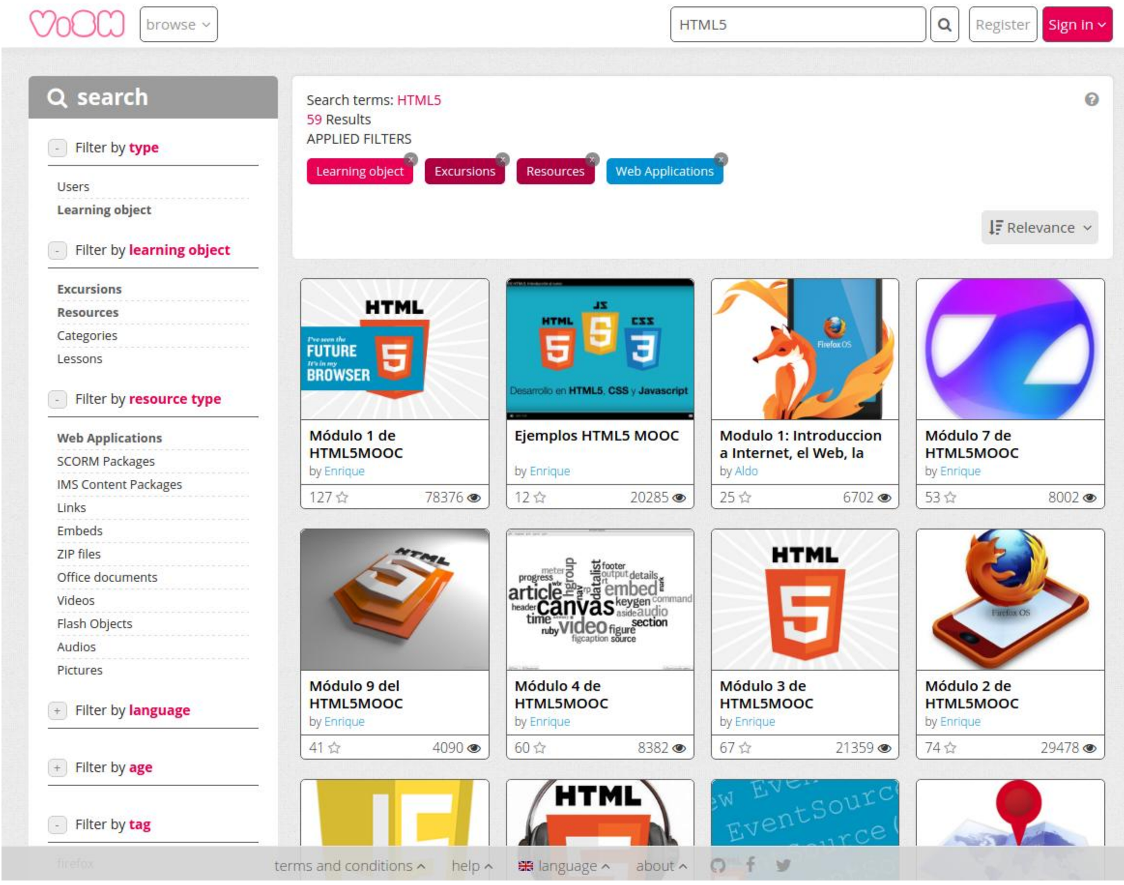

Figure 3.6: Search service of ViSH

ViSH defines a relevance ranking metric for sorting resources that combines three different indicators: relevance to the search query, quality and popularity. This metric is defined according to the following equation:

$$R_R(QT,R) = W_{R_{QT}} \times R_{QT}(QT,R) + W_P \times P(R) + W_Q \times Q(R), \qquad R_R \in [0,1]$$
$$\text{where } R_{QT}(QT,R) \text{ is the relevance on a 0-1 scale}$$
$$\text{of the query terms } QT \text{ for the resource } R, \tag{3.18}$$
$$P(R) \text{ is the popularity score of } R,$$
$$Q(R) \text{ is the quality score of } R, \text{ and}$$
$$W_{R_{QT}} = 0.8,\ W_P = 0.1, \text{ and } W_Q = 0.1$$

The function $R_{QT}(QT,R)$ is defined according to the following general equation:

$$R_{QT}(QT,R) = \frac{\sum_{i=1}^{N} W_{m_i} \times N_W(QT,m_i)}{\sum_{i=1}^{N} W_{m_i} \times MIN(L_{m_i}, L_{QT})}, \qquad R_{QT} \in [0,1]$$
$$\text{where } m_i \text{ is the i-th text metadata field of the resource } R,$$
$$QT \text{ is a text string that contains the query terms,} \tag{3.19}$$
$$N_W(QT,m_i) \text{ is the number of unique words in } QT \text{ matched in } m_i,$$
$$L_{m_i} \geq 0 \text{ and } L_{QT} \geq 1 \text{ are, respectively, the length in words of } m_i \text{ and } QT, \text{ and}$$
$$W_{m_i} \geq 0 \text{ is the weight of } m_i \text{ relative to the other metadata fields}$$

In order to particularize this general equation to the ViSH scenario, three metadata fields are considered for the resources: title (m_T), description (m_D) and keywords (m_K). These metadata are present in all resources of ViSH and are indexed by the search engine.

Thereby, the particularized equation is:

$$R_{QT}(QT, R) = \frac{W_{m_T} \times N_W(QT, m_T) + W_{m_D} \times N_W(QT, m_D) + W_{m_K} \times N_W(QT, m_K)}{W_{m_T} \times MIN\left(L_{m_T}, L_{QT}\right) + W_{m_D} \times MIN\left(L_{m_D}, L_{QT}\right) + W_{m_K} \times MIN\left(L_{m_K}, L_{QT}\right)}, \quad R_{QT} \in [0,1] \tag{3.20}$$

where $W_{m_T} = 50$, $W_{m_D} = 1$ and $W_{m_K} = 40$

The relevance ranking metric defined in Equation 3.18 is used in the search services of ViSH to sort resources by relevance to the search queries. This same metric is also used as a basis for sorting the other types of objects (i.e. collections and users). Collections are treated in the same way as resources. In the case of users, names are used instead of titles, areas of interest (provided in the form of tags) are used as keywords, and quality scores have a fixed value of 0.5 out of 1. The use of a common metric as a basis for ranking all objects allows searching for objects of multiple types in a same query.

The ViSH search service also offers a “browsing mode”. It works like the normal mode, but the objects are initially sorted according to the default ranking metrics defined in the above section instead of by relevance (which is not possible since there are no query terms). This mode also allows pre-applying filters. This feature is very useful because it can be used to provide users with pages to browse objects of a specific type, tagged with a certain keyword, or in a specific language. On ViSH it is used to provide links to allow users to explore all Interactive Presentations, lessons, uploaded resources (i.e. files, links and embeds), and users. Thanks to the search service, users can also click on any tag on ViSH to see all objects that contain the text of that tag in any of their text metadata fields indexed by the search engine.

Finally, it is worth pointing out that ViSH provides a search API that allows external applications to perform searches on the platform. Its main aim is to enable the search and retrieval of Learning Objects from the repository. The specification of the ViSH search API is available at the ViSH wiki: http://github.com/ging/vish/wiki. This API provides access to all of the search features of ViSH. It not only provides access to all search features available for users through the user interface of the ViSH search service (e.g. search by query terms, basic filters and sorting criteria), it also provides access to new features (e.g. specification of the number of results to be retrieved, new filters and retrieving by identifier). Details are included in the API specification. An example of the use of the ViSH search API is showed in next section, which describes the advanced search service. Another example can be found in [341], which described the use of the ViSH search API in the Go-Lab platform.

3.3.2.9 Advanced Search

In addition to the basic search service described in the above section, ViSH offers an advanced search service that provides additional search features but is more complex. A key difference between both search services is that the advanced search service can perform searches not only in ViSH, but in external systems that have implemented the ViSH search API. Thereby, if several LORs are developed with the ViSH software (or implement the ViSH search API), the advanced search service allows searching for objects of all of them. Thus, searches performed with the advanced search service are not local. The advanced search service has been developed as a standalone web application that communicates with the ViSH search API. Besides all the features offered by the basic search service, it allows to indicate the systems in which to search, specify the maximum number of results that should be retrieved from each system, apply new filters (creation date, age range, quality and license), and choose between two ways of visualizing the search results (gallery or table). The ViSH advanced search service is available for all users (registered or not) through the web portal.

3.3.2.10 Catalogue

Besides the search services, ViSH users can use a catalogue to discover or search for resources. The user interface of the catalogue is practically the same as in the basic search service (shown in Figure 3.6). Users can use the same filters (language, age and tags) and sorting criteria (popularity, quality, creation date, update date, number of visits, and number of favorites). The essential difference is that there is a new filter that allows users to filter resources by subject. Thereby, users can use the catalogue to search for resources about a specific topic.

The subjects shown in the catalogue are termed “catalogue categories” and are defined through tags (e.g. “computer science” or “history”). A category can be defined through one or more tags (e.g. a category “Education” can be defined with the tags “education”, “learning”, and “teaching”). Besides, a category can contain other categories (e.g. a category “Humanities” can include all resources of other category “History”). Based on the tags of these categories, resources are automatically included in the catalogue. The ViSH catalogue allows two modes of cataloguing. That is, it supports two different ways of determining the resources that should be included in a certain category of the catalogue. The two modes are:

- *Match tag*. This mode includes in a category only those resources that have been tagged with any of the tags of the category.
- *Match any*. This mode includes in a category those resources that contain, in any of their text metadata fields indexed by the search engine (i.e. title, description and keywords), the text of any of the tags of the category.

Tags are compared in a case-insensitive manner. Moreover, translations for tags can be defined to include in a category resources on the same subject from multiple languages.

Another relevant feature of the catalogue is the possibility of setting a quality threshold, in such a way that resources with a quality score below that threshold are automatically excluded from the catalogue.

ViSH allows defining different settings for the catalogue, including the categories to be used, the mode of cataloguing, the type of resources to be catalogued, and the quality threshold. Further details are included in the section of the customization feature. On the ViSH instance running at http://vishub.org, the catalogue has around 20 categories (Technology, Computer Science, Biology, Chemistry, Geology, History, ...), the “match any” cataloguing mode is used, only Interactive Presentations are catalogued, and a quality threshold of 5 (out of 10) is set.

3.3.2.11 Recommender System

ViSH has a recommender system that recommends resources stored in the repository to the users. There are three places where recommendations are shown:

- *Resource pages*. On the page of each resource, suggested resources are shown in a sidebar on the right side (see Figure 3.3). Recommendations are generated based on the user profile (in case the user is logged in) and the resource the user is viewing.
- *Interactive Presentations*. When users reach the last slide of an Interactive Presentation (like the one of Figure 3.4), they can request recommendations of similar Learning Objects. This can be done even if the Interactive Presentation is outside ViSH.
- *Homepage*. The homepage of the users shows a section with resources recommended for them according to their user profiles (see Figure 3.8).

The ViSH recommender system has been developed based on a hybrid recommendation model that combines content-based, demographic and context-aware techniques, along with the use of the quality and popularity metrics defined in the above sections. This recommendation model and the ViSH recommender system are described in detail in chapter 7 of this thesis. This chapter also reports an evaluation of the ViSH recommender system.

3.3.2.12 Audience Response System

Audience Response Systems (ARSs), also called Classroom Response Systems (CRSs), allow an entire classroom to respond to questions using remote control devices. The responses are instantly collected and summarized, and can be presented to the class in visual format, usually in chart form. Responses are always anonymous to peers. ARSs can be used to provide feedback for both students and teachers in order to improve instruction, stimulate class discussion, and improve student engagement and learning performance. A review of the literature on ARSs can be found in [377]. Furthermore, [378] provides an overview of the existing types of ARSs. The ARS provided by ViSH is a web-based ARS. It just requires an HTML5 compliant web browser to connect to a poll and answer the questions. Hence, a wide range of devices (e.g. mobile phones, tablets, PCs, ...) can be used as remote control devices.

The ARS of ViSH enables teachers to launch questions created with ViSH Editor. Firstly, teachers have to use ViSH Editor to create a new Interactive Presentation (or edit an existing one) and add questions to it. A specific setting must be set for those questions that want to be launched with the ARS. Secondly, the Interactive Presentation that contains the questions should be published on ViSH (if it was not already published). Then, teachers can access the Interactive Presentation through the ViSH web portal and launch the questions with the ARS by clicking on a button placed below them. To use this feature, teachers have to be logged in. Once a question is launched, a poll with a unique URL is created on ViSH. This URL is the one the audience needs to answer the question of the poll. In the Interactive Presentation in which the question was launched, a panel is popped up displaying the URL to answer the question, a QR code which also contains this URL, and some buttons to share the poll in social networks (see Figure 3.7). Teachers can display this panel using the classroom projector, allowing the students to copy the URL from the projection screen or to get it from the QR code using their mobile phones. Besides, teachers can share the poll URL in other ways such as messaging systems. Students can use any device with an HTML5 compliant web browser to answer the question of the poll. Answers are always sent anonymously since currently there is no support for participation of authenticated users. Teachers can also see the results of the polls in real time from the poll panel. Results are presented in chart form (e.g. a bar graph or pie chart), where the type of graph depends on the type of the launched question. Teachers can also close a poll, preventing it to accept more responses, and save it on ViSH. On the ViSH web portal, teachers can view all their created polls. They can change the state (open/closed) of the polls as well as remove any of them. Teachers can also view the responses to each poll, as well as additional data such as the question that was launched, the Interactive Presentation that included that question, and the opening and closing date. The results can be downloaded in XLSX format, so they can be processed using spreadsheet software such as Microsoft Excel or LibreOffice Calc. More details on the implementation of the ARS of ViSH can be found in [378].

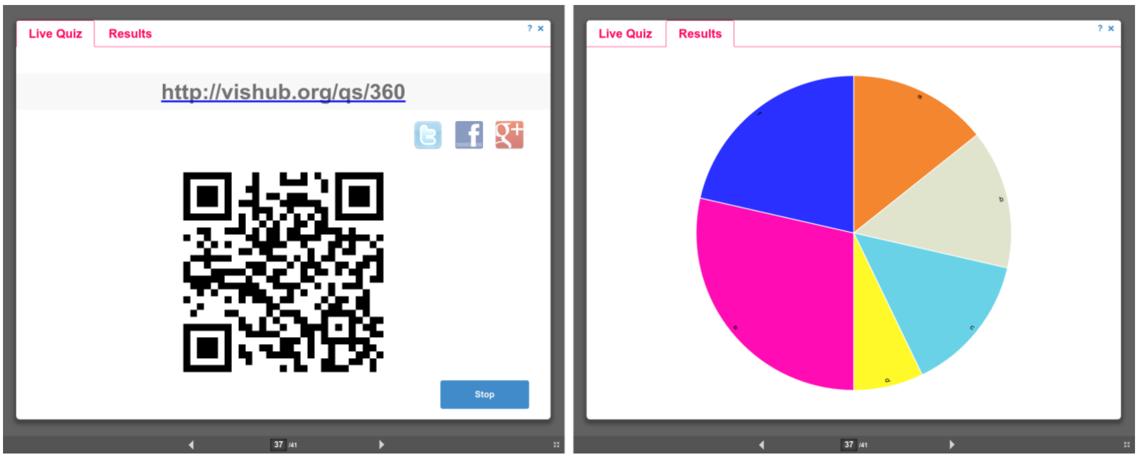

Figure 3.7: Poll panel of the Audience Response System of ViSH

3.3.2.13 Tracking System

ViSH has a tracking system that allows storing data about user interactions in its database. This tracking system provides an API that can be used by the different components of ViSH. Throughout this section, the term “tracker” will be used to refer to any tool, system or component that uses the API of the tracking system to store data about user interactions. In order to store an interaction, trackers are required to provide its identifier, an authentication token, the user agent of the web browser of the user whose interaction in going to be stored (this is required to prevent the storage of interactions performed by bots such as web crawlers), and the data of the interaction in JSON format. Trackers are free to choose the data model in which the interactions are stored. Future versions of ViSH will provide additional features for e-Learning standards such as CAM [164] or IMS Caliper Analytics [165]. Moreover, trackers can store additional data of an interaction such as data about the user who performs the interaction (e.g. if the user is logged or not, language, areas of interest or popularity in ViSH), a referrer URL, and the identifier of other interaction stored by the ViSH tracking system (which allows trackers to store chains of interactions and not just isolated interactions).

Currently, the ViSH tracking system is primarily used to store data about the interactions that users have with the Interactive Presentations created with ViSH Editor. These Learning Objects are shown in the web browsers through the use of a player called ViSH Viewer, which is a fully client-side web application (see chapter 4 for details). The use of this player is completely transparent for end users. ViSH Viewer captures all relevant interactions with the Learning Objects during each learner session (i.e. during each uninterrupted period of time a learner is accessing a Learning Object). Captured interaction data include total time spent on the Learning Object, the number of mouse clicks, questions answered correctly and incorrectly, etc. Further details on these data are included in chapter 6 of this thesis. The captured data about the interactions are sent by ViSH Viewer to the tracking system just before the user closes the web browser in order to be stored in the ViSH database. The next section exposes one use in ViSH of these stored interaction data.

3.3.2.14 Learning Analytics

Besides the tracking system that allows storing data on user interactions in the database, ViSH provides scheduled tasks to process these data in order to generate learning analytics. These tasks are performed periodically in the background. Once the learning analytics have been generated, they are used to provide feedback to users with the intention of driving interventions. Thereby, the learning analytics cycle is closed.

The current version of ViSH only generates learning analytics from the data about the interactions of the users with the Interactive Presentations created with ViSH Editor. These analytics are used to provide feedback to authors about the Learning Objects they have created with ViSH Editor. Several learning analytics are generated, but only three of them are finally shown to authors: average time spent on the Learning Object per learner session (in seconds), permanency rate, and average number of mouse clicks per learner session. Further details about these learning analytics are described in chapter 6 of this thesis. Thereby, ViSH provides authors with feedback about the effectiveness of the Learning Objects they have created and published, and hence it facilitates them to enhance these Learning Objects.

3.3.2.15 Metadata Provider

ViSH offers a service that allows external systems to harvest metadata of the published Learning Objects using the OAI-PMH [166] standard. This service is offered by exposing the metadata of the Learning Objects through an OAI-PMH target (also termed OAI-PMH data provider interface). Thereby, other systems can build value-added services by using the metadata stored in ViSH. At present, only metadata of the Interactive Presentations are offered through the OAI-PMH target. The version supported by ViSH is OAI-PMH 2.0. The OAI-PMH target allows to retrieve XML metadata records in two formats: Simple Dublin Core [120] and IEEE LOM [119]. Besides, ViSH supports the LOM profile of the ODS portal [131], [132]. This feature allowed the ODS portal to harvest metadata stored in ViSH in order to integrate and offer Learning Objects published on ViSH in its repository. Thus, Interactive Presentations created by the ViSH community can now also be discovered through the ODS portal.

3.3.2.16 Web Portal

The web portal constitutes the presentation layer of ViSH. This component encompasses the user interface of all tools and features offered by the system to end users. It is responsible to enable users to use the features of the business layer from the user interface, and hence it is also responsible for a large part of the usability of the system. Next, the most important pages of the web portal of ViSH are described:

- *Homepage*. The homepage is only available for registered users and has three main sections (see Figure 3.8). The first section is a row that shows a combination of recent and popular resources. More specifically, half of the resources are randomly selected from the most popular resources among the most recent ones, and other half of the resources are randomly selected from the most recent resources among the most popular ones. The second section is another row that shows resources recommended for the user. Finally, the third section shows the most popular resources randomly ordered. The default ranking metrics are used as popularity metrics. Each time a user enters on the homepage, different resources are shown. Thus, the homepage is very dynamic. Furthermore, the user has another section called “My Network” that can be displayed by clicking on a tab. This section shows to the user only those resources published by the users that he/she is following on ViSH. ViSH allows specifying which type of resources should be shown in the homepage. On the ViSH instance running at http://vishub.org, the homepage only shows Interactive Presentations, which are the main resources of the platform.

- *User profile page*. Every registered user has a profile page. On this page, users can edit their profile information (e.g. avatar, country, areas of interest, etc.), see all the resources they have uploaded or created using the authoring tools, see their personal collections, and see their contacts in the social network of ViSH (i.e. their followers and the users they are following). When users visit the profile page of other user, they can see the profile information, public resources and contacts of that user. Moreover, personal collections that the user has made visible are also shown.
- *Settings page*. This page allows users to specify various settings such as their password, email, language and notification settings. The language can also be changed at any time by clicking on a button in the footer.

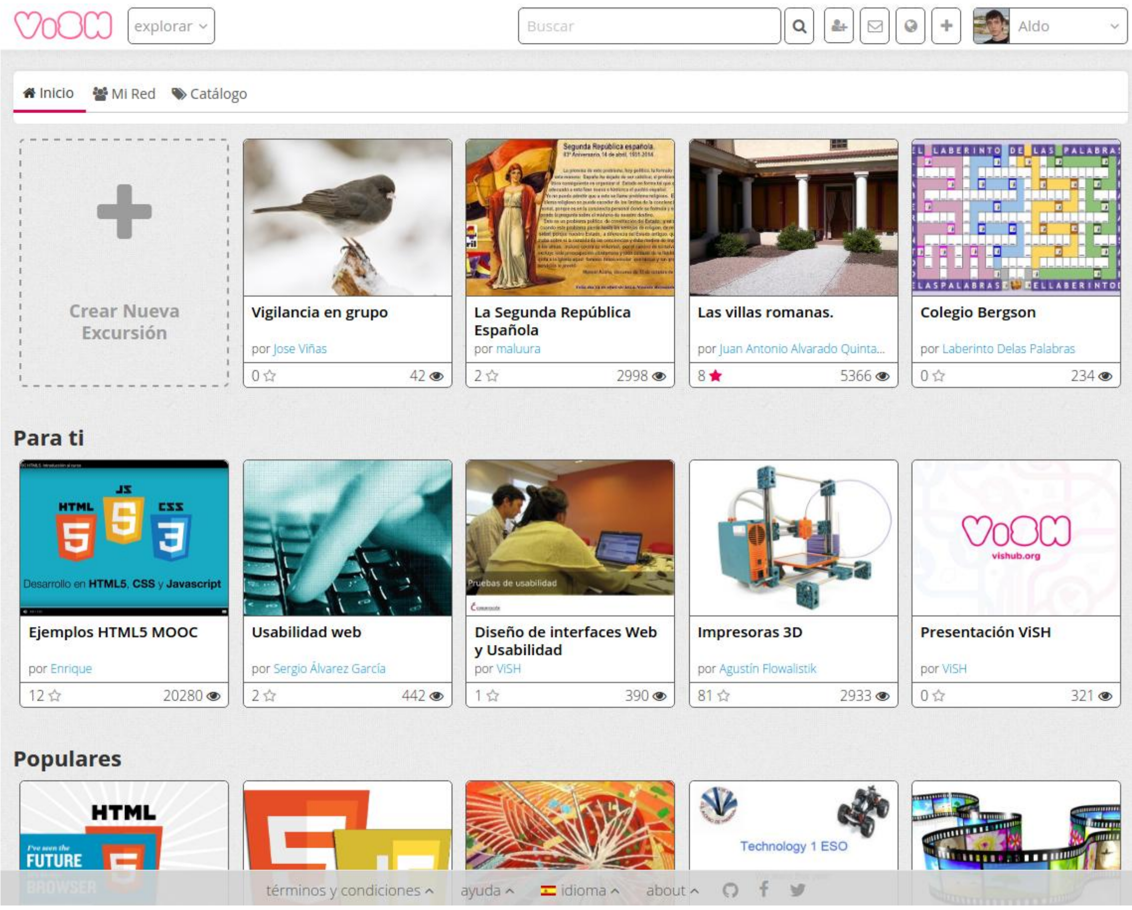

Figure 3.8: Homepage of a user on the ViSH platform

ViSH provides multilingual support. The current version is fully available in English and Spanish, and also provides several translations for four more languages: German, French, Dutch and Hungarian. Translations for more languages can be included in an easy way.

Finally, it is worth noting that the web portal provides context-sensitive help for the different pages, tools and sections of the user interface. Moreover, users have available a manual as well as videotutorials in order to learn how to use the different features and tools offered by the ViSH platform.

3.3.2.17 Administration

ViSH allows the creation of user accounts for administrators. Administrators are users with additional privileges that can manage any object of the platform including user accounts, resources, collections and evaluations. They are hidden users in the sense that they do not appear in any page of the web portal and they are not indexed by the search engine. Administrators have access to all data of the platform with the exception of private personal information of the users (e.g. the private messages or the results of the polls conducted with the ARS). Furthermore, they can remove and edit resources, collections and comments. They also have the power to cancel accounts of regular users as well as to appoint new administrators. The LOEP system also provides additional features for administrators such as appoint reviewers, create assignments, manage evaluations, and view evaluation data (further details are included in chapter 5). Nevertheless, administrators are required to have two different accounts for ViSH and LOEP. A new page termed “Administration Panel” is available on the ViSH web portal for the administrators of the platform. The most important feature offered in this panel is the report dashboard. Three different types of reports are shown in this dashboard: reports of inappropriate content (e.g. spam), notification of errors in the resources (e.g. a broken link), and warnings of low quality resources. The first two types are generated directly by the end users. The third type of report is automatically generated by the evaluation system based on the quality evaluations. Concretely, a report of this type will be generated each time a Learning Object obtains an overall quality score below a certain threshold. Based on these reports, an administrator might remove a resource that infringes on copyright, notify an author of a broken link, or detect a resource that is not useful for learning and stop its distribution.

3.3.2.18 Customization

As was mentioned in the introduction to this chapter, the software that runs ViSH is open source and can be used for developing simple LORs as well as more complex e-Learning platforms. An example that illustrates this capacity of the ViSH software is EducaInternet [60], [379], an e-Learning platform to learn and teach about safe and responsible use of digital technologies which was built upon the ViSH software. From a technical point of view, EducaInternet is similar to ViSH but with a new presentation layer. A description of EducaInternet is included in chapter 9 of this thesis. Each system created with the ViSH software and deployed on the Web is termed “ViSH instance”. This chapter has described, so far, the main features offered by the ViSH software and how this software has been used to create the ViSH instance available at http://vishub.org (i.e. the ViSH platform). This section focuses on the features offered by the ViSH software in order to facilitate the creation and configuration of new ViSH instances.

First off, it is worth pointing out that the source code of ViSH is open source, documented and publicly available at the GitHub repository http://github.com/ging/vish. Therefore, all components of ViSH can be customized by developers in order to create new systems. Besides, the wiki of the ViSH source code repository (available at http://github.com/ging/vish/wiki) includes a guide that explains how to fork this repository and sync the fork in order to keep it up to date with the changes of the ViSH software.

The main drawback of the above approach to customize a ViSH instance is that it may require a considerable development effort as well as to have high knowledge of the system. For this reason, ViSH provides a YAML configuration file where several settings of a ViSH instance can be specified. In each release of the ViSH software, new settings are added in order to facilitate the customization of a ViSH instance. Next, some of the main settings that can be specified in the version of ViSH described in this chapter are listed (the full list is available on the page of the wiki entitled "Setting up a ViSH instance"):

- *Name*. The name of the ViSH instance.
- *Email*. Configuration of the email sender, the contact email address, and the email address to be used for sending notifications.
- *Languages*. The languages that will be available for users in the ViSH instance.
- *Register policy*. Three policies are supported: "only register" (users can freely register, invitations are disabled), "only invitation" (users need to be invited to register), and "hybrid" (users can freely register and also they can invite other users). The latter register policy is the one used in http://vishub.org.
- *Available models*. The objects that will be available in the ViSH instance. For example, an instance can be configured to not provide collections, lessons or links. Moreover, the type of objects that will be shown in the homepage or the catalogue can also be specified.
- *Available services*. The services that will be available in the ViSH instance. An instance may disable the ARS, the catalogue, the advanced search or the media conversion service that converts videos and audios to HTML5 compliant formats. The evaluation system and the tracking system can also be disabled.
- *Social Networks*. The social networks (Twitter, Facebook and Google Plus) that will be available for sharing resources, including the credentials required for each case.
- *External repositories*. The external repositories that will be available in the ViSH instance and their corresponding credentials. At present, ViSH supports three general

content providers: YouTube, SoundCloud and Flickr, and two LORs: Europeana [57] and LRE [133]. These repositories are used in the ViSH Editor authoring tool to allow authors to search and use their resources.

In addition to general settings, there are settings for specific services such as:

- *Evaluation system*. The settings required to use a LOEP instance (e.g. URL of the LOEP instance, LOEP API version, credentials, etc.). The quality threshold that will be used to generate warnings of low quality resources can also be specified.
- *Catalogue*. The catalogue categories, the mode of cataloguing, the type of resources that will be catalogued, and the quality threshold to be used in the catalogue.
- *Advanced search*. The different ViSH instances (or systems that have implemented the ViSH search API) available in the advanced search service.
- *Recommender system*. Several parameters of the ViSH recommender system can be specified. These parameters are introduced in chapter 7 of this thesis.

Lastly, all the parameters of the metrics used by ViSH can be specified in the configuration file. The values of the parameters indicated in the equations shown in this chapter are the ones currently used in the ViSH instance running at http://vishub.org. However, these values can be customized by each instance. Table 3.1 summarises all the parameters that can be customized for each of the metrics used by ViSH and presented in this chapter.

Table 3.1: Customizable Parameters of the ViSH Metrics

Metric(s)	Equation(s)	Parameters
Overall quality for resources	3.1	W_{Q_R}, W_{Q_L}, W_{Q_T}
Popularity for downloadable resources	3.6	W_{F_V}, W_{F_B}, W_{F_D}
Frequencies with which resources are visited, bookmarked and downloaded.	3.7 - 3.9	T_P
Popularity for non-downloadable resources	3.10	W_{F_V}, W_{F_B}
Popularity for users	3.12	W_{N_F} , W_{P_R}
Default ranking for resources	3.14	W_P, W_Q
Default ranking for collections	3.15	W_P, W_Q
Relevance ranking	3.18	$W_{R_{QT}}$, W_P, W_Q
Query relevance ranking	3.20	W_{m_T}, W_{m_D}, W_{m_K}

Thereby, a ViSH instance can specify weights for the different criteria based on its specific usage scenario. For example, if a LOR wants to give more importance to end user evaluations than to peer reviews, it can specify parameters in such a way that $W_{Q_L} > W_{Q_R}$. Furthermore, a ViSH instance can define coefficients to modify the popularity scores in order to favour some types of objects over the others. In summary, ViSH instances can customize the metrics according to their needs and preferences.

3.3.2.19 Courses and Integration with LMSs

ViSH has the ability to be integrated with Moodle. This feature enables to use a ViSH instance to offer courses and deliver them by using a Moodle instance. A new type of object called “Course” is incorporated to ViSH. These objects represent courses inside the ViSH web portal. When users access a course in the ViSH web portal, they go to a page that shows basic metadata of that course (e.g. title, description and keywords). On this page, registered users can enrol in the course. Courses can be open or private. In the case of private courses, users need a password to enrol. Once a user has enrolled in a course, a link is shown to enable the user to access the course in the Moodle instance. ViSH supports single sign-on (SSO) using Central Authentication Service (CAS). Thereby, when users log in to ViSH they are automatically logged in to Moodle and vice versa. Thus, users are not required to enter their login credentials again to access a course in Moodle from ViSH, or to access ViSH from the Moodle instance. Authentication is performed against the ViSH database (i.e. with the ViSH credentials). The support of the SSO feature requires the use of a CAS server, and to specify in the ViSH configuration file that this feature is going to be used as well as the settings of the CAS server. The SSO feature allows administrators to manage both the ViSH instance and the Moodle instance using the same account. In the current version, only administrators are allowed to create courses. Besides the implementation of the course object and the SSO for Moodle, no more features have been implemented with respect to the integration of ViSH with LMSs. The Learning Objects of ViSH are integrated into the Moodle courses by using the existing sharing and integration features (e.g. links, embeds, downloadable files and SCORM packages). More features will be developed in future versions (e.g. integrate data from the gradebooks of the Moodle instance into ViSH). At the time of writing, the course feature has not been deployed in http://vishub.org, but a Moodle instance is going to be set up to do so. Conversely, the course feature has been already used in the EducaInternet platform to deliver SPOCs. Results of this experience are reported in chapter 9.

3.4 Evaluation and Results

3.4.1 Evaluation of the User Acceptance

An online survey was conducted among the end users of the ViSH platform to collect general feedback, including feedback about the different features, services and tools offered by the platform. An email with the link to the survey was sent to all users registered in ViSH. Besides, a link to the survey was included in the ‘About’ menu of the web portal, which can be displayed by clicking on a button placed at the footer. A total of 200 surveys were collected. The sample consisted of 200 end users, 49.5% males and 50.5% females, 19 to 65 years of age (M=43.2, SD=9.9), of which 80.5% were educators, 14.5% were students, and 5% were users with other occupations (e.g. researchers). Table 3.2 shows the main results of the survey including for each question the number of responses (N), the mean value (M) and the standard deviation (SD).

Table 3.2: Results of the ViSH Survey

Question	**N**	**M**	**SD**
Previous experience with other e-Learning systems 1 (none) – 5 (a lot)	200	3.2	1.2
What is your overall opinion of the ViSH platform? 1 (awful) – 5 (excellent)	200	4.0	0.7
How would you describe the experience of learning to use ViSH? 1 (very difficult) – 5 (very easy)	200	3.9	0.9
Please rate your opinion about the following features of the ViSH platform 1 (awful) – 5 (excellent)			
Social network	168	3.6	1.0
Uploading and publication of resources (i.e. Learning Object manager)	183	4.0	0.9
Download of resources	174	4.0	0.9
Resource metadata	160	3.8	0.9
ViSH Editor authoring tool	181	3.9	1.0
ViSH Lesson Editor authoring tool	114	3.7	0.9
Collections	168	3.6	1.0
Evaluation system	173	3.9	0.9
Search service	194	3.8	0.8
Advanced search service	151	3.6	0.9
Catalogue	175	3.7	0.9
Recommender system	169	3.7	0.9
Audience Response System (ARS)	96	3.7	0.9
Homepage of the web portal	181	3.8	0.9
Help and tutorials	176	4.1	0.9
Please rate the usefulness of the following types of resources that you can find in ViSH 1 (not useful) – 5 (very useful)			
Files (pictures, videos, audios, PDF files, SCORM packages, ...)	192	4.0	0.9
Links and embeds (i.e. linked or embedded external resources)	191	4.0	0.9
Interactive Presentations (i.e. Learning Objects created with ViSH Editor)	191	4.2	0.8
Lessons (i.e. Learning Objects created with ViSH Lesson Editor)	188	4.0	0.9
Collections of resources	189	3.9	0.9
ViSH can be used for many different activities. Which of the following are more important for you? Please rate the importance of each one using a scale from 1 to 5 1 (unimportant) - 5 (very important)			
Responses from educators (N_{MAX}=161)			
Connect with other users and share experiences	158	3.9	0.9
Search for educational resources	158	4.3	0.8
Share resources	157	4.1	0.9
Publish my resources	157	3.9	1.0
Create novel resources	158	4.2	0.9
Create and publish collections of resources	155	4.0	0.9

Question	N	M	SD
ViSH can be used for many different activities. Which of the following are more important for you? Please rate the importance of each one using a scale from 1 to 5 1 (unimportant) - 5 (very important)			
Responses from educators (N_{MAX}=161)			
Use resources in the classroom to support face to face learning	157	4.2	0.9
Use resources as activities or assessments for students	158	4.2	0.8
Use resources in VLEs (e.g. Moodle or Blackboard Learn)	157	4.0	0.9
Use resources for self-learning	157	4.1	0.9
Involve students in the creation and/or evaluation of educational content	157	3.9	1.0
		Yes	**No**
Would you recommend ViSH to others?	200	95.0%	5.0%

The results of the online survey show that ViSH has a high acceptance among the users of its community. Overall opinion recorded a mean of 4.0 on a 1-5 scale and 95% of the users answered that they would recommend ViSH to others. Furthermore, ViSH was found easy to use by its end users (M=3.9, SD=0.9). In general, users were satisfied with the different features offered by the system. All features obtained a rating higher or equal than 3.6 on a 1-5 scale. The features most highly rated were “help and tutorials” (M=4.1, SD=0.9), “uploading and publication of resources” (M=4.0, SD=0.9), “download of resources” (M=4.0, SD=0.9), the “ViSH Editor authoring tool” (M=3.9, SD=1.0) and the “evaluation system” (M=3.9, SD=0.9). Contrarily, “social network” features (M=3.6, SD=1.0), “collections” (M=3.6, SD=1.0) and the “advanced search service” (M=3.6, SD=0.9) obtained the lowest ratings. Anyway, there were no major differences among the evaluated features since all ratings were within the range 3.6-4.1 (on a 1-5 scale). Regarding the different types of resources that are offered by ViSH, users rated “Interactive Presentations” (i.e. the Learning Objects created with the ViSH Editor authoring tool) as the most useful resources (M=4.2, SD=0.8), followed by “lessons” (i.e. the Learning Objects created with the ViSH Lesson Editor authoring tool), “files”, and “links and embeds” that obtained the same rating (M=4.0, SD=0.9). “Collections of resources” obtained a rating of 3.9 on a 1-5 scale. Finally, educators were also asked about the importance of the different activities that can be performed with ViSH. All activities were considered important (all of them were rated above 3.8), but the ones that achieved higher ratings were “search for educational resources” (M=4.3, SD=0.8), “create novel resources” (M=4.2, SD=0.9), “use resources in the classroom to support face to face learning” (M=4.2, SD=0.9), and “use resources as activities or assessments for students” (M=4.2, SD=0.8). It is worth pointing out that, in order to allow educators to perform all the activities that they considered important, the whole Learning Object life cycle should be supported. Thus, is of vital importance for a LOR to support the whole Learning Object life cycle to be useful for end users.

3.4.1.1 Evaluation of the Audience Response System

In order to evaluate the ARS provided by ViSH, another survey was conducted to collect feedback from teachers and students who used the system in their classrooms. Two different questionnaires were used in the survey: one for teachers and other one for their students. The participants of the survey were four teachers and their students. The teachers were ViSH users familiarized with the platform who volunteered to participate. Thereby, the sample consisted of 4 teachers, all males, 26 to 46 years of age (M=37.3, SD=10.3), and 43 students, 22 males (51.2%) and 21 females (48.8%), 13 to 30 years of age (M=18.0, SD=5.3). A short videotutorial (available on ViSH) about how to use the ARS was provided to the teachers. Then, each teacher used the ARS in at least one lecture. After using the ARS in the classroom, the teacher and the students filled out the questionnaires. The results are summarized in Table 3.3 shown below.

Table 3.3: Results of the Audience Response System Survey

Question	**Teachers (N=4)**		**Students (N=43)**	
	M	**SD**	**M**	**SD**
What is your overall opinion of the ARS? 1 (awful) – 5 (excellent)	3.8	0.5	4.1	0.7
Please rate the value of the ARS as an educational tool 1 (worthless) – 5 (extremely valuable)	4.5	0.6	4.2	0.8
How would you describe the ease of setup and use of the ARS? 1 (awful) – 5 (excellent)	4.0	0.0	-	-
	Yes	**No**	**Yes**	**No**
Would you use the ARS again (in your lectures)?	100%	0%	-	-
Would you recommend other teachers to use the ARS?	100%	0%	-	-
Would you like the ARS to be used for other courses too?	-	-	90.7%	9.3%

These results indicate that both teachers and students had a good overall opinion of the ARS provided by the ViSH platform. Besides, results also show that they considered that the ARS is a valuable educational tool and that they were in favour of using the ARS again in the future. Moreover, teachers considered that the ARS was easy to setup and use in their classrooms. This fact indicates that ViSH can facilitate teachers to integrate ICT in their classrooms by providing TEL services such as the ARS.

3.4.2 Usability Evaluation

In order to evaluate the usability of the ViSH platform, a lab test was conducted. The lab test is a usability method that involves a one-on-one session between a moderator (a usability specialist) and each of the participants. In each session, the moderator gives the corresponding participant a set of tasks to perform on the system in question and asks the participant to think aloud while completing the tasks. In this lab test a total of 12 people were recruited to participate, 8 males and 4 females, 22 to 59 years of age (M=32.8, SD=12.5), of which 6 were teachers, 3 were engineers, and 3 were undergraduate students. Participants were requested to perform five representative tasks in the ViSH e-Learning platform: search and download a resource (Task 1), publish a resource and its metadata on the platform (Task 2), create a simple Learning Object with the ViSH Editor authoring tool and publish it (Task 3), perform a search that requires to use several filters and sort the results according to a specific criterion (Task 4), and access the profile page of a specific user, follow that user, and add one of his resources to a new collection (Task 5). Thereby, participants used the main features of the ViSH platform including the search services, the Learning Object manager, the ViSH Editor authoring tool, the social network and the collections. The tasks were performed in a specific order by each participant to avoid carryover effects. Participants did not receive help or support from the moderator. After each task participants had to indicate their emotions with the use of expressive cartoon figures and the intensity of each of these emotions on a 1-5 scale. In this lab test the cartoon figures provided by the LEMtool [380] were used, which express four positive (joy, desire, fascination, satisfaction) and four negative (sadness, disgust, boredom, dissatisfaction) emotions using facial expressions and body postures (see appendix A for an image of these cartoon figures). The screen and audio were recorded in every session of the lab test so that they could be post processed to measure the task times and number of mouse clicks. After completing all the tasks, each participant filled out a SUS (System Usability Scale) [279] questionnaire (see section 2.6 for details on SUS). Lab sessions lasted around 40 minutes each. Lastly, in order to measure learnability, three of the participants (one teacher and two engineers) attended two additional sessions in which they performed again the same five tasks. Thereby, each of these participants performed three trials. The time between trials was one day.

In order to measure different aspects of usability, a total of six metrics were used: task completion, task efficiency, clicks efficiency, learnability, task satisfaction and overall satisfaction. The definitions of all these usability metrics are included in the appendix A of this thesis. For each metric, a final usability score was calculated on a 0-100 scale. Figure 3.9 shows the main scores obtained in the usability evaluation of ViSH. Next, a brief explanation of how each of the final usability scores was calculated is provided (see appendix A for further details):

- *Task completion*: score was calculated as the percentage of tasks successfully performed by the participants within a specific amount of time and with no errors.
- *Task efficiency*: score was calculated by comparing the time spent by the participants on completing the tasks with the time required by an expert. The time required by an expert was estimated by measuring and averaging the time spent by two users with extensive expertise using ViSH on performing the tasks of the usability test.
- *Clicks efficiency*: score was calculated by comparing the number of mouse clicks required by the participants to accomplish the tasks with the minimum number of mouse clicks required.

- *Learnability*: score was calculated by comparing the task completion, task efficiency and clicks efficiency scores between the last and first trial performed by three of the participants.
- *Task satisfaction*: score was calculated based on the emotions reported by the participants using the cartoon figures.
- *Overall satisfaction*: score was obtained from the overall scores yielded by the SUS questionnaires filled out by the participants.

Figure 3.9: Usability scores of ViSH obtained in the usability evaluation

The results of the usability evaluation show that participants succeeded in completing the tasks within the required time and with no errors in more than 90% of the cases. This finding is important since it means that users are able to effectively use the main features offered by the ViSH platform without any prior training. The obtained task efficiency score indicates that participants required on average around 1.6 times more time than an expert to successfully complete the tasks, which can be considered as a satisfactory result given that participants had not previously used ViSH. Furthermore, the high learnability score obtained shows that participants significantly improved their performance on the tasks after the first trial. This score indicates that little time and effort is needed to learn how to use ViSH. According to the task satisfaction score which was calculated based on emotions reported by the participants using the cartoon figures, it can be stated that participants were notably satisfied with respect to their performance on the tasks. This score also indicates that ViSH is not only easy to use but also pleasant to use. Lastly, the final score obtained from the SUS questionnaires points out that, in general, participants had a good opinion on the overall usability of the ViSH platform. In conclusion, the results of the usability evaluation were very positive and showed that users find the main features offered by the ViSH platform easy and pleasant to use. These results can be considered highly reliable since the usability evaluation involved 12 participants, which is a suitable number when the lab test usability method is used [381].

3.4.3 Comparison of Features

This section presents a comparison of ViSH with other LORs in terms of features provided. The comparison is made based on the master list of LORs' features proposed by Sampson and Zervas [46], and the results of the study of Zervas, Alifragkis and Sampson [47] who analyzed the adoption level of this list by 49 major LORs. First, the master list of LORs' features is exposed in Table 3.4, indicating which features are supported by ViSH and providing the necessary clarifications. Then, the adoption level of the master list of LORs' features obtained by the ViSH platform is compared with those adoption levels obtained in [47] by 49 major LORs.

Table 3.4: Master List of LORs' Features

Feature	Supported by ViSH	Clarifications
Store and Share Learning Objects and Links to External Learning Objects	✓	ViSH allows end users to store Learning Objects by uploading files. Learning Objects created by the users with the provided authoring tools are also stored in the platform. Besides, users can store links to external Learning Objects as well as embeds. All resources can be shared through unique URLs.
Search for Learning Objects	✓	ViSH provides search services that allow end users to search for Learning Objects published on the platform. Users can search by inputting query terms and can also filter and sort the search results according to different criteria.
Browse Learning Objects	✓	The search service of ViSH offers a "browsing mode", in which end users can browse Learning Objects and filter and sort them according to different criteria. Moreover, ViSH users can browse Learning Objects through a catalogue.
View Learning Objects	✓	ViSH end users can view the web-based Learning Objects stored in the platform directly in the web portal through a browser.
Download Learning Objects	✓	All Learning Objects published by uploading files can be downloaded. Besides, Learning Objects created with the ViSH Editor authoring tool can be downloaded as SCORM packages.
Rate/Comment	✓	The end users of ViSH can evaluate the published Learning Objects through web forms by using two different Learning Object evaluation models: WBLT-S (for learners) and WBLT-T (for teachers). Moreover, appointed reviewers can evaluate Learning Objects using LORI. Users can enter comments in their evaluations, and also they can comment on the published Learning Objects without evaluating them.
Bookmark Learning Objects	✓	ViSH allows registered users to bookmark Learning Objects to add them to their favorites, as well as to save Learning Objects in personal collections.
Ranking Metrics for Learning Objects (termed Knowledge Filter in the master list)	✓	In the search services, ViSH allows users to sort the retrieved Learning Objects not only by relevance, but also by creation date, update date, popularity, quality, number of visits and number of favorites. The relevance ranking metric used by ViSH to sort resources combines three different indicators: relevance to the search query, quality and popularity. The quality scores are obtained based on user evaluations, and the popularity scores are obtained based on the frequencies with which the Learning Objects are visited, downloaded and bookmarked.

Automatic Recommendations of Learning Objects	✓	ViSH has a recommender system that recommends Learning Objects to the end users taking into account their profiles and the previously accessed resources.
Mash-ups by using federated searches	✓	The ViSH Editor authoring tool offered by ViSH enables users to combine Learning Objects from different sources (e.g. LORs, general content providers, users' files) in order to create new Learning Objects in the form of Interactive Presentations.
Store Learning Object metadata	✓	ViSH allows end users to describe the Learning Objects they store in the platform with metadata, which are also stored in the system.
View Learning Object metadata	✓	End users can view the metadata of the published Learning Objects through the web portal and also as IEEE LOM metadata instances in XML format. On the ViSH web portal, end users can also view popularity and quality indicators to decide whether to use or not a specific Learning Object.
Download Learning Object metadata	✓	ViSH allows end users to download the metadata of the Learning Objects in XML format compliant with IEEE LOM.
Learning Object metadata validation	✓	The evaluation system of ViSH allows the automatic evaluation and measurement of the metadata quality of the published Learning Objects by using a set of metrics. Since one of these metrics measures the degree to which metadata instances match the IEEE LOM standard definition, the evaluation system also supports validation of Learning Object metadata.
Social Tagging of Learning Objects	✓	ViSH allows the owners of Learning Objects to add keywords in the form of tags to their Learning Objects. The most popular tags of the platform are suggested to users when they add these keywords.
Personal Accounts	✓	ViSH allows end users to create and manage their own personal accounts and to specify their personal information and areas of interest. User profile pages show the public information, published resources (i.e. contributions to the LOR) and contacts of the users of the ViSH community.
Forums	✓	According to the master list, this feature should enable users to communicate and exchange ideas in an asynchronous way about the use of Learning Objects that are stored in a LOR. ViSH does not provide traditional forums as such, but it provides other features that support these same goals. On the one hand, ViSH allows users to comment and talk about the published Learning Objects. On the other hand, ViSH provides a private messaging system that allows users to communicate with each other in an asynchronous way. This messaging system allows establishing conversations among two or more users.
Wikis	✗	ViSH provides a wiki that contains documentation of the project, but it does not enable end users to create their own wikis.
RSS Feeds	✗	According to the master list, this feature should enable users to be informed via RSS readers about new Learning Objects that are added to the LOR without visiting the LOR. ViSH provides registered users with an activity timeline to which they can access in order to be informed about the new Learning Objects that the users they are following have published on the platform. However, no RSS feed is offered.
Blogs	✗	ViSH has a blog that publishes news about the platform, but it does not enable end users to create their own blogs.
Social Networks	✓	ViSH provides a social network which supports typical social networking features (e.g. user profile pages, following/follower relationships, activity timelines, notifications, etc.).

The current version of ViSH supports 18 (86%) of the 21 features of the master list of LORs' features proposed by [46]. The results of [47], in which 49 major LORs were analyzed, show that the analyzed LORs had implemented on average 51% of the features of the master list, and that only around 10% of them had implemented more than 70% of the features. Of the 49 analyzed LORs, 48 (98%) had implemented a smaller number of features of the master list than ViSH, and the remaining 1 (2%) had implemented the same number of features than ViSH (i.e. 18 features). Figure 3.10, which has been adapted from [47], shows the number of features of the master list of LORs' features supported by ViSH and by each of the 49 LORs analyzed in [47]. Lastly, it is worth indicating that the features not supported by ViSH are rare features used in very few LORs. Concretely, [47] found that RSS feeds, blogs and wikis were used, respectively, by 29%, 14% and 2% of the LORs.

The master list of LORs' features was proposed as a list of features that LORs should have in order to meet the demands of the educational communities. Therefore, based on the adoption level of the master list obtained by ViSH, it can be stated that ViSH is capable of meeting the main demands of the educational communities. Furthermore, the comparison clearly shows that ViSH outperforms most of the existing LORs in terms of features offered to end users. Finally, it is also worth mentioning that ViSH provides more features that are not included in the master list of LORs' features used in this comparison such as authoring tools, open licensing (i.e. OER management), peer review, educational tools (e.g. ARS), learning analytics, provision of metadata, integration with LMSs and administration.

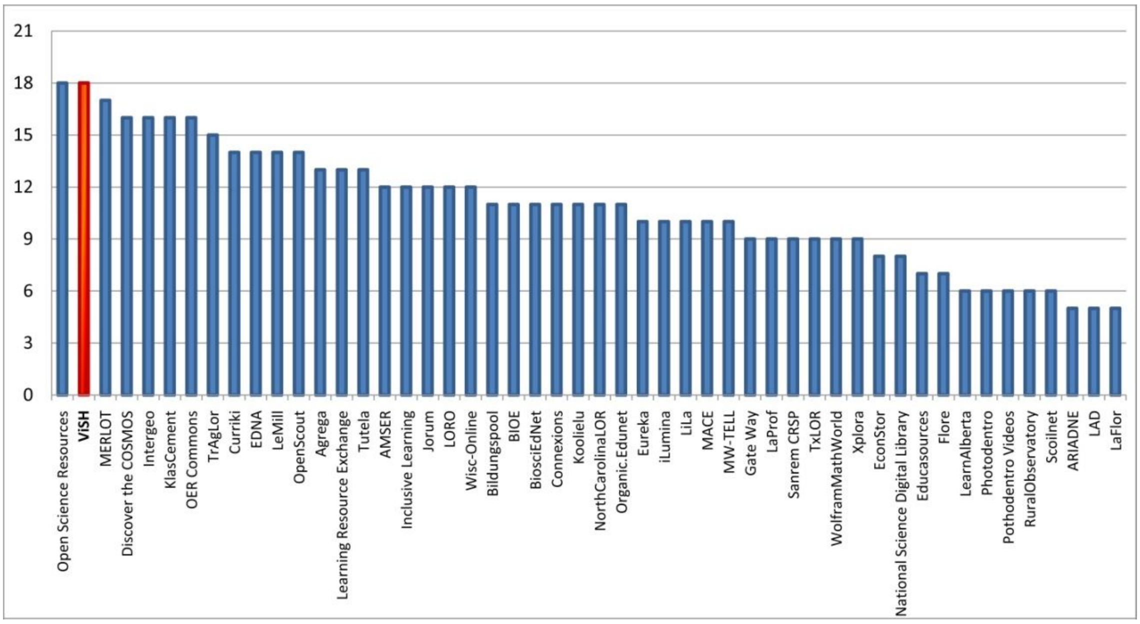

Figure 3.10: Number of features of the master list supported by ViSH and other LORs

3.4.4 Quantitative Analysis

In order to provide empirical evidence of the use of the ViSH platform to create and distribute Learning Objects a quantitative analysis was conducted. The data for this analysis were obtained from the ViSH database, except the number of visits to the ViSH web portal that were measured using Google Analytics. Data correspond to the period from April 2012 to June 2016, except the number of learning hours delivered which is provided since August 2014, date in which the tracking system of ViSH started to operate.

3.4.4.1 Number of Published Resources

Figure 3.11 shows the cumulative number of resources that have been published on the ViSH platform over the analyzed period. These resources include both resources that have been uploaded to ViSH as well as Learning Objects that have been created using the authoring tools offered by the platform. On ViSH, all resources should be published under open licenses. Thus, all the resources provided by ViSH are OER (typically available under Creative Commons licenses). As of June 2016, more than 2,500 OER are provided by the ViSH platform. Of these resources, 35.4% are files, 53.3% are Learning Objects created with the authoring tools, and 11.3% are links or embeds. Of the Learning Objects created by the ViSH users with the authoring tools, almost all (> 95%) are Interactive Presentations created with ViSH Editor. This fact is mainly because the ViSH Editor authoring tool has been available since the beginning of the platform while the authoring tool to create lessons was incorporated later, and because the Interactive Presentations are the most important and promoted type of resource.

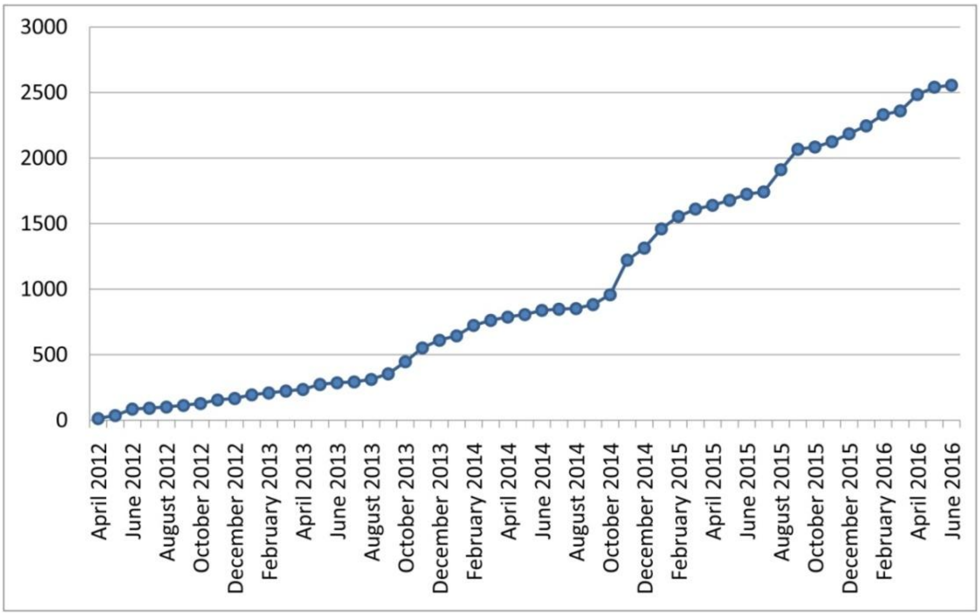

Figure 3.11: Cumulative number of resources published on the ViSH platform

Although ViSH is a hybrid LOR given that it provides e-Learning resources stored by it as well as links to resources stored by other systems, the results of this quantitative analysis indicate that the ViSH platform is mostly content-based since most of the resources it provides (around the 90%) are locally hosted.

According to the results of this analysis, the size of the ViSH repository (defined as the number of provided resources) is around 2,500. This size is consistent with others reported in the literature for different existing LORs. For instance, a survey of 59 LORs found than 76% of them offered less than 10,000 resources [48]. Other relevant work is the quantitative analysis conducted in [212] that analyzed 24 content-based LORs, and found that the average size of these LORs was around 4,000 and that the size of around half of them was lower than 2,000. An important aspect to keep in mind is that most of the resources published on the ViSH platform have been created by the users either by using the authoring tools offered in the platform, or by using other authoring tools and publishing the created resources as files. On the one hand, this fact allows offering original resources in the repository. However, on the other hand, this fact leads to a smaller repository size because authoring and submitting own resources requires more effort from users than submitting links or OER from other repositories.

The growth rate measured in resources published per day is around 1.7 for the analyzed period. This value is slightly higher than the average growth rate of around 1.4 obtained for content-based LORs in the analysis conducted in [212]. Nonetheless, it is still far from the average growth rate of around 11.0 that the above analysis obtained for link-based LORs. The results presented in this section concerning the growth of the ViSH repository are consistent with the findings of [212], which suggested that LORs grow approximately linearly over time but with two different growth rates: one initial and then one mature. In the case of ViSH, the "break-point" (the point until which the initial grow rate is maintained) has been reached in September 2013, 1.5 years after the first resource was published. The results presented in this section are also consistent with [211], which indicated that resources were being stored in LORs in flood patterns (straight up lines) and/or flow patterns (slow ascendant lines).

In summary, these results of the quantitative analysis of the ViSH platform show that it has managed to establish a LOR with a significant amount of OER in the form of Learning Objects. They also suggest that the size of the LOR will continue to grow linearly in the future. Besides, these results indicate that the authoring tools offered by ViSH have allowed its users to create and share open Learning Objects with the entire world. Chapter 4 of this thesis presents an evaluation of the effectiveness of the Learning Objects created by the ViSH community with the ViSH Editor authoring tool. The results of this evaluation are complementary to those exposed in this section because they show that the Learning Objects provided by the ViSH platform are not only numerous, but also, on average, effective from the learners' perspective.

3.4.4.1 Number of Registered Users and Contributors

Figure 3.12 shows the cumulative number of end users who have registered on the ViSH platform over the analyzed period. ViSH achieved to incorporate an average of 4.4 users per day. The number of registered users has grown approximately linearly over time but with different growth rates. In some periods the user growth rate was much higher than the average, probably due to various events such as the start of MOOCs in which the ViSH platform was used. As of June 2016, more than 6,500 users are part of the ViSH community.

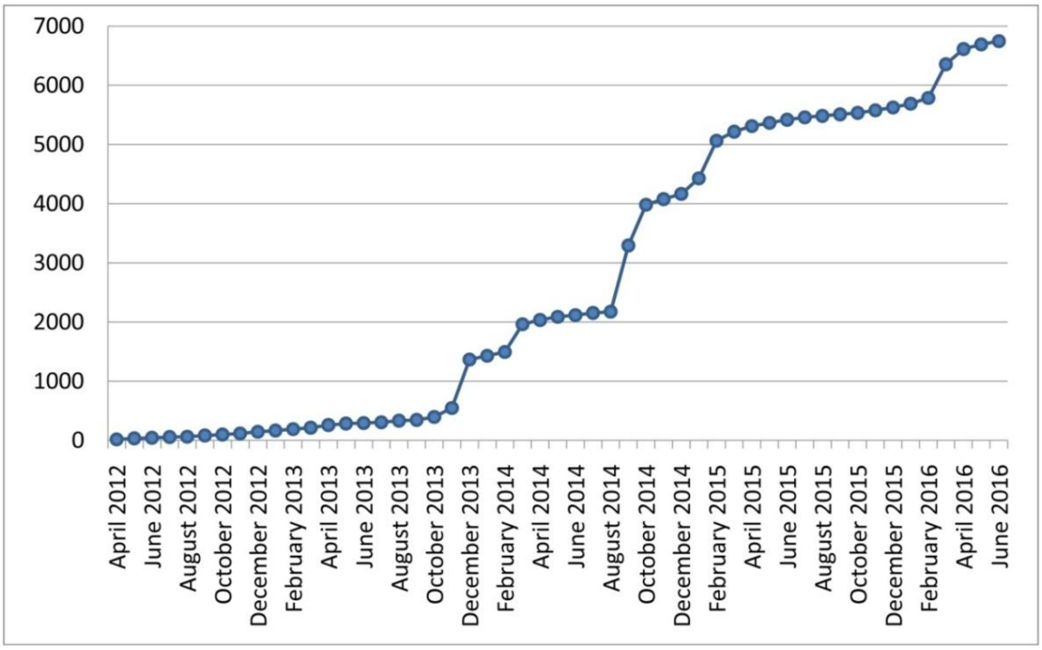

Figure 3.12: Cumulative number of registered users on the ViSH platform

Figure 3.13 shows the cumulative number of contributors. This number has been calculated by counting the registered users that have published at least one resource on the ViSH platform.

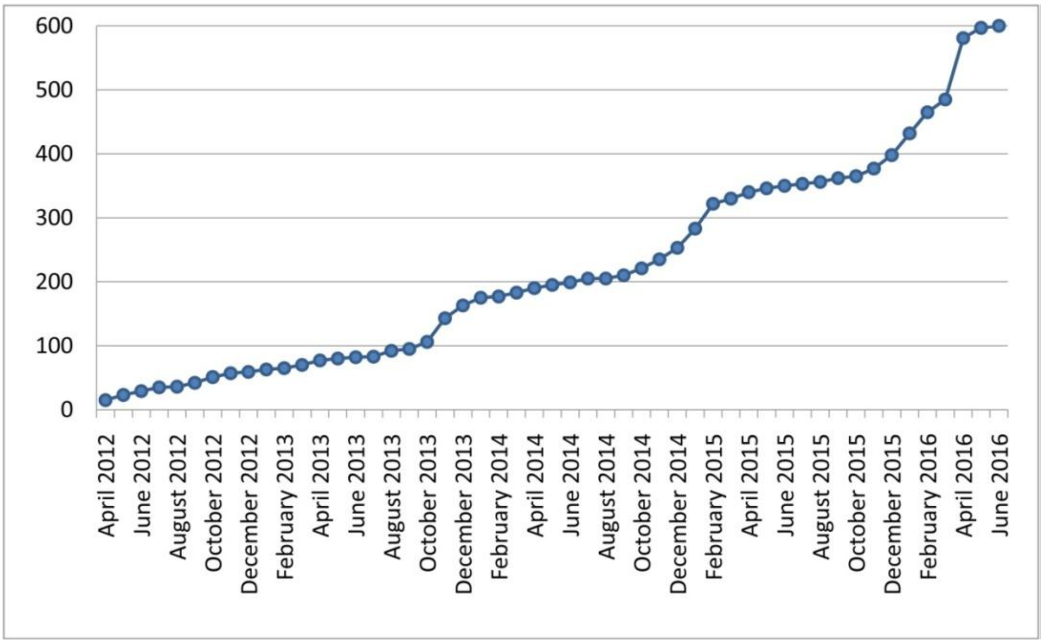

Figure 3.13: Cumulative number of contributors on the ViSH platform

As of June 2016, ViSH has around 600 contributors. This result is similar to others reported in the literature. For example, the quantitative analysis conducted in [212] found that the amount of contributors per LOR ranged between 100 and 1,500. In the analyzed period, ViSH achieved to incorporate a new contributor each 2.5 days. This contributor growth rate is notably better than the average one obtained in [212], which showed that LORs, on average, added a new contributor each 4.5 days. The number of contributors on the ViSH platform has grown approximately linearly over time with different growth rates. This result is consistent with [212], which showed that the number of contributors grow linearly in most LORs. It is worth pointing out that the differences among contributor growth rates are less pronounced that in the growth of registered users. As in the previous case, the high growth rates are probably due to different events such as dissemination activities of the ViSH platform among educators. The results of this quantitative analysis also indicate that around 10% of the members of the ViSH community are producers of OER (i.e. contributors) while the remaining 90% are consumers. Of the producers, around 86% have created at least one Learning Object by using the authoring tools offered by the platform. Moreover, results revealed that ViSH is affected by the Pareto principle (20/80 rule), since the 20% of the contributors published the 80% of the resources. This finding is also consistent with those of the quantitative analysis previously conducted in [212]. During the analyzed period, each contributor published 4.3 resources on average on the ViSH platform. Although this result can be considered moderately satisfactory, is significantly lower than the ratios of 8.8 and 12.5 achieved in [212] by the LORs Connexions and MERLOT respectively.

Summarizing, these results show that the ViSH platform has managed to establish a LOR with a relatively large community of users. Around 10% of these users have contributed to ViSH by publishing OER as well as by creating Learning Objects with the offered authoring tools. The results suggest that the ViSH community will continue to grow linearly in the future, both in terms of registered users as well as in terms of contributors. The obtained ratio of published resources per contributor was lower compared to those from other well-known LORs. A possible way to improve this ratio in ViSH would be the implementation of some type of incentive mechanism for contributors. In this regard, a positive finding of this analysis is that ViSH has achieved to incorporate new contributors quicker than other LORs. This fact denotes that the features provided by ViSH to create and publish resources are effective.

Finally, it is worth remarking that this analysis also contributes by providing more evidence for the better understanding of the Learning Object life cycle and the requirements, gaps and opportunities for LORs. The obtained findings are consistent with those of quantitative analyses previously conducted such as [211], [212]. The following sections analyze aspects that have not been covered in previous studies such as the number of visits and the number of learning hour delivered.

3.4.4.2 Number of Visits

As has been explained throughout this chapter, many features of the ViSH platform do not require users to register and login in order to use them. These features include the search services, the catalogue and the recommender system among others. Thereby, any user, registered or not, can search, explore, access and download the published resources. Taking this into account, in addition to the number of registered users on the ViSH platform, other relevant measure of the use of the system is the number of visits. Figure 3.14 shows the number of visits to the ViSH web portal over the analyzed period. It is worth clarifying that visits were measured with Google Analytics by counting the number of sessions. Therefore, visits were not counted as page views but as sessions in which users visited one or more pages.

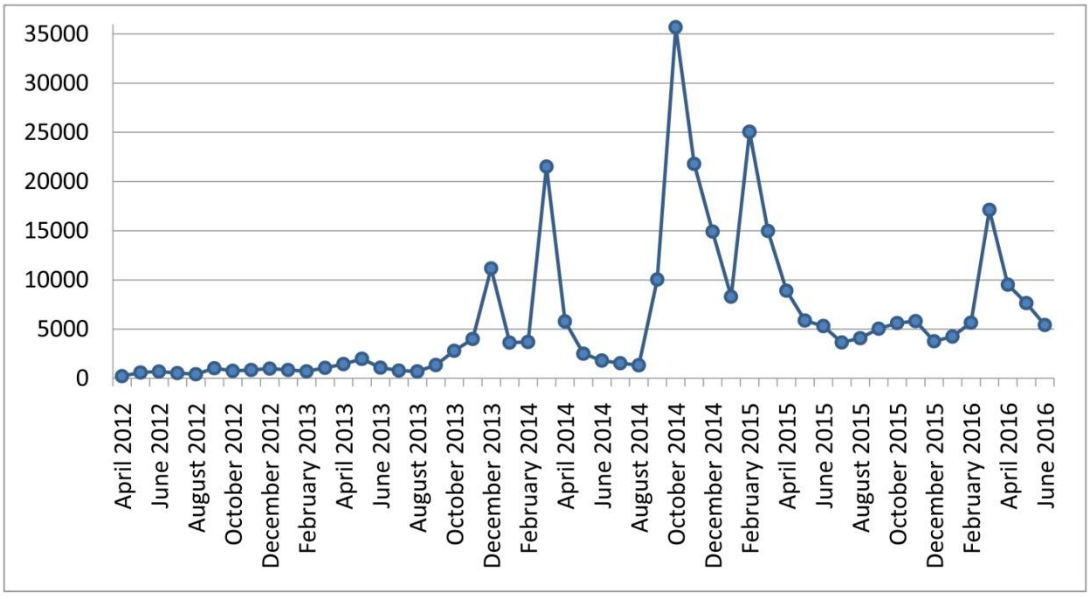

Figure 3.14: Number of visits to the ViSH platform

As of June 2016, the ViSH platform has received more than 300,000 visits, which means an average of around 200 visits per day. These results show that ViSH has generated significant interest among the educational community. The number of received visits varied significantly among months. Probably this is mainly due to the use of the ViSH platform in certain educational experiences, especially in MOOCs, which can cause many visits in short periods of time. It can also be noted that, in general, the activity of the ViSH platform in terms of visits has been lower during summer months. This is an expected result given that in these months the educational institutions are also, in general, less active.

The number of visits to resources (i.e. views of resource pages) is another relevant measure. As of June 2016, the resources published on the ViSH platform have been viewed around 1,300,000 times according to the records of its database. Thus, users viewed on average 4.3 resources per visit. Moreover, published resources were downloaded around 355,000 times. These results indicate that the resources of ViSH generated interest among end users.

3.4.4.3 Number of Learning Hours Delivered

In addition to the number of times that resources of the ViSH platform have been accessed, other important measure of use is the number of learning hours delivered by these resources. For this quantitative analysis, these hours were collected by using the tracking system of ViSH. Therefore, only learning hours delivered by Learning Objects created with ViSH Editor (i.e. Interactive Presentations) were collected. Thereby, the number of learning hours delivered represents the number of hours that users have spent interacting with the Interactive Presentations on the ViSH platform or on other VLEs. Only learner sessions with significant interactions from users are taken into account for measuring delivered learning hours. Unlike the other cases, the data presented in this section correspond to the period from August 2014 to June 2016, since they were collected from the date in which the tracking system started to operate. Figure 3.15 shows the cumulative number of learning hours delivered by the ViSH platform over the analyzed period measured as explained above.

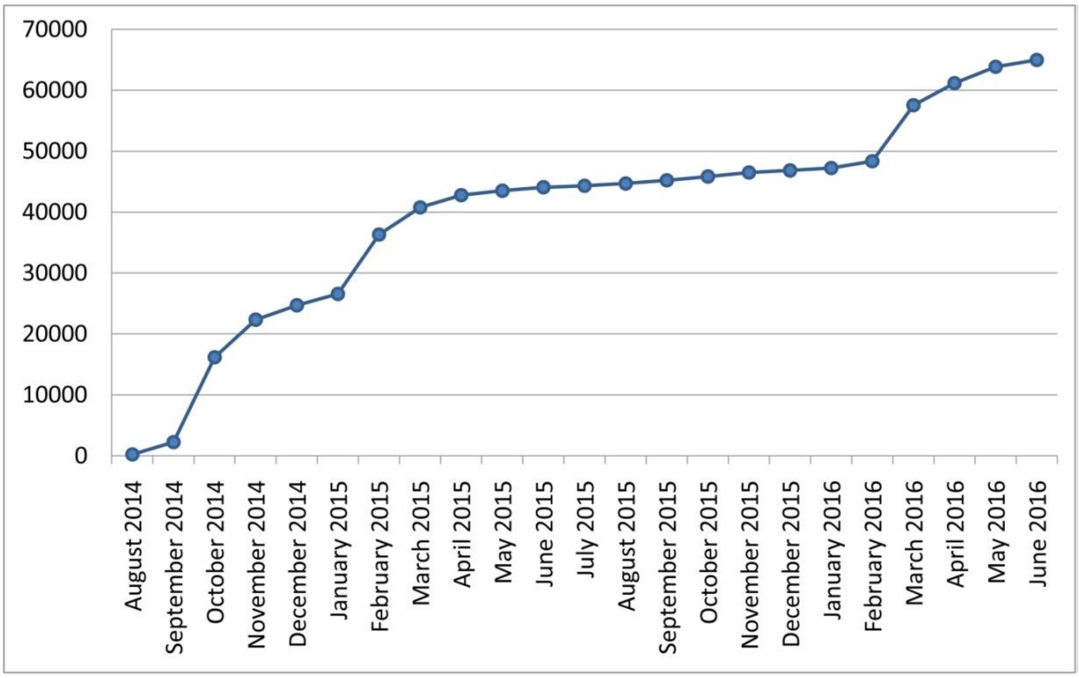

Figure 3.15: Cumulative number of learning hours delivered by the ViSH platform

The ViSH platform has delivered around 65,000 learning hours from August 2014 to June 2016, which means that, on average, it has delivered around 95 learning hours per day. These results of the quantitative analysis, together with those of the above section, provide evidence that the ViSH platform has been effective in distributing OER in the form of Learning Objects. Furthermore, they suggest that ViSH has succeeded in enabling the users of its community to share OER with the entire world. An evaluation of the effectiveness of the Learning Objects that delivered these learning hours can be found in chapter 4 of this thesis. The results of this evaluation show that, in general, these Learning Objects are effective from the learners' perspective.

3.5 Conclusions

This chapter presents the results of the design, implementation, deployment and evaluation of ViSH, an e-Learning platform to create and distribute Learning Objects. ViSH consists of a Learning Object Repository (LOR) enriched with new features that have been designed and implemented to satisfy the needs of the educational communities, and to support the whole Learning Object life cycle including the management of OER in the form of Learning Objects. The chapter describes the architecture of the ViSH platform and the main features it provides: social network, Learning Object manager, Learning Object authoring tools (ViSH Editor and ViSH Lesson Editor), collections and bookmarks, evaluation system and quality metrics, popularity and ranking metrics, search services, catalogue, recommender system, ARS (Audience Response System), tracking system, learning analytics, metadata provider, web portal, administration, courses and integration with LMSs. The software that runs the ViSH platform is open source and can be used for developing new LORs. The features offered by the ViSH software to create, configure and customize new LORs are also described in this chapter.

Several characteristics of ViSH were evaluated. Firstly, an online survey was conducted among 200 end users of the ViSH platform. The results of this survey showed that ViSH has high user acceptance, and that users found ViSH easy to use, were satisfied with all the offered features, perceived the different types of resources provided by ViSH as useful, and considered important all the activities for which ViSH was designed. Another survey was conducted to evaluate the ARS provided by ViSH. The results of this survey indicated that both teachers and students had a good overall opinion of the ARS and that they considered that it is a valuable educational tool. Secondly, a lab test with 12 participants was conducted to evaluate the usability of the ViSH platform. The results of the lab test showed that ViSH is easy and pleasant to use, that users can use the main features offered by ViSH without any prior training, that users have a good opinion on the overall usability of ViSH, and that little time and effort is needed to learn how to use ViSH. Thirdly, a comparison of ViSH with other LORs in terms of features supported was made. The features supported by ViSH suggest that it is capable of meeting the main demands of the educational communities. Moreover, the comparison showed that ViSH outperforms most of the existing LORs in terms of features offered to end users. Lastly, a quantitative analysis of the ViSH platform was conducted in order to provide empirical evidence of its use to create and distribute Learning Objects. Results of the quantitative analysis showed that ViSH has managed to establish a LOR with a significant amount of OER in the form of Learning Objects and a relatively large community of users, of which a significant proportion have contributed to ViSH by creating and publishing Learning Objects. Results also suggested that the number of published Learning Objects, users and contributors in ViSH will continue to grow linearly in the future. The number of visits to the ViSH web portal, the number of visits and downloads of the published resources, and the number of learning hours delivered, indicated that ViSH has generated notable interest among the educational community and that ViSH has been effective in distributing OER in the form of Learning Objects.

In conclusion, the results of the evaluation presented in this chapter provide evidence that ViSH is an effective system to create and distribute Learning Objects, and that the ViSH platform has succeeded in building a relatively large community of users that creates and shares OER in the form of Learning Objects with the entire world. Therefore, the objective of the thesis addressed in this chapter has been satisfactorily achieved. It is worth pointing out that ViSH can be used for delivering a wide variety of learning experiences in different settings. In this regard, chapter 9 of this thesis describes some learning experiences that have been delivered using the ViSH platform, as well as some learning experiences delivered using EducaInternet, an e-Learning platform developed by using the ViSH software.

The research question of the thesis covered in this chapter was the following: Which features need to be considered in the implementation of a system to create and distribute Learning Objects? To address this question, this chapter first describes the main features implemented by ViSH, which encompass almost all the features implemented by existing LORs according to the exposed comparison of features. The different needs for which these features were implemented as well as the different benefits and possibilities they can offer are described. Then, the chapter shows the results of an online survey among 200 end users of the ViSH platform in which feedback about the offered features was collected. Lastly, the chapter presents the results of a quantitative analysis that provide evidence of how effective have been the features implemented in ViSH in creating and distributing Learning Objects. The results of the survey indicated that users were satisfied and found useful the features for end users implemented by ViSH. Hence, all of these features should be at least considered in the implementation of systems to create and distribute Learning Objects. There are more features (e.g. search API, metadata provider and administration panel), which were not included in the survey because they cannot be evaluated by end users, but that should also be taken into account in the implementation of LORs because they cover important needs in the distribution of Learning Objects. The results of the quantitative analysis confirmed that a system that implements all the features described in this chapter is able to create and distribute Learning Objects in an effective way.

The first step in the development of a LOR is the implementation of its core features: storage, searching and retrieval of Learning Objects. The storage feature should support a wide range of file formats, including support for Learning Objects created according to different e-Learning standards (e.g. SCORM and IMS content packages). In addition to upload files, this feature ought to support the storage of links to external Learning Objects. Of crucial importance for a LOR is also to allow users to describe Learning Objects with appropriate metadata.

Besides, in order to effectively support the whole Learning Object life cycle, it is essential for a LOR to allow contributors to publish Learning Objects under open licenses such as Creative Commons. Regarding the search feature, a LOR must use ranking metrics to facilitate users to locate suitable Learning Objects. These metrics can combine different indicators with the relevance to the search query such as the popularity and quality of the Learning Objects. However, the use of popularity scores require to implement popularity metrics, while the use of quality scores require to implement an evaluation system that allows users to evaluate the published Learning Objects. In this regard, different Learning Object evaluation models and quality metrics can be used for different audiences (e.g. learners, teachers and appointed reviewers). LORs can implement other features to facilitate users to discover or search Learning Objects such as a catalogue, a browser, a recommender system, or an advanced search service to perform federated searches. LORs should allow users to view and download the published Learning Objects and their metadata directly in their web portals whenever possible. If both content and metadata are provided by using e-Learning standards the reusability and sharing of the Learning Objects will be improved. Furthermore, it would be desirable to provide information such as popularity indicators, quality evaluations and comments for end users to decide whether to use or not the Learning Objects. All published resources should have their own unique URL to be effectively shared. Additional features can be implemented to facilitate the sharing of resources such as embed codes or social network buttons.

In order to support the authoring stage of the Learning Object life cycle, a LOR should also offer authoring tools to its end users. The results of the evaluation presented in this chapter show that Learning Object authoring tools have played a key role in the success of the ViSH platform. Regarding this, it is important that authored Learning Objects are published under open licenses to enable their reuse. Another feature implemented in ViSH that a LOR might consider, is the use of learning analytics to provide authors with feedback about the effectiveness of the Learning Objects they create. However, the use of learning analytics requires implementing a tracking system to collect and store interaction data in the LOR database. In addition to create Learning Objects, users have found useful to create personal collections to organize their resources as well as to use bookmarks. Besides tools for creating, publishing and sharing Learning Objects, a LOR should provide features that enable and foster the creation and maintenance of a community of users. An ideal way to achieve this is to use a social network that enables the members of the community to meet each other, exchange ideas and collaborate. Interesting features that the social network of a LOR might offer are among others personal accounts, user profile pages, contacts, comments on the Learning Objects, notifications and private messaging. Forums are other feature that can be useful for the community of users. Lastly, LORs should also consider the implementation of incentive mechanisms in order to motivate users to contribute by creating and publishing resources.

LORs might also consider implementing additional educational tools. An example of these tools is the ARS offered by the ViSH platform, which has shown to be perceived as a valuable educational tool by both teachers and students. Other feature worthy of consideration is the integration with LMSs in order to deliver courses. This integration allows LORs to incorporate many of those functionalities offered by traditional VLEs.

Besides features for end users, LORs should also consider to provide features for external applications. In this chapter, two examples of these features are described: a search API that allows e-Learning systems to find and retrieve Learning Objects from ViSH, and an OAI-PMH target that allows metadata harvesters to collect Learning Object metadata from ViSH. Features like these can make more effective the distribution of Learning Objects.

Although a LOR can be managed by technical staff, it is desirable that it allows the creation of user accounts for administrators. Ideally, administrators should be able to manage the whole system from the user interface. Example of useful administration features are reports of inappropriate content, notification of errors and warnings of low quality resources.

Finally, it is also very important for a LOR to be distributed under an open source license to allow its customization and improvement. Customization features that allow the LOR staff to configure a LOR without changing the source code are also advisable. As mentioned earlier, the sustainability is an ongoing challenge for LORs. Many LORs were developed in the scope of a project and their development and maintenance were abandoned when the project funding ended. In open source LORs, the community of users and developers can continue with their development and maintenance after the initial funding ends contributing to their long-term sustainability. More benefits of open source software for education can be found in [382].

Summarizing, this chapter makes four main contributions. The first contribution is the ViSH platform itself. The software that runs the ViSH platform is open source and can be used for developing LORs enriched with features to effectively support the whole Learning Object life cycle and satisfy the needs of the educational communities. The second contribution is the quantitative analysis of the ViSH platform, which provides more evidence for the better understanding of the Learning Object life cycle and the requirements, gaps and opportunities for LORs. The third contribution is the answer to the research question. This chapter describes a wide range of features that should be considered in the implementation of a system to create and distribute Learning Objects. Finally, this chapter proposes solutions to address several barriers that hamper the authoring and distribution of Learning Objects. The main proposal is a comprehensive system to create and distribute Learning Objects called ViSH. Besides, the chapter describes the different solutions that were adopted in ViSH to overcome various barriers to the authoring and distribution of Learning Objects, which can be also applied to other systems. Among these solutions, it is worth highlighting the ranking, quality and popularity metrics for Learning Objects as well as the features to implement quality control mechanisms.

Chapter 4

An Easy to Use Authoring Tool to Create Effective and Reusable Learning Objects

Authoring tools play a crucial role in the development of learning content facilitating the creation of Learning Objects. However, not much work has been done in order to determine if educators actually can use these tools to easily create effective and reusable Learning Objects. This chapter addresses this issue by presenting and evaluating an open source Learning Object authoring tool called ViSH Editor. Three factors were evaluated: the user acceptance and usability of the authoring tool, the quality and learning effectiveness of the Learning Objects created with such a tool, and the reusability of these resources. The user acceptance was evaluated with a survey among 180 users, and the usability was evaluated through a lab test. Quality evaluation was conducted using LORI (Learning Object Review Instrument). The learning effectiveness was evaluated through learner surveys and test scores. Finally, reusability was evaluated by using the LORI instrument, by measuring metadata quality using a set of metrics, and by a quantitative analysis of reuse. Results show that ViSH Editor is an authoring tool capable of allowing educators to create effective and reusable Learning Objects easily.

4.1 Introduction

Learning Objects have emerged in recent years as a fundamental strategy for creating, sharing and delivering learning resources. However, there are still some barriers hampering the use and adoption of Learning Objects. First, although there are several Learning Object Repositories publicly available on the Web such as MERLOT [275], LRE [133], OpenStax CNX (formerly Connexions) [208], [209] or Europeana [57], teachers find it difficult to locate suitable Learning Objects. Many teachers perceive the search process as time consuming and they can take over an hour to find an appropriate resource [43]. In order to alleviate this problem, Learning Object Repositories usually adopt measures such as the development of easy to use search tools [44], and the use of ranking metrics [218]–[221], quality control mechanisms [39] and recommender systems [42]. Although these measures can speed up the search process, teachers usually need to customize the Learning Objects they find to adapt them to their needs [52]. Besides, the low availability of topic specific Learning Objects is another barrier [13]. One way to overcome these barriers is to allow teachers to create their own Learning Objects. However, the creation of Learning Objects is a highly technical and time consuming task. A solution to this issue is the use of authoring tools that allow educators to create effective Learning Objects with little effort and low cost without requiring them any programming knowledge or strong computer skills.

A trained author can achieve a ratio of around 4 hours of authoring to produce 1 hour of instruction using an authoring tool and importing existing materials, while the creation of the same type of learning resource without using the tool is estimated to take between 300 and 1,000 hours per hour of instruction [229]. For an authoring tool to achieve an easy, fast and effective creation process is essential to reuse existing resources and therefore it would be advisable the adoption of the Learning Object strategy. The success of this approach for creating Learning Objects through an authoring tool will depend on three key factors:

1. The user acceptance and usability of the authoring tool. Educators need to create the Learning Objects in an easy and pleasant way even if they have little computer skills.
2. The quality and learning effectiveness of the created Learning Objects. The Learning Objects created with the authoring tool should be well designed, achieve high user acceptance and be effective in terms of learner engagement and academic performance.
3. The capacity of the created Learning Objects to be reused and shared. Authoring tools based on the Learning Object approach need to go beyond creating effective learning resources in an easy way. They need to be able to generate these resources in such a way that they can be easily reused in different e-Learning systems and educational environments. Besides, an authoring tool that aims to create open Learning Objects should facilitate their sharing and discoverability.

Moreover, according to [255], an authoring tool should not only be easy to use and produce Learning Objects with good quality and high reusability but also be distributed under an open source license to allow its customization. Open source software has many advantages and offer several benefits for open education in comparison to proprietary software [382].

There are some works about open source Learning Object authoring tools in the literature [232]–[240], [255], [257], but none of them have conducted an evaluation covering the aforementioned three key factors. Therefore, further research is required to determine if educators can actually use Learning Object authoring tools to create effective and reusable Learning Objects easily.

This chapter presents an easy to use and open source Learning Object authoring tool called ViSH Editor to facilitate the creation of effective and reusable Learning Objects. It contributes to the state of the art of open source authoring tools for creating Learning Objects by describing a tool with novel and distinguishing features and providing a complete evaluation.

The chapter is organized as follows. Next section shows the objective and the research question of this thesis that this chapter covers. Section 4.3 describes the main features of the ViSH Editor authoring tool. Section 4.4 reports the results of the evaluation. More specifically, sections 4.4.1, 4.4.2, and 4.4.3 present, respectively, the results of the evaluation of the first, second, and third factor. Finally, section 4.5 provides the conclusions of the chapter.

4.2 Objectives

This chapter addresses the following objective of the thesis:

- *Design, implement and evaluate an authoring tool to facilitate the creation of Learning Objects.*

Next section shows the results of the design and implementation of the ViSH Editor authoring tool, and the section after that reports the results of its evaluation.

Besides, the chapter explores the following research question of the thesis:

- *Can educators create effective and reusable Learning Objects easily if they are provided with suitable authoring tools? And if so, which characteristics should be taken into account in the implementation of these tools?*

The question is answered based on the results of the evaluation of the three key factors presented in the introduction: the user acceptance and usability of the ViSH Editor authoring tool, the quality and learning effectiveness of the Learning Objects created with such a tool, and the capacity of these resources to be reused.

4.3 Description of ViSH Editor

ViSH Editor is a web-based open source authoring tool that aims to facilitate the creation of effective and reusable Learning Objects [383]. The tool is publicly available at http://vishub.org, the website of the ViSH e-Learning platform. A detailed description and evaluation of ViSH is included in chapter 3 of this thesis. ViSH Editor has been used for more than four years in ViSH with considerable success. Hundreds of users have used ViSH Editor for authoring a significant amount of Learning Objects which are nowadays published on the ViSH platform. It is worth pointing out that ViSH Editor can be used to create Learning Objects about any topic and for any educational level. The ViSH community have used it to create resources to teach maths, physics, technology, biology, chemistry and history among other topics.

4.3.1 Architecture of the Tool

The tool consists of two main components: an editor (ViSH Editor) and a player (ViSH Viewer). ViSH Editor is a client-server web application that allows creating Learning Objects and saving them in JSON format. ViSH Viewer is a fully client-side web application that allows displaying the Learning Objects created with ViSH Editor in a web browser and interacting with them. Both applications have been developed in HTML5 and can be used with just an HTML5 compliant browser. Thus, the created Learning Objects can be accessed from any device with an HTML5 compatible web browser without any installation being needed. The communication between the ViSH Editor client and the server is performed through an API. So, the tool is not tied to any specific backend technology and different server implementations can be developed for integrating the tool in different environments. Besides, the tool can be customized for different environments by specifying diverse settings such as the look and feel of the user interface, texts and translations, and features available to the end users.

The ViSH Editor authoring tool is open source. On the one hand, the source code of ViSH Viewer and the client part of ViSH Editor is available at http://github.com/ging/vish_editor. On the other hand, a Ruby on Rails implementation of the server part of ViSH Editor is available at http://github.com/ging/vish. This implementation is the one used on the ViSH platform. Furthermore, a wiki with documentation about the ViSH Editor authoring tool is available at http://github.com/ging/vish_editor/wiki. This documentation includes installation and configuration instructions, the definition of the data model and API specifications. At the time of writing, ViSH Editor 0.9.4 is the latest version released. This chapter describes this version of ViSH Editor.

4.3.2 Learning Object Model

Learning Objects can be combined among them to build more complex ones forming a hierarchy where the different levels of the hierarchy are called aggregation or granularity levels. Learning Object models define these levels of granularity and specify how the components can be aggregated as well as their properties [185]. The main Learning Objects that can be created with ViSH Editor are the Interactive Presentations, which consist of a series of slides displayed in a certain sequence, where each of these slides can be created by the author using different types of resources. The Interactive Presentations are built according to the Learning Object model of ViSH Editor which defines four levels of granularity according to Figure 4.1:

- The first level, which corresponds to the most granular or atomic level, includes raw media files like images, audios, videos, flash objects and documents as well as other resources such as paragraphs of text, questions and quizzes, websites and web applications (including SCORM and IMS content packages).
- The second level has a single Learning Object called “slide” that consists of a collection of level one Learning Objects.

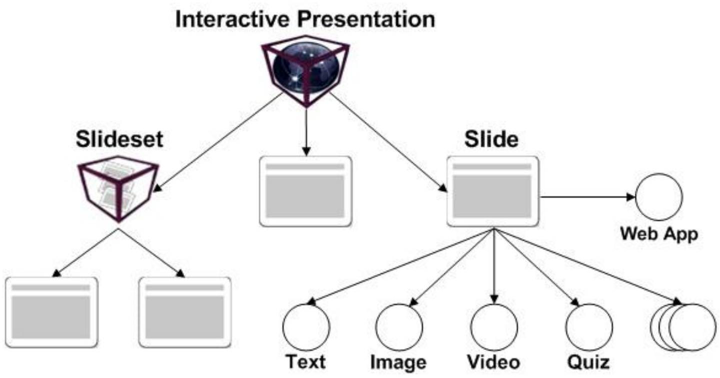

Figure 4.1: Learning Object model of ViSH Editor

- The third level includes a series of Learning Objects termed "slidesets" which are built as a composition of slides. The current version of the tool allows creating three different slidesets: Flashcards, Virtual Tours and Enriched Videos [376]. Flashcards are "resources presented as an image background with 'hot zones' identified by animated arrows on which the learner can click to see additional content that the author has previously linked". Virtual Tours are similar to Flashcards, but they are presented as interactive maps where the 'hot zones' are places identified by map pins. Lastly, Enriched Videos are "videos augmented with other resources (e.g. questions, images, websites, ...) which can be selected and customized by the author, and that can be displayed automatically when the video reaches a specific point of time or when the learner requests one of them explicitly by selecting it in the progress bar or in a side menu". Figures 4.2, 4.3 and 4.4 show, respectively, an example of a Flashcard, a Virtual Tour and an Enriched Video created with ViSH Editor.
- The fourth and last level corresponds to the Interactive Presentations. These Learning Objects can contain Learning Objects of the third level or directly slides. Nevertheless, they cannot contain other Interactive Presentations although they can incorporate the Learning Objects with which they are built. Figure 4.5 shows two slides of an Interactive Presentation created with ViSH Editor.

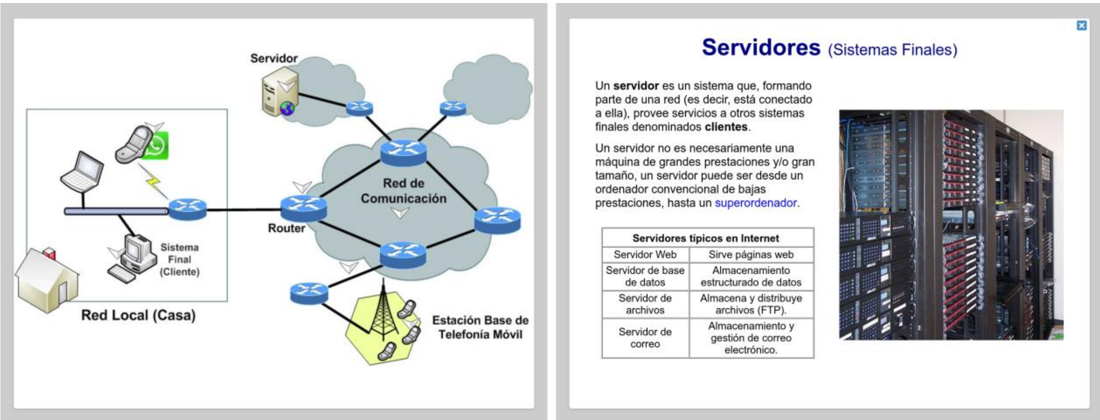

Figure 4.2: Flashcard created with ViSH Editor

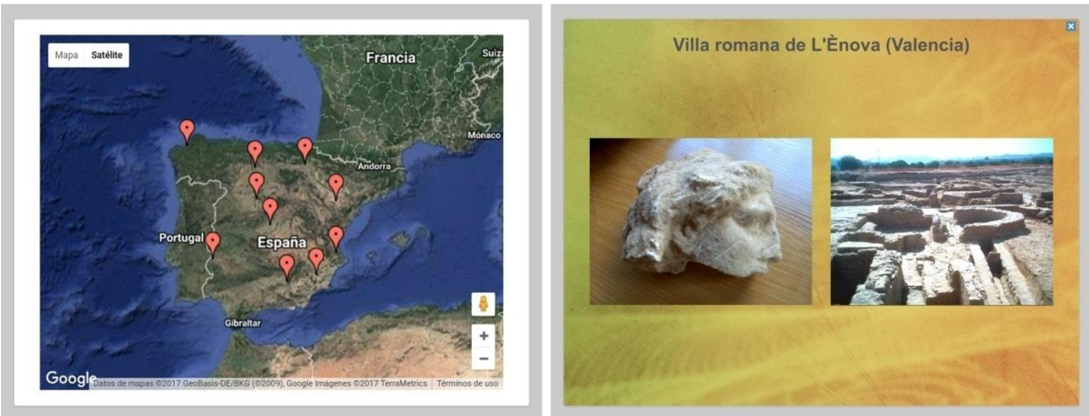

Figure 4.3: Virtual Tour created with ViSH Editor

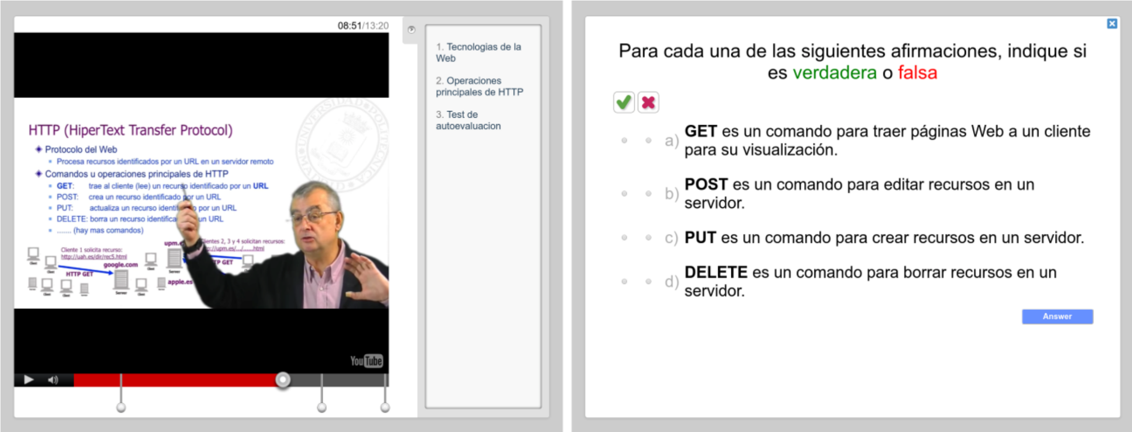

Figure 4.4: Enriched Video created with ViSH Editor

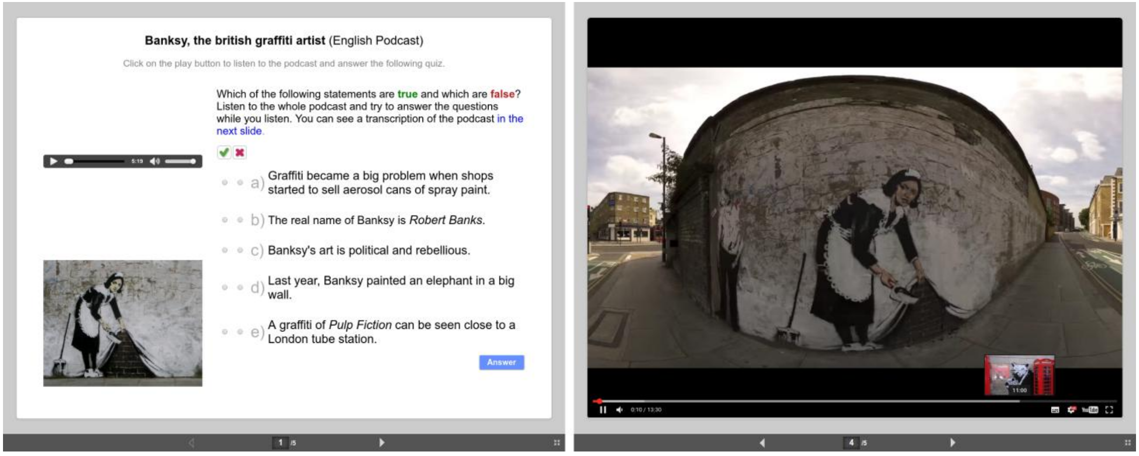

Figure 4.5: Interactive Presentation created with ViSH Editor

4.3.3 Features

ViSH Editor is based on the WYSIWYG (What You See Is What You Get) paradigm. It provides a user friendly interface where the Learning Object to be created is presented as a presentation of slides, on which the authors can add new slides and move or remove the existing ones. Each slide is created from a template and inside it authors can create and insert the different types of content. Figure 4.6 illustrates the user interface of ViSH Editor. The tool offers different themes which allow applying a predefined combination of colours, fonts and effects such as slide transitions. Authors can preview the Interactive Presentations they are creating from a learner's perspective at any time. Interactive Presentations can be saved as drafts so they can be only accessed by their author until their publication. Once an Interactive Presentation is published, it can be accessed by anyone from any device with an HTML5 compliant web browser. There are several videotutorials available for users to get started with the tool and learn how to use specific features. In addition, context-sensitive help is provided in the different sections of the user interface. ViSH Editor provides multilingual support and is available in several languages such as English, Spanish, French and German.

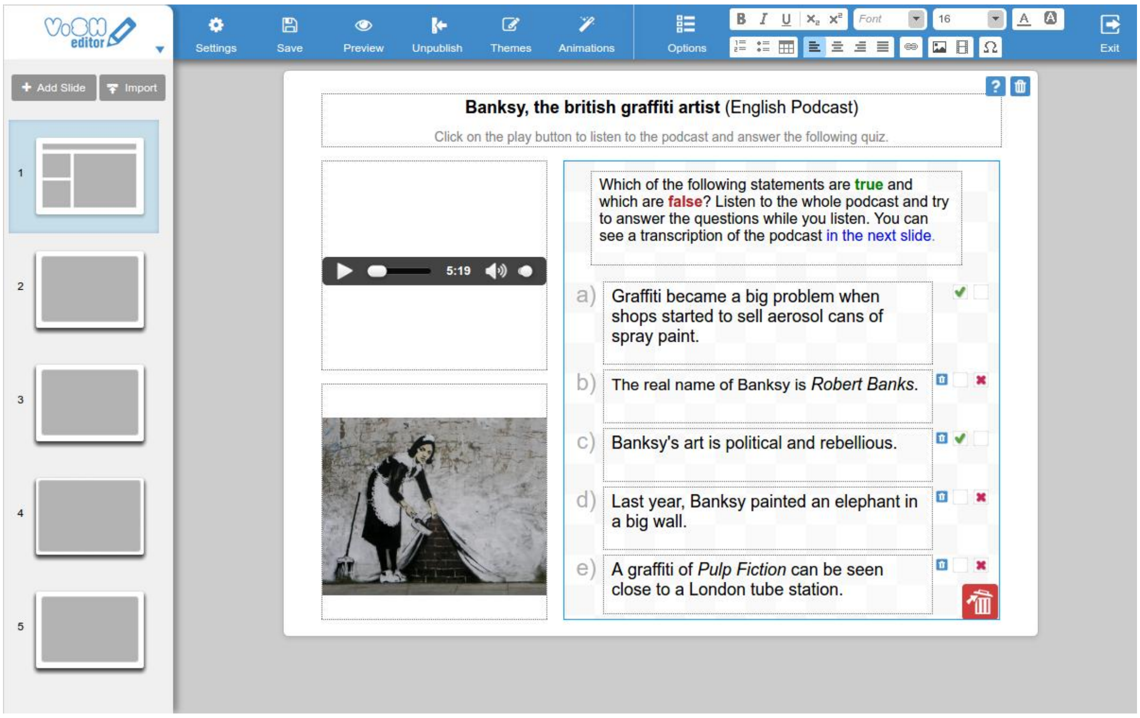

Figure 4.6: User interface of ViSH Editor

In ViSH Editor, authors can create paragraphs of text using a WYSIWYG rich text editor. They can also create different types of self-graded questions (multiple choice, true/false, short answer, sorting) and specify several settings for them such as the maximum number of attempts or the choices shuffling. An Audience Response System is available allowing teachers to pose a question included in a slide and get instant feedback from the audience, which just needs a device with an HTML5 compliant web browser to connect to the poll and answer the question [378]. Besides creating content from scratch, authors can insert many types of resources: pictures, audios, videos, flash objects, documents, websites, HTML5 applications, SCORM packages (conformant to SCORM 1.2 [147] or SCORM 2004 4th Edition [110]), IMS content packages (conformant to IMS CP 1.1.4 [113]), etc. These resources can be added via their URL, by uploading them or by searching on different Learning Object Repositories and general content providers such as ViSH, Europeana, LRE, Flickr, YouTube and SoundCloud. Moreover, IMS QTI [115] and Moodle XML [153] questions can be imported from XML files. Authors can also create other interactive Learning Objects with ViSH Editor such as Flashcards, Virtual Tours or Enriched Videos and integrate them into the Interactive Presentations. ViSH Editor also allows importing slides from PDF slideshows into the Interactive Presentations. This way, PDF slideshows can be quickly and easily converted to web-based Learning Objects which can be later enriched with more content and resources. Authors can also import slides from other Interactive Presentations (created by them or by other users) retrieved from external files or web repositories. Besides, they can create derivative works by cloning Interactive Presentations that have been published under licenses that allow that type of reuse.

ViSH Editor enables authors to fill the metadata of the Learning Object through the user interface. They can indicate several metadata such as title, description, language, keywords (in the form of tags), subject, avatar (an image for representing the Learning Object), educational context, recommended age range, difficulty, typical learning time and educational objectives. Attachment files can be included to provide complementary materials such as lesson plans or usage recommendations. Authors can also specify a license for the Learning Object before publishing it on the ViSH platform. On ViSH, all resources should be published under open licenses. The ViSH Editor tool available on ViSH allows authors to select among all Creative Commons licenses [199] and public domain. Nonetheless, it would be possible to customize the available licenses for different contexts. Authors also have the possibility of specifying more options such as if the users will be allowed to comment on the Interactive Presentation after being published. In addition to all these metadata, more metadata are automatically included by ViSH Editor such as the author, creation date, update date, identifier of the Learning Object, version of ViSH Editor employed, and technical requirements. Almost all metadata fields allowed by ViSH Editor can be represented using the IEEE LOM [119] standard. In this regard, the ViSH platform allows users to download the metadata of the Interactive Presentations created with ViSH Editor as LOM metadata instances in XML format.

Interactive Presentations created with ViSH Editor are saved on the ViSH platform in JSON format. However, they can be exported to SCORM 1.2 and SCORM 2004 4th Edition enabling their integration in SCORM compliant VLEs such as Moodle [79], Sakai [80] or Blackboard Learn [81]. Metadata are included in the SCORM packages according to IEEE LOM. The conformance of the SCORM packages was validated using the latest versions of the ADL SCORM Test Suite (see section 2.2.3.3.5 for details). Interactive Presentations can be also exported as JSON files which can be opened by the editor tool. Furthermore, the created questions can be exported to IMS QTI 2.1 and Moodle XML 2.8 to be reused in other systems. The generated IMS QTI questions were validated using the official IMS QTI online validator, and the Moodle questions were tested in different versions of Moodle (including Moodle 2.8). In addition to export the created Interactive Presentations to different formats, they can be shared through a URL as well as embedded in a website by using an embed code. All the Learning Objects created with ViSH Editor provide an API allowing third-party web applications to communicate with the player (i.e. ViSH Viewer) and handle the Interactive Presentations (e.g. by advancing slides) allowing this way more sophisticated integrations. A couple of examples of the use of this API are described in chapter 8 of this thesis.

Other feature that is worth mentioning is the tracker provided by ViSH Viewer, which allows capturing data about the interactions of the learners with the Interactive Presentations (e.g. number of mouse clicks). These interaction data are then stored in the ViSH platform, which uses them for generating learning analytics (see chapters 3 and 6 for further details).

4.3.3.1 Advanced Integration of Packaged Learning Objects

The most distinguishing feature of ViSH Editor compared to other Learning Object authoring tools is the advanced integration of packaged Learning Objects. Within this context, the term "packaged Learning Object" refers to any file that contains or represents a Learning Object.

The advanced integration of packaged Learning Objects enables authors to insert and integrate into the Interactive Presentations they are creating Learning Objects packaged or created according to different content integration e-Learning standards, as well as HTML5 web applications that do not adhere to any e-Learning specification. Thereby, authors can reuse and combine Learning Objects created with other authoring tools and e-Learning systems as well as e-Learning resources obtained from digital repositories that follow some e-Learning standard. The current version of ViSH Editor allows integrating Learning Objects that adhere to the following standards: IMS QTI 2.1, Moodle XML 2.8, IMS CP 1.1.4, SCORM 1.2 and SCORM 2004 4th Edition (see chapter 2 for a description of these standards). Generic web applications can be also integrated allowing the reuse of the huge amount of tools and applications available on the Web and that are useful for education. Besides, e-Learning content developers can build and publish web applications for being used in Interactive Presentations. An API is provided to the developers in order to allow the integrated web applications to communicate with ViSH Editor and use advanced features (e.g. access to user data and grading). The specification of the API can be found at the ViSH Editor wiki available at http://github.com/ging/vish_editor/wiki.

This integration does not only allow integrating the content of the packaged Learning Objects into the Interactive Presentations, it also manages the communication (if any) between the integrated Learning Objects and the VLEs, in such a way that the Interactive Presentations will behave as one single resource or activity in the eyes of the VLEs into which they are integrated. For instance, an author can insert several SCORM packages in an Interactive Presentation in such a way that when this presentation is exported to SCORM and integrated into a VLE like Moodle, it will behave as one single resource. The Interactive Presentation will send to Moodle a single completion status, score and success status based on the interactions of the learner with the Learning Objects that were contained in the added SCORM packages, as well as with the rest of the content. Once authors insert a Learning Object, they can specify different settings for it such as the assigned score (for Learning Objects that report scores) or different options related to the presentation of the content. For the created questions, authors can specify other settings in addition to the assigned score such as the maximum number of attempts or the choices shuffling. The implementation of this innovative feature was a technical challenge because content integration e-Learning standards were not designed with this use case in mind, and because the combination of Learning Objects packaged or created according to different specifications needed to be addressed too. Further details on the integration model implemented in ViSH Editor to provide this feature are included in chapter 8 of this thesis.

4.4 Evaluations and Results

4.4.1 Evaluation of the Authoring Tool

4.4.1.1 Evaluation of the User Acceptance

An online survey was conducted among the users of the ViSH platform to gather general feedback about the ViSH Editor authoring tool. An email with the link to the survey was sent to all ViSH users that had used ViSH Editor to create and publish at least one Learning Object. Besides, a link to the survey was also included in the 'About' section of the tool. A total of 180 surveys were collected. The sample consisted of 180 authors, 44% males and 56% females, 18 to 65 years of age (M=40.2, SD=11.7). Table 4.1 shows the main results of the survey including for each question the number of responses (N), the mean value (M) and the standard deviation (SD). Some questions of the survey were related to concrete features of ViSH Editor. Each of these questions was answered only by the users who have used the corresponding feature and therefore in these cases the number of responses differs from the number of respondents.

Table 4.1: Results of the ViSH Editor Survey

Question	N	M	SD
Previous experience with authoring tools 1 (none) – 5 (a lot)	180	3.7	1.1
What is your overall opinion of ViSH Editor? 1 (awful) – 5 (excellent)	180	4.0	0.5
How would you describe the experience of learning to use ViSH Editor? 1 (very difficult) – 5 (very easy)	180	4.0	0.9
Please rate the usefulness of the Interactive Presentations created with ViSH Editor 1 (not useful) – 5 (very useful)	180	4.4	0.8
Please rate your overall experience using various features of ViSH Editor 1 (awful) – 5 (excellent)			
Writing text	175	3.9	0.9
Adding multimedia resources	177	4.1	0.9
Adding websites	162	4.1	0.9
Uploading your own files	168	4.0	0.9
Creating quizzes	142	3.8	1.0
Creating Flashcards	126	3.9	1.1
Creating Virtual Tours	132	3.8	1.1
Creating Enriched Videos	116	3.8	1.0
Importing other ViSH Editor Learning Objects	128	4.1	0.9
Importing slideshows from PDF files	141	4.0	1.0
Help and walkthroughs	155	4.0	0.9
Would you recommend ViSH Editor to others?	180	**Yes**	**No**
		93.3%	6.7%

The results of this survey show that ViSH Editor has a high user acceptance among the users of the ViSH community. Overall opinion recorded a mean of 4.0 on a 1-5 scale and 93.3% of the users answered that they would recommend the tool to others. Authors found the tool easy to use (M=4.0, SD=0.9) and were very satisfied with the usefulness of the Interactive Presentations created with it (M=4.4, SD=0.8). Besides, authors felt that the different features offered by the tool were suitable. All these features obtained ratings higher or equal than 3.8 on a 1-5 scale. Since the combination of different types of content is a characteristic of successful Learning Objects [15], it is important for Learning Object authoring tools to offer suitable features for that. In this case, authors were satisfied with the features provided by ViSH Editor to add and combine text, multimedia resources, websites, own files and quizzes. The creation of quizzes seems to be a key feature since they allow to effectively enhance the quality of Learning Objects [384]. Authors were also satisfied with the features for creating novel Learning Objects (i.e. Flashcards, Virtual Tours and Enriched Videos). The comments provided in the survey showed that authors found useful to create new innovative resources. Lastly, the results obtained by the features for importing and integrating Learning Objects indicate that authors were able to reuse Learning Objects in an effective way.

4.4.1.2 Usability Evaluation

A lab test with 12 participants was conducted in order to evaluate the usability of the ViSH Editor authoring tool. The lab test is a usability method that involves a one-on-one session between a moderator (usability specialist) and each of the participants. The moderator gives the participants a set of tasks to perform on the system in question and asks them to think aloud while they complete the tasks. A total of 12 people participated in this lab test, 8 males and 4 females, 21 to 59 years of age (M=32.6, SD=12.7). Five of the participants were teachers, three were engineers and four were undergraduate students. Participants were requested to perform five representative tasks using the ViSH Editor tool: create a very basic Learning Object and publish it (Task 1), create a slide with text and one image identical to other one provided in printed format (Task 2), create a self-graded multiple choice question (Task 3), add a website through its URL and then search and add a particular web application (Task 4), and create a Flashcard with a specific image background and an arrow which should open a new slide containing a YouTube video (Task 5). Thereby, participants used the main features of ViSH Editor, including those features provided by the tool to add text, multimedia resources, websites, questions, own files and Flashcards. Each participant performed the tasks in a specific order to avoid carryover effects. Participants did not receive help or support from the moderator. After each task participants had to indicate their emotions with the use of expressive cartoon figures and the intensity of each of these emotions on a 1-5 scale. In this evaluation the cartoon figures provided by the LEMtool [380] were used, which express four positive (joy, desire, fascination, satisfaction) and four negative (sadness, disgust, boredom, dissatisfaction) emotions using facial expressions and body postures (see appendix A for an image of these cartoon figures). The screen and audio were recorded in every lab session so that they could be post processed to measure the task times and number of mouse clicks. Besides, recordings allow hearing what was exactly said in every moment. After completing all the tasks, each participant filled out a SUS (System Usability Scale) [279] questionnaire (see section 2.6 for details on SUS). Lab sessions lasted around 45 minutes each. Lastly, in order to measure learnability, three of the participants (one teacher and two engineers) attended two more sessions in which they performed again the same five tasks. Thereby, each of these participants performed three trials. The time between trials was one day.

A total of six metrics were used in this evaluation to measure different aspects of usability. These usability metrics, whose definitions are included in the appendix A of this thesis, are the following: task completion, task efficiency, clicks efficiency, learnability, task satisfaction and overall satisfaction. A final usability score on a 0-100 scale was calculated for each metric. Next, a brief explanation of how each of these final usability scores was calculated is provided (see appendix A for further details):

- *Task completion*: score was calculated as the percentage of tasks successfully performed by the participants within a specific amount of time and with no errors.
- *Task efficiency*: score was calculated by comparing the time spent by the participants on completing the tasks with the time required by an expert. The time required by an expert was estimated by measuring and averaging the time spent by two users with extensive expertise using ViSH Editor on performing the tasks of the usability test.
- *Clicks efficiency*: score was calculated by comparing the number of mouse clicks required by the participants to accomplish the tasks with the minimum number of mouse clicks required.
- *Learnability*: score was calculated by comparing the task completion, task efficiency and clicks efficiency scores between the last and first trial performed by three of the participants.
- *Task satisfaction*: score was calculated based on the emotions reported by the participants using the cartoon figures.
- *Overall satisfaction*: score was obtained from the overall scores yielded by the SUS questionnaires filled out by the participants.

Figure 4.7 reports the main final scores obtained in this usability evaluation of the ViSH Editor authoring tool. Furthermore, Figure 4.8 shows the variations across trials of the scores yielded by the different performance metrics (task completion, task efficiency and clicks efficiency), which were used to calculate the final learnability score.

Figure 4.7: Usability scores of ViSH Editor obtained in the usability evaluation

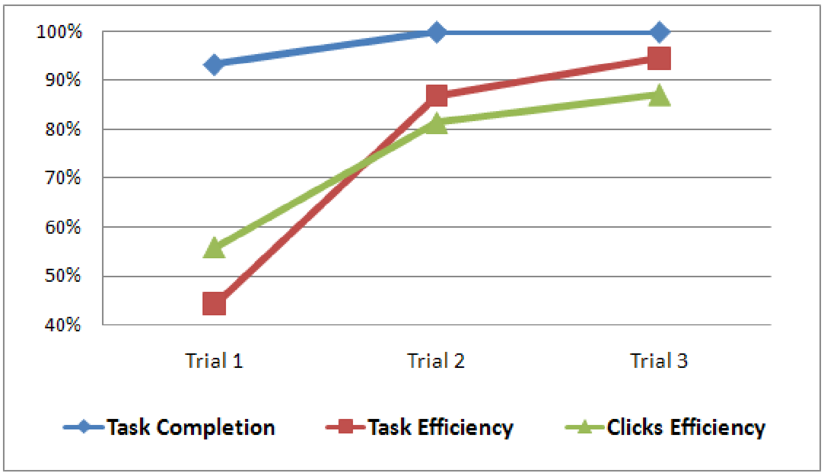

Figure 4.8: Learnability of ViSH Editor: performance scores across trials

The results of the usability evaluation show that participants succeeded in performing the tasks within the required time and with no errors in more than 90% of the cases. This fact means that users without any prior training are able to use the tool to carry out the main tasks such as adding slides with multimedia resources, including self-graded questions, creating slidesets and publishing the authored Learning Objects. Although in this lab test only the creation of Flashcards was evaluated, the process to create the other type of slidesets is quite similar. The value of 49 obtained in the task efficiency score indicates that participants in the first trial required on average approximately the double of time than an expert to successfully accomplish the tasks. However, the results also show that efficiency scores notably improve after the first trial. Participants who attended several sessions obtained an average task efficiency score of 87 and 95 in the second and third trial respectively. The obtained average clicks efficiency scores in the second and third trial were respectively 81 and 87. These improvements across trials led to a high learnability score, which points out that little time and effort is needed for becoming proficient with ViSH Editor. According to the value of 76 obtained in the task satisfaction score, which was calculated based on emotions reported by the participants using the cartoon figures, it can be stated that participants were notably satisfied with respect to their performance on the tasks. This score indicates that users found ViSH Editor not only easy to use but also pleasant to use. Lastly, the high overall satisfaction score obtained (i.e. the score obtained from the SUS questionnaires) points out that, in general, participants had a good opinion on the overall usability of the ViSH Editor authoring tool. Summarizing, the results of the usability evaluation were very positive and indicated that ViSH Editor is easy and pleasant to use, that authors without any prior training can use it to carry out the main tasks, and that little time and effort is needed for becoming proficient with the tool. These results can be considered highly reliable since the usability study involved 12 participants, which is a suitable number when the lab test usability method is used [381].

To date, there are hardly any studies that have quantitatively measured the usability of open source Learning Object authoring tools. Most studies on this subject have not collected usability measures and only provide qualitative results. One exception is the usability evaluation carried out in [257] with six users, where the GLO Maker open source authoring tool achieved a task success rate of around 90%. In the evaluation presented in this section, ViSH Editor achieved a task success rate of 92%. Although these results cannot be compared due to the differences between the tasks, there is a consensus that authoring tools that obtain high scores on usability measures such as task success rate can be considered easy to use.

4.4.2 Quality and Effectiveness Evaluation of the Created Learning Objects

4.4.2.1 Quality Evaluation

ViSH has a team of reviewers who evaluate the Learning Objects published on the platform using LORI (Learning Object Review Instrument) [273] through a web-based platform called LOEP (Learning Object Evaluation Platform). Details about the evaluation system of ViSH are included in chapter 3 of this thesis. Moreover, details about LORI can be found in section 2.6, as well as in chapter 5 of this thesis which presents the LOEP system.

A total of 18 reviewers participated in the evaluations of this study: 6 e-Learning experts, 9 educators and 3 designers. Reviewers used the version 1.5 of LORI which considers the 9 criteria (or LORI items) listed in Table 4.2. When using LORI, reviewers have to rate each item using a 5-point scale. A total of 316 Learning Objects created with ViSH Editor were evaluated using LORI. Each of them was evaluated on average by 3.3 reviewers. Quality scores were calculated on a 0-10 scale according to the “LORI Weighted Arithmetic Mean” metric proposed and validated in chapter 5 of this thesis. This metric calculates the overall score of a Learning Object as the weighted arithmetic mean of all LORI items scores, giving different importance to each criterion. The used weights were those obtained through a survey among the ViSH reviewers (i.e. the collected weights as termed in chapter 5). When a Learning Object is scored higher or equal to five according to this metric it can be considered of high enough quality to be used for education. Further details on this metric can be found in [385] as well as in chapter 5 of this thesis. Table 4.2 shows the main results of the LORI evaluations. Figure 4.9 shows the histogram of the quality scores obtained by the Learning Objects according to the “LORI Weighted Arithmetic Mean” metric used in this evaluation.

Table 4.2: Quality Scores of ViSH Editor Learning Objects based on LORI (N=316)

	M	**SD**
Overall score (LORI Weighted Arithmetic Mean quality metric) 0 – 10	6.1	1.7
LORI items 1 – 5		
1. Content quality	3.7	0.9
2. Learning goal alignment	3.7	0.9
3. Feedback and adaptation	2.7	1.0
4. Motivation	3.5	0.9
5. Presentation design	3.3	0.9
6. Interaction usability	3.3	0.8
7. Accessibility	3.4	0.7
8. Reusability	3.2	0.9
9. Standards compliance	4.5	0.4

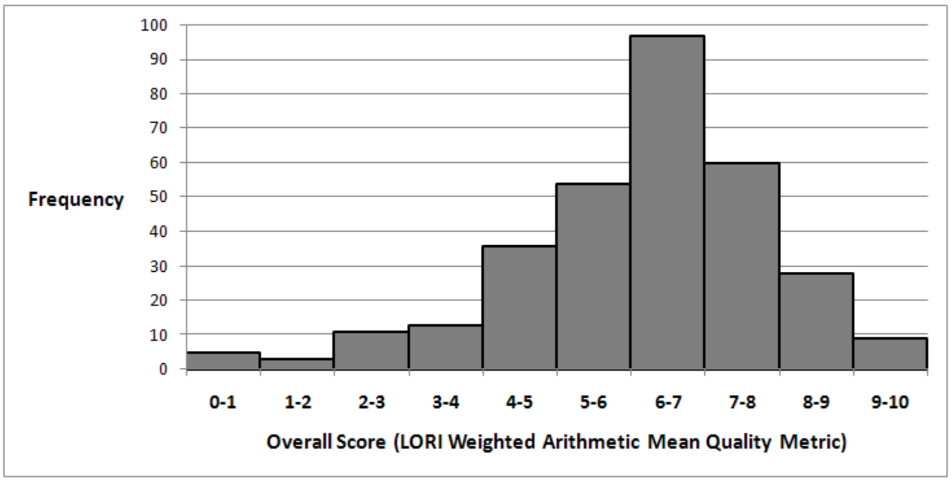

Figure 4.9: Histogram of LORI scores obtained by ViSH Editor Learning Objects

Learning Objects created with ViSH Editor and published on the ViSH platform obtained satisfactory average scores on all criteria as well as a good average overall quality score (M=6.1, SD=1.7) from the reviewers who evaluated them using LORI. The “feedback and adaptation” (M=2.7, SD=1.0) criterion was the only one which recorded a mean below the midpoint of the scale. This indicates that although ViSH Editor provides powerful features to provide feedback and adaptation such as quizzes and the integration of adaptive Learning Objects, some authors do not use them regularly. This also points out that more work could be done for facilitating the creation of adaptive content. The “interaction usability”

(M=3.3, SD=0.8) criterion indicates that ViSH Editor was able to allow authors to create interactive and easy to use Learning Objects. However, the value obtained was moderate and this brings to light that some authors are not taking full advantage of the features to add interactive resources. Histogram of LORI quality scores shows that there are Learning Objects with very different quality scores. Nevertheless, around 80% of the Learning Objects were scored higher than 5. This evidence points out that although authoring tools like ViSH Editor can facilitate authors the creation of high quality Learning Objects, they cannot guarantee it.

4.4.2.1.1 Quality Evaluation of Enriched Learning Objects

Besides creating Learning Objects from scratch, ViSH Editor allows authors to enrich existing e-Learning resources [384]. For instance, ViSH Editor allows authors to convert PDF slideshows (created using Microsoft PowerPoint, LibreOffice or any other tool) into Learning Objects in the form of Interactive Presentations, which can be enriched later by adding different resources such as quizzes and slidesets (i.e. Flashcards, Virtual Tours and Enriched Videos).

In order to evaluate the effectiveness of ViSH Editor to enrich existing e-Learning resources, an additional study was conducted. This study analyzed the influence of the presence of two types of resources: quizzes and slidesets, on the quality of the Learning Objects created with ViSH Editor. For the study, the same 316 Learning Objects created with ViSH Editor of the above section were used. Thus, each of the Learning Objects involved in this study was evaluated on average by 3.3 reviewers using the LORI instrument. The quality scores of these Learning Objects were calculated in the same way as the above section, that is, on a 0-10 scale according to the "LORI Weighted Arithmetic Mean" metric and by using the weights obtained through the survey among the ViSH reviewers. Learning Objects were classified in four groups depending on the presence or absence of quizzes and slidesets: group A was formed by Interactive Presentations with quizzes (N=75), group B by Interactive Presentations without quizzes (N=241), group C by Interactive Presentations with slidesets (N=101), and group D by Interactive Presentations without slidesets (N=215). Comparisons were made between groups A and B, and groups C and D, with respect to the average overall quality score yielded by the "LORI Weighted Arithmetic Mean" metric, and with respect to the average scores of the LORI items. Overall quality scores are expressed on a 0-10 scale, and the scores of the LORI items are expressed on a 1-5 scale. For each comparison, a series of independent samples t-tests were conducted to determine if there were significant differences between the two groups in terms of their scores. Besides, Cohen's d effect size was used to determine the practical significance of the differences in average overall quality scores and average LORI items scores. When using Cohen's d as a measure of effect size, a value of 0.2 indicates a small, 0.5 a medium, and over 0.8 a large effect size [386]. Tables 4.3 and 4.4 show, respectively, the results of the study.

Table 4.3: Comparison between Learning Objects with and without Quizzes

	Learning Objects with Quizzes (N=75)		**Learning Objects without Quizzes (N=241)**		**Independent samples t-test p-value (2-tailed)**	**Cohen's d effect size**
	M	**SD**	**M**	**SD**		
Overall score (LORI Weighted Arithmetic Mean quality metric) 0 – 10	7.3	1.5	5.8	1.6	< 0.001	**0.96**
LORI items 1 – 5						
1. Content quality	4.1	0.9	3.6	0.8	< 0.001	0.62
2. Learning goal alignment	4.2	0.8	3.6	0.9	< 0.001	0.65
3. Feedback and adaptation	3.8	0.7	2.4	0.8	< 0.001	**1.77**
4. Motivation	4.0	0.9	3.3	0.9	< 0.001	0.78
5. Presentation design	3.6	0.8	3.2	0.9	< 0.001	0.54
6. Interaction usability	3.8	0.7	3.2	0.8	< 0.001	0.77
7. Accessibility	3.6	0.5	3.3	0.7	< 0.001	0.55
8. Reusability	3.6	0.9	3.1	0.9	< 0.001	0.58
9. Standards compliance	4.6	0.4	4.4	0.4	0.020	0.31

Table 4.4: Comparison between Learning Objects with and without Slidesets

	Learning Objects with Slidesets (N=101)		**Learning Objects without Slidesets (N=215)**		**Independent samples t-test p-value (2-tailed)**	**Cohen's d effect size**
	M	**SD**	**M**	**SD**		
Overall score (LORI Weighted Arithmetic Mean quality metric) 0 – 10	6.9	1.1	5.8	1.8	< 0.001	**0.72**
LORI items 1 – 5						
1. Content quality	4.0	0.6	3.5	0.9	< 0.001	0.63
2. Learning goal alignment	4.1	0.5	3.6	1.0	< 0.001	0.60
3. Feedback and adaptation	3.0	1.0	2.6	1.0	0.004	0.35
4. Motivation	3.8	0.6	3.3	1.0	< 0.001	0.50
5. Presentation design	3.6	0.7	3.1	0.9	< 0.001	0.54
6. Interaction usability	3.8	0.6	3.1	0.9	< 0.001	**0.86**
7. Accessibility	3.7	0.5	3.2	0.7	< 0.001	0.72
8. Reusability	3.7	0.6	3.0	0.9	< 0.001	0.81
9. Standards compliance	4.5	0.4	4.5	0.5	0.636	- 0.06

The group of Learning Objects with quizzes and the group of Learning Objects without quizzes differed statistically significantly in overall quality score as well as in all scores of the LORI items. Learning Objects with quizzes had a significant difference with a large effect size (Cohen's d = 0.96) in overall quality score. A large effect size was also found in the score of the "feedback and adaptation" item (Cohen's d = 1.77). This finding was expected because the presence of quizzes has a large positive impact on feedback, since quizzes allow providing feedback concerning the quality and correctness of a learner's response. The significant positive impact on overall quality score was also expected due to the improvement of the score of the feedback and adaptation item. Furthermore, the medium effect size of the "interaction usability" item (Cohen's d = 0.77) was also expected because quizzes add interactivity.

The group of Learning Objects with slidesets and the group of Learning Objects without slidesets differed statistically significantly in overall quality score as well as in eight of the nine scores of the LORI items. Learning Objects with slidesets had a significant difference with a medium effect size (Cohen's d = 0.72) in overall quality score. Large effect sizes were found in the "interaction usability" (Cohen's d = 0.86) and the "reusability" (Cohen's d = 0.81) items. The significant positive impact on the score of the interaction usability item was expected, since Learning Objects with slidesets (i.e. with Flashcards, Virtual Tours and/or Enriched Videos) always provide interactive features and, according to the LORI user manual, static Learning Objects should be rated with the minimum score in this item. Thus, due to the improvement of the score of this item, the significant positive impact on overall quality score was also expected.

Most of the rest of the score differences with meaningful effect sizes obtained in this study were not expected. A possible explanation for these improvements is that Learning Objects with quizzes and/or slidesets are more likely to have been created by authors with better skills. Therefore, the score differences obtained in this study may not be only attributable to the presence of quizzes and slidesets, but also to other factors such as the differences in authors' skills to create Learning Objects and use the ViSH Editor authoring tool. Anyway, in the comparison between Learning Objects with and without quizzes, the effect sizes for the feedback and adaptation item and the overall quality score were significantly larger than the other ones. Similarly, in the comparison between Learning Objects with and without slidesets, the effect size for the interaction usability item was the largest one, and a medium (close to large) effect size was found in the overall quality score. Taken all these into account, it can be suggested that the presence of quizzes and the presence of slidesets are two positive significant factors on Learning Object quality, and therefore the proposed approach for enriching existing e-Learning resources with the ViSH Editor authoring tool is effective.

In order to confirm the relationship between Learning Object quality and the presence of quizzes and slidesets, other analysis was conducted. The 316 Learning Objects were divided in four quartiles according to their overall quality, being the first quartile the one with Learning Objects with higher quality scores and the fourth quartile the one with Learning Objects with lower quality scores. Then, the four quartiles were compared with respect to the proportion of Learning Objects with quizzes and slidesets that each of them had. Two chi-square tests of independence using an alpha level set at 0.05 were performed to determine if the proportion of Learning Objects with quizzes and the proportion of Learning Objects with slidesets were independent of the Learning Object quartile. Results can be seen in Table 4.5 shown below.

Table 4.5: Presence of Quizzes and Slidesets in the Learning Object Quartiles

Quartile	N	Q_{MIN}	Q_{MAX}	Learning Objects with Quizzes	Learning Objects with Slidesets
				N (%)	N (%)
Q1	79	7.24	9.67	43 (54.4%)	33 (41.8%)
Q2	79	6.40	7.23	18 (22.8%)	37 (46.8%)
Q3	79	5.26	6.39	6 (7.6%)	25 (31.6%)
Q4	79	0.26	5.22	8 (10.1%)	6 (7.6%)
Chi-square test of independence	X^2			60.6	33.1
	p-value			< 0.001	< 0.001

Results show that the proportion of Learning Objects with quizzes and the proportion of Learning Objects with slidesets were larger in the quartiles in which the Learning Objects had higher quality. The results of the chi-square tests of independence were X^2=60.6 with p<0.001 in the case of Learning Objects with quizzes, and X^2=33.1 with p<0.001 in the case of Learning Objects with slidesets. In both cases, X^2 is higher than the critical value of 7.8 and hence the independence hypothesis is rejected. Thus, it can be assumed that there are statistically significant relationships between the presence of quizzes and the quality of the Learning Objects, as well as between the presence of slidesets and the quality of the Learning Objects. Based on these results, it can be concluded that there is a strong positive relationship between the presence of quizzes and slidesets and the quality of the Learning Objects.

4.4.2.2 Effectiveness Evaluation in ViSH

The Learning Objects created with ViSH Editor and published on the ViSH platform are also evaluated by end users using WBLT-S [9], [281]. WBLT-S allows assessing the effectiveness of Learning Objects from a learner’s perspective (see section 2.6 for more details). It considers the 13 criteria listed on Table 4.6. On ViSH, learners use a version of WBLT-S provided by the LOEP system which has a 7-point Likert scale (see chapter 5 for details).

A total of 72 Learning Objects created with ViSH Editor were evaluated by learners through WBLT-S generating a total amount of 909 evaluations (12.6 evaluations per Learning Object on average). Overall scores were calculated on a 0-10 scale using the “WBLT-S Arithmetic Mean” metric described in chapter 5 of this thesis. Thereby, the overall score of each Learning Object was calculated as the arithmetic mean of all WBLT-S criteria scores converted to a 0-10 scale. Table 4.6 shows the main results of the WBLT-S evaluations. Figure 4.10 shows the histogram of the scores obtained by the Learning Objects based on these WBLT-S evaluations.

Results show that Learning Objects created with ViSH Editor and published on the ViSH platform obtained satisfactory average scores on all criteria as well as a good average overall score (M=7.8, SD=1.7) from the learners who evaluated them using WBLT-S. The results of the WBLT-S evaluations also show that learners found the Learning Objects very engaging, beneficial for their learning and easy to use. Besides, learners indicated that they would like to use Learning Objects like those created with ViSH Editor in more occasions. Graphics and animations were scored satisfactorily (M=5.6, SD=1.2) pointing out that ViSH Editor allowed authors to effectively integrate this type of resources into their Learning Objects. The score obtained by the feedback criterion (M=5.2, SD=1.4) indicates that the tool was also effective in supporting authors to add quizzes and importing other assessment resources. Histogram of WBLT-S scores shows that around 95% of the Learning Objects were scored higher than 5. Thus, it can be stated that the ViSH Editor authoring tool has proven to be able to allow users to create Learning Objects effective from the learners' perspective.

Table 4.6: Learners' Scores of ViSH Editor Learning Objects based on WBLT-S (N=72)

	M	**SD**
Overall score (WBLT-S Arithmetic Mean quality metric) 0 – 10	7.8	1.7
WBLT-S criteria 1 – 7		
1. The learning object was well organized	5.9	1.1
2. The learning object was easy to use	6.0	1.1
3. The instructions in the learning object were easy to follow	5.7	1.3
4. The help features of the learning object were useful	5.5	1.3
5. Working with the learning object helped me learn	5.8	1.3
6. The feedback from the learning object helped me learn	5.2	1.4
7. The graphics and animations form the learning object helped me learn	5.6	1.2
8. The learning object helped teach me a new concept	5.7	1.2
9. Overall, the learning object helped me learn	5.8	1.4
10. I like the overall theme of the learning object	5.9	1.4
11. I found the learning object to be engaging	5.6	1.3
12. The learning object made learning fun	5.4	1.3
13. I would like to use learning objects like this again	6.0	1.3

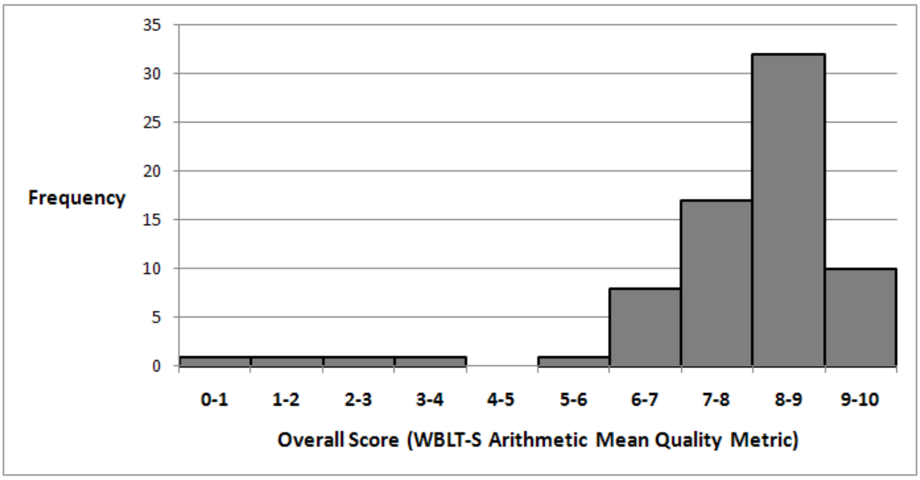

Figure 4.10: Histogram of WBLT-S scores obtained by ViSH Editor Learning Objects

4.4.2.3 Effectiveness Evaluation in a Classroom Environment

A study was conducted in a public secondary school in order to evaluate the effectiveness in terms of learner engagement and academic performance of the Learning Objects created with the ViSH Editor authoring tool.

A total of 38 twelfth grade students participated in the study, 16 males and 22 females, 17 to 18 years of age (M=17.2, SD=0.6). Students took a teaching unit about Internet and computer networks in a 12th grade subject called “Information and Communication Technologies”. The teaching unit was completed in five two-hour lessons (10 hours in total), which were conducted in a computer lab with Internet connection. In each lesson, students used one Learning Object created with ViSH Editor. Therefore, five Learning Objects were used in total. Students accessed the Learning Objects directly on the ViSH web portal. The teacher was present, encouraged students to pursue the learning activities and provided clarification when it was necessary, but students learned the content exclusively from the Learning Objects created with the ViSH Editor authoring tool.

After each lesson, the Learning Object used in that lesson was evaluated by the students through WBLT-S and by the teacher through WBLT-T [9], [281]. WBLT-T is a scale similar to WBLT-S but intended to be used by teachers to allow them to evaluate the effectiveness of the Learning Objects they employed in their lectures (see section 2.6 for further details). In this study, the students and the teacher rated each criterion using a 7-point Likert scale. Therefore, the 5 Learning Objects used in the teaching unit were evaluated by the 38 students generating 190 WBLT-S evaluations, and by the teacher generating 5 WBLT-T evaluations. The score of each criterion was calculated by averaging the scores given to the five Learning Objects used in the lessons. Overall scores were calculated on a 0-10 scale using the “WBLT-S Arithmetic Mean” and the “WBLT-T Arithmetic Mean” metrics described in chapter 5 of this thesis. Tables 4.7 and 4.8 show, respectively, the results of the students’ evaluations and of the teacher’s evaluations. The standard deviations included in these tables show the variation among scores of the five evaluated Learning Objects.

Finally, after completing the five lessons, students took an exam on paper about the concepts presented in the teaching unit. Students' exam grades recorded a mean of 9.2 out of 10 with a standard deviation of 0.9 (M=9.2, SD=0.9). The minimum grade was 6.0, so all students passed. Further details on this learning experience are included in chapter 9 of this thesis.

The results of this study show that both students and the teacher were very satisfied with the Learning Objects created through ViSH Editor that were used in the teaching unit. Learning Objects were perceived as easy to use and useful for teaching and learning. Besides, Learning Objects were able to engage and motivate the students. Therefore, it is not surprising that students reported that they would like to use similar Learning Objects in more occasions.

The learning outcomes achieved by the students were outstanding showing that the Learning Objects created with ViSH Editor can be very effective in terms of learner performance. It can be concluded, therefore, that ViSH Editor allows teachers to create effective Learning Objects in terms of learner engagement and academic performance.

Table 4.7: Students' Scores of the Learning Objects used in the Teaching Unit based on WBLT-S (N=5)

	M	**SD**
Overall score (WBLT-S Arithmetic Mean quality metric) 0 – 10	8.1	0.4
WBLT-S criteria 1 – 7		
1. The learning object was well organized	5.8	0.2
2. The learning object was easy to use	6.0	0.3
3. The instructions in the learning object were easy to follow	5.9	0.3
4. The help features of the learning object were useful	6.0	0.2
5. Working with the learning object helped me learn	5.9	0.3
6. The feedback from the learning object helped me learn	5.9	0.2
7. The graphics and animations form the learning object helped me learn	5.9	0.3
8. The learning object helped teach me a new concept	5.9	0.2
9. Overall, the learning object helped me learn	6.0	0.3
10. I like the overall theme of the learning object	5.8	0.3
11. I found the learning object to be engaging	5.9	0.3
12. The learning object made learning fun	5.8	0.3
13. I would like to use learning objects like this again	5.9	0.3

Table 4.8: Teacher's Scores of the Learning Objects used in the Teaching Unit based on WBLT-T (N=5)

	M	**SD**
Overall score (WBLT-T Arithmetic Mean quality metric) 0 – 10	9.5	0.3
WBLT-T criteria 1 – 7		
1. The learning object was easy for me to use	7.0	0.0
2. The learning object was easy for students to use	6.6	0.5
3. The students found the learning object instructions clear	6.8	0.4
4. The graphics and animations from the learning object helped students learn	7.0	0.0
5. The learning object enhanced student learning	7.0	0.0
6. The learning object helped clarify the concept(s) being taught	6.8	0.4
7. Overall, it was beneficial to me the learning object for teaching	6.8	0.4
8. The students were on task or focused when the learning object was being used	6.8	0.4
9. The students liked the interactive quality of the learning object	6.4	0.5
10. The students appeared to like the learning object	6.2	0.4
11. Overall, the students were engaged when the learning object was being used	6.2	0.4

4.4.3 Reusability Evaluation of the Created Learning Objects

4.4.3.1 Quality Evaluation from a Reusability Perspective

The ViSH reviewers team who evaluate the Learning Objects published on the platform using the LORI instrument [273] rate their accessibility, reusability and standards compliance. Accessibility takes into account if Learning Objects can be accessed from portable devices, reusability (as defined in LORI) assess the ability of Learning Objects to be used in varying learning contexts and with learners from differing backgrounds, and standards compliance assess the adherence of Learning Objects to e-Learning standards and specifications. Thus, the evaluation of these three criteria provides a measure of the capacity of the Learning Objects to be reused in different e-Learning systems and educational environments. Table 4.2 shows the results of the LORI evaluations. Reviewers rated Learning Objects positively in terms of "accessibility" (M=3.4, SD=0.7), "reusability" (M=3.2, SD=0.9) and "standards compliance" (M=4.5, SD=0.4). The high score obtained by the standards compliance criterion is because all Learning Objects created with the tool can be exported to SCORM 1.2 and SCORM 2004, and are described with IEEE LOM compliant metadata. In summary, these results indicate that ViSH Editor allows creating Learning Objects with suitable characteristics to facilitate their reuse in different contexts and e-Learning systems.

4.4.3.2 Metadata Evaluation

The evaluation of metadata is important in order to assess reusability because the more complete the metadata of a Learning Object are, the higher is its capacity to be found and reused [25].

The ViSH platform automatically calculates an overall metadata quality score on a 0-10 scale for all Learning Objects created with ViSH Editor and published on the platform. These calculations are performed through the LOEP system, which calculates the overall metadata quality scores by averaging the scores yielded by five metrics that measure metadata quality according to the following criteria: completeness, conformance, consistency, coherence and findability. Table 4.9 includes a brief description of each criterion. The scores for all these criteria are provided on a 0-10 scale. The metadata quality metrics that LOEP uses to calculate these scores were defined based on the metrics proposed by Ochoa [26]. All of them are fully explained in chapter 5 of this thesis, which describes the LOEP system in detail.

This evaluation reports metadata quality scores calculated in the ViSH platform for a total of 1,486 Learning Objects created with ViSH Editor. The averages of these metadata quality scores are presented in Table 4.9, and Figure 4.11 shows their histogram.

Results show that authors tagged most of the Learning Objects using ViSH Editor with good metadata (M=6.3, SD=1.3) in terms of completeness, conformance, consistency, coherence and findability. Histogram of metadata quality scores shows that metadata of around 82% of the Learning Objects recorded scores higher than 5 out of 10. The "completeness" score (M=7.1, SD=1.3) indicates that, in general, metadata contain enough information to have a comprehensive description of the Learning Objects. The “conformance” score (M=6.5, SD=1.1) points out that metadata are considerably useful for users in order to find, identify and select Learning Objects. The score obtained for the “consistency” criterion (M=10.0, SD=0.0) proves that metadata generated by ViSH Editor fully adhere to the IEEE LOM standard. For the criteria “coherence” and “findability”, average scores below 5 out of 10 were obtained together with high standard deviations. This is because authors did not tag some Learning Objects with important metadata such as their descriptions and keywords, and therefore the obtained coherence and findability scores for those resources were zero. Learning Objects tagged with these metadata fields recorded significantly better “coherence” (M=7.1, SD=2.7) and “findability” (M=6.3, SD=3.5) scores. In conclusion, the results of this evaluation show that ViSH Editor allows creating Learning Objects with appropriate metadata.

Table 4.9: Metadata Quality Scores of ViSH Editor Learning Objects (N=1,486)

	M	**SD**
Overall metadata quality score 0 – 10	6.3	1.3
Metadata quality scores 0 – 10		
1. Completeness: degree to which the metadata instance contains all the information needed to have a comprehensive representation of the described Learning Object.	7.1	1.3
2. Conformance: degree to which the metadata instance fulfils the requirements of a given community of users for a given set of tasks: find, identify, and select Learning Objects.	6.5	1.1
3. Consistency: degree to which the metadata instance matches the IEEE LOM metadata standard definition.	10	0.0
4. Coherence: degree to which all the fields of the metadata instance describe the same Learning Object in a similar way.	4.8	4.0
5. Findability: ease with which the metadata instance can be found.	3.2	3.9

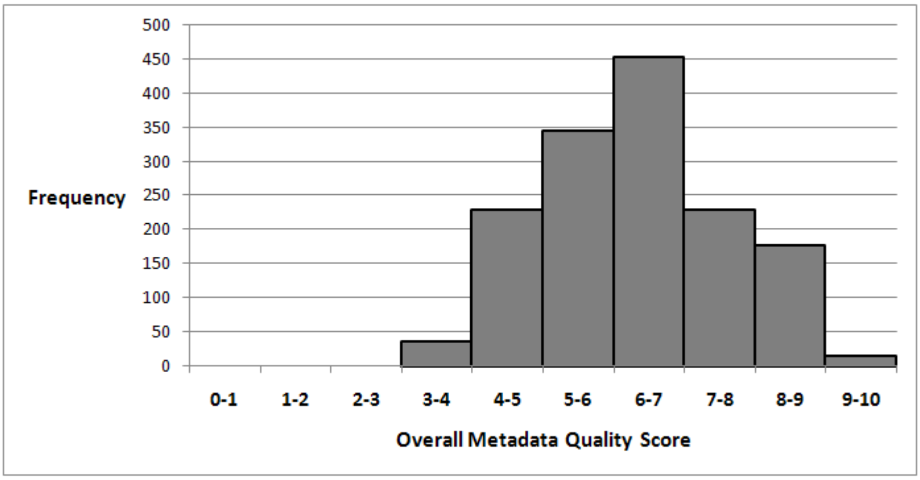

Figure 4.11: Histogram of metadata quality scores obtained by ViSH Editor Learning Objects

4.4.3.3 Quantitative Analysis of Reuse in ViSH

In order to provide empirical evidence of the reuse of the Learning Objects created ViSH Editor, a quantitative analysis of reuse was conducted in the ViSH platform. The data for this analysis were obtained from the ViSH database and correspond to 30 June 2016. Results are shown in Table 4.10. The number of visits and the number of downloads are provided since April 2012, and the number of learning hours delivered is provided since August 2014, date in which the tracking system of the ViSH platform started to operate. This later number represents the number of hours that users have spent interacting with the Learning Objects created with ViSH Editor on the ViSH platform or on other VLEs. Only learner sessions with significant interactions from users are taken into account for measuring delivered learning hours. Ratios of two different types of reuse were calculated. On the one hand, the percentage of Learning Objects reused to create new ones was calculated as the percentage of ViSH Editor Learning Objects hosted on ViSH that had been reused to create or enrich other ViSH Editor Learning Objects. On the other hand, the percentage of Learning Objects reused in collections was calculated as the percentage of ViSH Editor Learning Objects hosted on ViSH that had been saved by at least one user into a collection.

As of 30 June 2016, 1,358 Learning Objects created by ViSH users through ViSH Editor are published on the ViSH platform. The ViSH Editor Learning Objects hosted on ViSH have delivered around 65,000 hours of learning since August 2014 (around 95 hours per day, see chapter 3 for further details), have received more than 1 million of visits, and have been downloaded around 145,000 times. The percentage of Learning Objects reused to create new ones was 12.0%. This result is quite similar to the 11.5% obtained in the quantitative analysis of reuse conducted by Ochoa [26] in ARIADNE. The results reported in this section also show that around one of every three Learning Objects was reused in collections. This ratio of reuse is notably higher than those obtained by previous research [26], [27], in which ratios of reuse of around 23% and 19% were found respectively in the repositories Connexions and LRE. Taking into account all this empirical evidence, the results obtained in the LORI evaluations where the accessibility, reusability and standards compliance of the Learning Objects were assessed, and the metadata quality scores calculated, it can be stated that ViSH Editor is capable of creating Learning Objects with a high reusability that can be easily shared and distributed.

Table 4.10: Results of the Quantitative Analysis of Reuse conducted in ViSH

Number of ViSH Editor Learning Objects published	1,358
Number of learning hours delivered by ViSH Editor Learning Objects	64,984
Number of visits received by ViSH Editor Learning Objects	1,133,206
Number of downloads of ViSH Editor Learning Objects	145,365
Percentage of ViSH Editor Learning Objects reused to create new Learning Objects	12.0%
Percentage of ViSH Editor Learning Objects reused in collections	33.5%

4.5 Conclusions

This chapter presents ViSH Editor, an easy to use open source web-based authoring tool to create effective and reusable Learning Objects. The architecture, the Learning Object model and the main features of ViSH Editor are described. The chapter also presents a complete evaluation of the tool addressing three key factors: the user acceptance and usability of the ViSH Editor authoring tool, the quality and learning effectiveness of the Learning Objects created with such a tool, and the reusability of these Learning Objects.

User acceptance was evaluated with an online survey among 180 users. The results of this survey revealed a high user acceptance of the tool. Authors perceived ViSH Editor as easy to use, were very satisfied with the usefulness of the Learning Objects created with it, and felt that its features were suitable. Usability was evaluated through a lab test with 12 participants. The results of this usability evaluation were very positive and indicated that ViSH Editor is easy and pleasant to use, that authors without any prior training can use it to carry out the main tasks, and that little time and effort is needed for becoming proficient with it. The quality evaluation was conducted by using the LORI evaluation model. Results showed that the tool is able to allow authors to create Learning Objects with high quality, as well as to enhance the quality of existing e-Learning resources. The learning effectiveness was evaluated in two environments: in a Learning Object Repository (the ViSH platform described in chapter 3 of this thesis), and in a secondary school. Data for the evaluation were collected through learner surveys using the WBLT-S evaluation model. In the case of the secondary school, more data were collected through teacher surveys using the WBLT-T evaluation model and a test given to the students. The results of the evaluation of the learning effectiveness proved that ViSH Editor is able to allow authors to create effective Learning Objects in terms of learner engagement and academic performance. Finally, the reusability of the Learning Objects created with ViSH Editor was evaluated by using the LORI instrument, by measuring the quality of the metadata of the Learning Objects using a set of metrics, and by conducting a quantitative analysis of reuse. The results of this reusability evaluation showed that ViSH Editor is an authoring tool capable of creating Learning Objects described with appropriate metadata and with a high reusability that can be easily shared and distributed.

Based on the results of the evaluation presented in this chapter, it can be concluded that ViSH Editor is an authoring tool capable of allowing educators to create effective and reusable Learning Objects easily. Besides, the tool is distributed under an open source license, which is a requirement that some researchers have indicated that a Learning Object authoring tool should meet [255]. Therefore, in answer to the research question of the thesis addressed in this chapter, it can be concluded that educators can create effective and reusable Learning Objects easily if they are provided with suitable authoring tools. Nevertheless, it is worth pointing out that there is no authoring tool that can guarantee that the educational resources created with it have a suitable quality and learning effectiveness, although these tools can help authors to make this happen. Regarding the characteristics that should be taken into account in the implementation of these tools, this work suggests that Learning Object authoring tools should be easy to use even for users with little computer skills, should be able to create Learning Objects effective in terms of learner engagement and academic performance, and should be able to create these Learning Objects in such a way that they can be easily reused in different e-Learning systems and educational environments. In this chapter, various features of the ViSH Editor authoring tool that were found useful for the purpose of creating effective and reusable Learning Objects are described. All of them should be at least considered in the implementation of Learning Object authoring tools.

Firstly, Learning Object authoring tools should provide a user friendly interface that allows any user to easily and quickly create Learning Objects. Of crucial importance for these tools is also to provide features to integrate and combine different types of content and resources including text, images, audios, videos, websites, SCORM packages, IMS content packages, and other types of packaged Learning Objects. Besides, Learning Object authoring tools should also provide features to create and integrate questions and other assessment resources, as well as to create novel e-Learning resources. The results of the evaluation presented in this chapter show that authors notably appreciate the features for creating novel Learning Objects such as Flashcards, Virtual Tours and Enriched Videos. Moreover, features to enrich existing e-Learning resources are also advisable. An example of these features described in this chapter is the conversion of PDF slideshows into enriched web-based Interactive Presentations. Lastly, in order to create Learning Objects with high reusability, authoring tools should allow exporting the created resources to e-Learning standards such as SCORM to enable their integration into VLEs and other e-Learning systems. In this regard, Learning Object authoring tools should also allow authors to describe the Learning Objects with appropriate metadata and represent these metadata using metadata standards such as IEEE LOM. Open licensing is other key feature that these tools should support in order to enable the creation of Learning Objects that can be effectively reused. Moreover, the capacity of the authoring tools to create granular Learning Objects according to an open and documented Learning Object model is also beneficial for the reusability of the created Learning Objects. Finally, it is also very important for a Learning Object authoring tool to be distributed under an open source license to allow its customization and improvement.

In summary, this chapter makes two contributions. The first contribution is the ViSH Editor open source authoring tool, which has proven to be able to allow educators to create effective and reusable Learning Objects easily. This tool fully supports the authoring stage of the Learning Object life cycle. Besides, it also supports the reuse and maintenance stage because it allows updating the authored Learning Objects and reusing them to create other new ones. Educators can use the ViSH Editor authoring tool to create their own Learning Objects from scratch, as well as to modify other Learning Objects created with the tool available under certain open licenses in Learning Object Repositories such as the ViSH platform. Thus, ViSH Editor can help to overcome two major barriers to the use and adoption of Learning Objects: the limited availability of suitable Learning Objects, and the need to customize these Learning Objects to adapt them to specific contexts. The second contribution is the evaluation of the ViSH Editor tool, which has provided evidence that educators can create effective and reusable Learning Objects easily if they are provided with suitable authoring tools. Besides, several characteristics that should be considered in the implementation of such tools have been identified. Therefore, the results presented in this chapter can drive future development of better Learning Object authoring tools. Although there are some works in the literature that have described and evaluated open source Learning Object authoring tools [232]–[240], [255], [257], none of them have conducted an evaluation addressing all the aspects evaluated in this chapter. Therefore, this work can also be useful for developers and other researchers interested in evaluating Learning Object authoring tools. Besides, the evaluation of a Learning Object authoring tool in the context of a Learning Object Repository in which users freely create and share open Learning Objects also constitutes a novel contribution.

Chapter 5

A Web-based Platform to Provide Learning Object Evaluation

There is strong evidence that Learning Object Repositories (LORs) need to systematically evaluate and measure the quality of their Learning Objects in order to implement effective quality control mechanisms and enhance their features to discover Learning Objects. However, although several Learning Object evaluation models have been proposed, there is a lack of tools that can be effectively used by LORs to face this need. This chapter presents results of the design, implementation and evaluation of LOEP, an open source platform designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. The evaluation of LOEP included a quantitative analysis of an instance used by two LORs, user surveys, and three experiments in which several evaluation models and quality metrics were tested. Results show that LOEP is an effective system to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems, and that the quality scores provided by LOEP can be effectively used to sort Learning Objects by quality, to filter low quality Learning Objects, and to generate better Learning Object recommendations.

5.1 Introduction

Nowadays, there is a huge and rapidly increasing amount of Learning Objects available for learners and educators on the Web through Learning Object Repositories (LORs). This fact has created a critical need for LORs to systematically evaluate and measure the quality of the Learning Objects they host and distribute in order to establish quality control mechanisms. The lack of effective quality control mechanisms in LORs is one of the main barriers that hinder the uptake and usage of Learning Objects, especially for OER (Open Educational Resources) [258].

Firstly, teachers need some assurance of quality before making Learning Objects part of the curriculum. A recent survey showed that teachers identified the lack of quality control as a problem when using educational resources made by others, and that they agreed that features to evaluate these resources could be helpful [53]. This need for quality assurance becomes even more important for students in learner-centred or self-directed educational settings where they are expected to select their own learning resources, due to the risk of them being misinformed by inaccurate content, or of wasting time with poor instructional designs [284].

Secondly, LORs need some mechanism to evaluate and measure the quality of the Learning Objects submitted by their users in order to guarantee a minimum quality level of the published Learning Objects that they distribute.

Thirdly, LORs need to include quality indicators in the ranking metrics that they use in their search services in order to save users' time when searching for Learning Objects. In this regard, [43] found that teachers can take over an hour to find an appropriate Learning Object, and that several of them can note this process of searching Learning Objects to be time consuming and occasionally frustrating. The use of quality indicators can also be beneficial for other LORs' features in addition to search services. Quality indicators can be used to enhance any feature of a LOR that allow end users to discover Learning Objects like a catalogue, a browser, or a recommender system. A typical case is to use quality scores to filter low quality Learning Objects. Examples of how quality scores of Learning Objects can be used in the search service, the catalogue and other features of a LOR can be found in chapter 3 of this thesis, which presents the ViSH e-Learning platform. Moreover, chapter 7 describes a Learning Object recommender system that uses quality scores to enhance its recommendations.

Lastly, LORs also need to validate the metadata of the Learning Objects as well as to evaluate and measure the quality of these metadata. For LORs, metadata are very important because they make it easier to found and retrieve the available Learning Objects. The need for validating Learning Object metadata was evidenced by [217], who analyzed more than 600,000 IEEE LOM [119] metadata instances provided by 7 different LORs and found that more than 30% of them presented errors. The quality of the metadata also matters. For instance, [25] found that the more complete the metadata of a Learning Object are, the higher is its capacity to be found and reused. Thus, LORs should also evaluate and measure the quality of the metadata of the Learning Objects that they distribute.

In conclusion, there is strong evidence that LORs need to systematically evaluate and measure the quality of Learning Objects in order to implement effective quality control mechanisms and enhance their features for searching and discovering Learning Objects. As a consequence of this need, a plethora of evaluation models have been proposed to evaluate the quality of Learning Objects such as LORI [273], WBLT-S and WBLT-T [9], [281], COdA [263], HEODAR [264], [265], LOAM [266], LOEI [267], LOEM [268] and MECOA [274]. Besides, some LORs such as MERLOT [275], [276] and LRE [133] have defined their own evaluation models. The variety of environments in which Learning Objects can be created, distributed, integrated and used, as well as the multiple criteria that can be evaluated, suggest that no single evaluation model is sufficient. This is the main reason why so many different models to evaluate Learning Objects have been developed. All these Learning Object evaluation models can be characterized by several properties including: intended audience (e.g. end users, reviewers, learners, teachers or software systems), evaluation criteria (pedagogical, usability, reusability and metadata), type of evaluation (qualitative and/or quantitative), metrics (i.e. if the model defines quality metrics to calculate overall quality scores for the evaluated Learning Objects), type of output (e.g. a review, a score or a vocabulary value), and context (e.g. a specific country or educational setting). A comprehensive review on Learning Object evaluation, including descriptions of the most relevant Learning Object evaluation models and quality metrics, is included in section 2.6 of this thesis.

In order to implement quality control mechanisms, many LORs such as the aforementioned MERLOT and LRE have implemented their own evaluation systems. Evidence of this trend can be found in a survey of 59 well-known LORs [48], which identified 27 LORs that followed some quality control policy, and 23 LORs that had some resource evaluation/rating or review policy. However, the current trend for LORs that want to implement a quality control mechanism is to develop their own evaluation models and evaluation tools, which has three main shortcomings. First off, it is costly. Secondly, it fosters the creation of unnecessary Learning Object evaluation models, which might be unreliable or have not been effectively tested. In most cases, LORs can use existing Learning Object evaluation models appropriate for their scenario. Lastly, if Learning Objects are evaluated in a LOR according to custom models, the evaluation data cannot be easily used outside that LOR, and cannot be used to compare these Learning Objects with other ones from other LORs. In order to produce interoperable quality evaluations, LORs need to use common and open evaluation models and quality metrics. The work presented in this chapter aims to break this trend of reinventing the wheel each time a system to evaluate Learning Objects is developed, or at least to provide an alternative way of providing Learning Object evaluation to e-Learning systems.

Some software tools have been developed to evaluate the quality of Learning Objects. Examples of these tools can be found for different evaluation models including tools that have implemented LORI [283], [293], HEODAR [264], MECOA [274] and LOAM [294], [295]. However, these tools only support one Learning Object evaluation model and, as was mentioned above, the variety of environments in which Learning Objects can be consumed requires using several evaluation models. For example, one model may be more suitable for peer review processes carried out by appointed reviewers and the staff of a LOR, while other model may be more suitable for evaluating Learning Objects in a classroom environment from the learners' or the teacher's perspective. Besides, the evaluation of different criteria requires using different models. For instance, LORs can use an evaluation model to automatically calculate the metadata quality of Learning Objects by employing a software system. This can bring several benefits for LORs, especially given that human reviewers have difficulties to evaluate metadata quality appropriately, and that there are some characteristics that they are unable to evaluate [26]. Furthermore, new evaluation models can be designed and used to determine the quality of the Learning Objects available in a LOR based on data about the implicit interactions of the end users (e.g. time spent on the Learning Objects). These Learning Object evaluation models with high scalability might be very useful for OER repositories, which seek sustainable solutions capable of providing quality assurance for large quantities of resources [39].

Other major limitation of the current tools to evaluate the quality of Learning Objects is that they cannot be effectively integrated into LORs in such a way that the quality evaluations can be used in these LORs. Typically, Learning Object evaluation tools are tied to a specific LOR or are developed as standalone applications without LOR connection features. Another limitation of these tools is that the context in which Learning Objects are used is usually not taken into account, and this should be considered because the context can significantly influence the acceptance and instructional effectiveness of Learning Objects [31]–[33], [36], [291] (see section 2.3.4 for details). Lastly, other desirable features that these tools might offer are management of reviewers and evaluation assignments, generation of statistics about quality evaluations and scores, and integration of the results of the quality evaluations in the metadata of the evaluated Learning Objects.

This chapter presents the results of the design, implementation and evaluation of an open source web-based platform to provide systematic evaluation of Learning Objects to e-Learning systems. The name of this platform is LOEP, which stands for Learning Object Evaluation Platform. LOEP is the first system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. This characteristic of LOEP makes it suitable to be used in many different scenarios, contexts and e-Learning systems. Besides, LOEP resolves the limitations of existing tools for evaluating Learning Objects described in the above paragraphs. As part of the evaluation, a quantitative analysis of a LOEP instance used by two LORs was conducted. Moreover, this chapter presents the results of an evaluation of the user acceptance and usability of LOEP, as well as the results of three experiments that tested some Learning Object evaluation models and quality metrics supported by the platform. These results provide insights into the benefits for LORs of using Learning Object evaluation, a topic on which not much research has been done.

The organization of this chapter is as follows. Next section shows the objectives and research questions of this thesis covered in the chapter. Section 5.3 describes LOEP in detail: section 5.3.1 provides an overview of the system, section 5.3.2 details the Learning Object evaluation models and quality metrics supported by it, section 5.3.3 describes the main features offered, and section 5.3.4 illustrates some scenarios of use. The results of the evaluation of LOEP are presented in section 5.4. Lastly, section 5.5 draws the conclusions of the chapter.

5.2 Objectives

Two objectives of the thesis are addressed in this chapter:

- *Design, implement and evaluate a system that provides systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems and that supports multiple evaluation models and quality metrics.*

- *Propose and evaluate new quality metrics for Learning Objects. This goal includes the conception, proposal and evaluation of a predictive metric to estimate the quality of Learning Objects based on the interactions that learners have with them.*

With regard to the first objective, the next section shows the results of the design and implementation of the LOEP platform, and the section after that reports the results of its evaluation. Regarding the second objective, section 5.3.2 includes definitions of new quality metrics for Learning Objects, and section 5.4.4 reports the results of the evaluation of some of these metrics. The process followed to define the predictive metric is fully described in the next chapter of this thesis, which also presents the results of an evaluation of the metric.

This chapter also covers the following two research questions of the thesis:

- *How can the quality of Learning Objects be evaluated, measured and transformed into quality scores that can be understood by humans and automatically processed by information systems? Can these quality scores be used to filter low quality Learning Objects and to enhance search services as well as recommender systems?*
- *Which features should have a system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems?*

The first research question is answered based on the results of the evaluation of Learning Object models and quality metrics reported in section 5.4.4. To answer the second research question, this chapter enumerates and describes the different features that had to be implemented in the LOEP platform to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems.

5.3 Description of LOEP

5.3.1 Overview

LOEP is an open source web-based platform that provides systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. LOEP aims to be flexible, extensible and customizable. Flexible in the sense that it can be used in different scenarios, educational contexts and systems, extensible in the sense that it can be easily extended with new Learning Object evaluation models and quality metrics, and customizable in the sense that it can be easily modified to add new features. The source code of LOEP is publicly available at http://github.com/agordillo/LOEP under an open source license. Besides, a wiki is available at http://github.com/agordillo/LOEP/wiki with documentation on LOEP. This documentation contains installation and configuration instructions, configuration guides, tutorials about how to add new Learning Object evaluation models and quality metrics, and API specifications. LOEP is open to contributions and feedback from the educational community in order to achieve a unified and robust solution for the evaluation of Learning Objects and the sharing of interoperable quality evaluations. An instance of LOEP is currently deployed at http://loep.upm.es. Figure 5.1 shows its frontpage. This instance is used by two LORs: ViSH [56] and EducaInternet [60], to provide systematic evaluation of Learning Objects and generation of quality scores. The access to this LOEP instance is restricted to administrators and appointed reviewers of ViSH and EducaInternet. Chapter 3 of this thesis provides a detailed description of the ViSH platform, including details about how and for what purposes are used in ViSH the LOEP instance. Furthermore, a description on EducaInternet can be found in chapter 9 of this thesis.

This chapter describes LOEP 1.1, which is the latest released version at the time of writing. A description of a previous version can be found at [387]. The schema of Figure 5.2 represents the main entities that make up LOEP. Next, each of these entities is explained:

Learning Object. Administrators and external applications such as LORs can register or add new Learning Objects to LOEP for these Learning Objects to be evaluated. In order to register a Learning Object on LOEP only two metadata are required: name and location (URL) of the Learning Object. Thereby, LOEP does not store the content of Learning Objects but it stores links to them. Future versions will also allow the option of storing Learning Objects by uploading files. In addition to name and location, more metadata can be provided for a Learning Object: the repository (or system) that hosts or distributes the Learning Object, description, keywords (in the form of tags), language, type of learning resource, technology or format, and types of resources included in the Learning Object. Besides, a link (i.e. a URL) to the metadata of the Learning Object can be provided in order to enable the evaluation of these metadata. Future versions will allow the option of providing Learning Object metadata by uploading files.

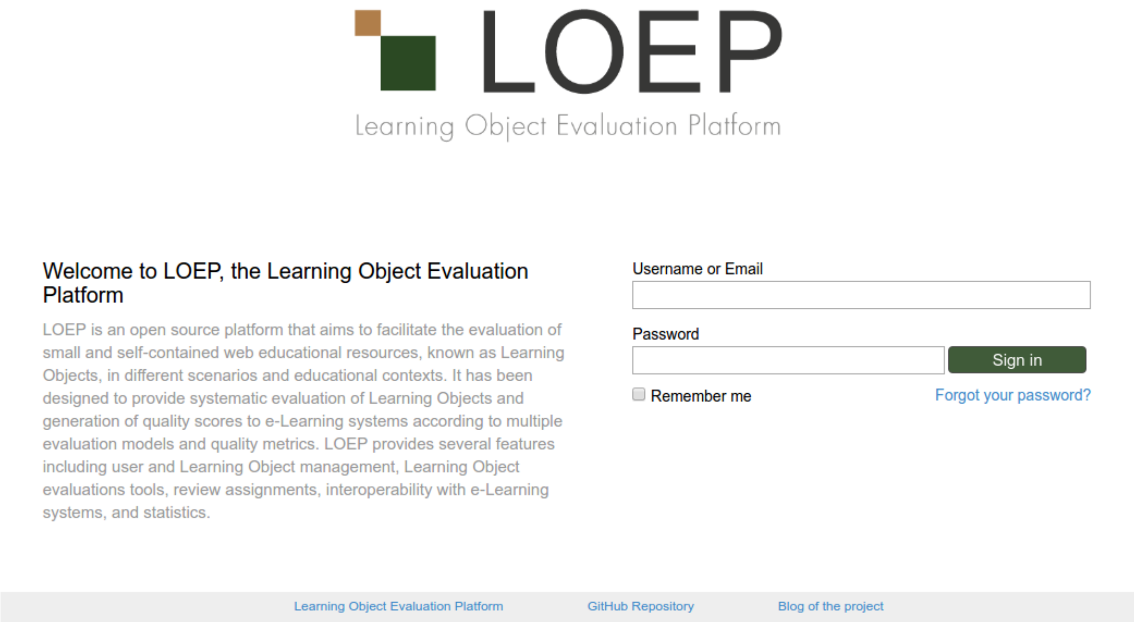

Figure 5.1: Frontpage of the LOEP platform

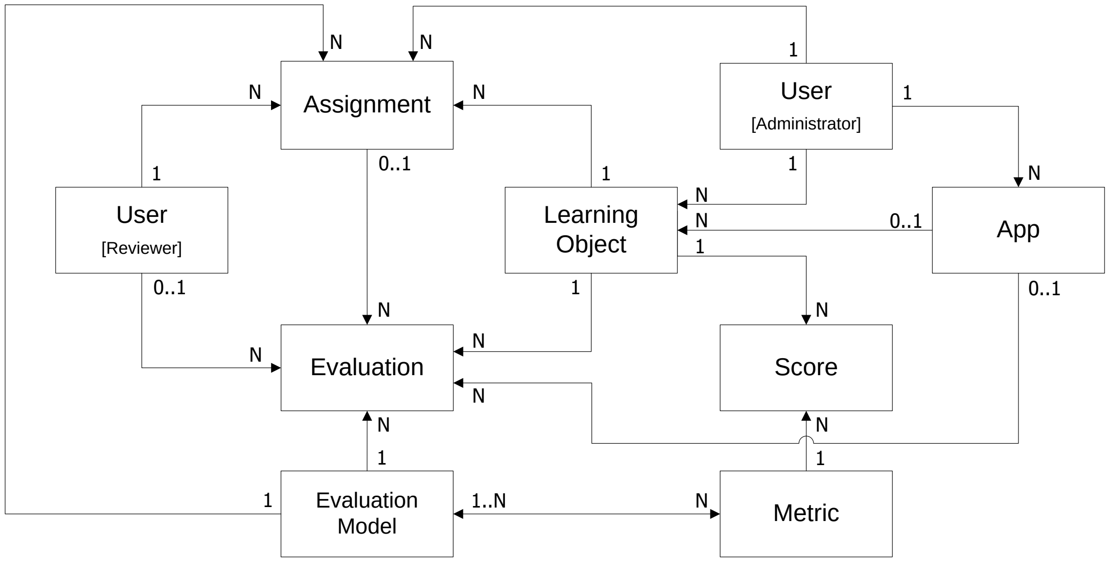

Figure 5.2: Main entities of LOEP

Moreover, LOEP also allows applications to provide learning analytics (obtained from user interactions) for the Learning Objects, enabling this way to evaluate these Learning Objects based on the interactions that users had with them. Learning Objects can be added according to three different scopes: public, protected and private. Public Learning Objects can be viewed and evaluated by any reviewer. Reviewers can view protected Learning Objects but they only can evaluate those for which they have assignments. Lastly, private Learning Objects can only be viewed and evaluated by reviewers that have been specifically assigned to do so.

Evaluation Model. These entities are the evaluation models that are available in LOEP to evaluate Learning Objects. Each evaluation model allows evaluating Learning Objects according to its criteria. Both qualitative and quantitative evaluations for the criteria are supported. The evaluation models can be classified as manual or automatic: manual evaluation models are those that require people to perform the evaluations, and automatic evaluation models are those that can be used without human intervention. An evaluation model enables to define quality metrics that make use of its evaluations.

Evaluation. An evaluation is always carried out according to an evaluation model and assesses one single Learning Object. An evaluation is performed by a software system (if the evaluation model is automatic) or by humans (if the evaluation model is manual). In the case of human evaluations, these can be conducted by reviewers, by end users of the applications registered on LOEP, or by external users. Reviewers can perform evaluations as a result of an assignment, or by reviewing public Learning Objects on their own initiative. So, an evaluation may or may not have an associated assignment. With regard to the evaluations from end users, LOEP supports anonymous evaluations as well as evaluations from authenticated users. Lastly, external users can evaluate certain Learning Objects by using evaluation links generated by the administrators.

Metric. Metrics allow to quantitatively measure the quality of Learning Objects according to certain criteria. The quantitative quality measurements calculated by the metrics are termed scores. Multiple metrics can be defined based on the same evaluation model, and multiple evaluation models can be used to define a single metric. Furthermore, it is possible to create compound metrics by combining other metrics. A metric is characterized by the evaluation models and criteria it takes into account, the mathematical process it uses to calculate the final quality score, and the scale in which this score is yielded.

Score. A score is a numerical rating of a Learning Object calculated according to a quality metric. A Learning Object can have as many different scores as there are metrics available in the platform. Given a certain Learning Object, it is possible to calculate a score if the Learning Object has been evaluated with all the evaluation models required by the metric that calculates that score. For instance, if a quality metric is defined as the average rating of all criteria of a certain evaluation model, it would be possible to calculate scores based on this metric for all Learning Objects evaluated with that model. A Learning Object is considered to have been evaluated with an evaluation model when each rateable criterion of the evaluation model has been rated in at least one evaluation.

User. LOEP provides user management handling three roles: administrators, reviewers and guests. Administrators can add Learning Objects, register applications, invite new users, appoint new reviewers, create assignments to request certain reviewers to evaluate certain Learning Objects, and generate links to enable external users to evaluate specific Learning Objects registered on LOEP. Reviewers have a list of assignments that indicates which Learning Objects they should evaluate and with which evaluation models. Moreover, reviewers may freely review public Learning Objects although they have not been assigned. Section 5.3.3 provides further details on features provided by LOEP for reviewers and administrators. Finally, guests are users with very limited permissions. They are allowed to access certain areas of the platform such as the documentation page, but they cannot perform evaluations or create or modify any other entity.

Assignment. An assignment requests a reviewer to evaluate one single Learning Object according to a certain evaluation model. When administrators create “complex assignments” that involve multiple reviewers, Learning Objects and/or evaluation models, these complex assignments are generated by creating several simple assignments. An assignment can be in three states: pending, completed or rejected. A completed assignment may have one single or many associated evaluations depending on its evaluation model. For example, evaluation models targeted to reviewers such as LORI only allow one evaluation per user and Learning Object, while other models targeted to different audiences such as WBLT-S allow multiple evaluations per assignment. This might be useful, for instance, to record in a single assignment all the evaluations of a certain Learning Object carried out by the students of a same class.

App. Administrators can register external applications such as LORs, LMSs, MOOC providers and any other type of e-Learning system. Registered applications can log in to LOEP with their own credentials (a name and an authentication token) and have the same permissions as the administrator who registered them. Thus, they can realize actions similar to those performed by human administrators including registering new Learning Objects, updating existing Learning Objects, and getting information from the LOEP database such as quality evaluations and scores. Besides, an API is provided in order to facilitate registered applications to integrate LOEP and use it to provide systematic evaluation of Learning Objects and generation of quality scores. Further details are included in section 5.3.3.

5.3.2 Learning Object Evaluation Models and Quality Metrics

The current version of LOEP supports all the Learning Object evaluation models listed in Table 5.1: LORI 1.5 [273], LOEM [268], WBLT-S and WBLT-T [9], [281], SUS [279], and two new evaluation models, one for automatically evaluating the quality of metadata compliant with the IEEE LOM [119] standard which uses a set of metrics that were defined based on the metadata quality metrics proposed in [26], and other one for estimating overall quality based on learners' interactions.

Table 5.1: Learning Object Evaluation Models supported by LOEP

Evaluation Model	Intended Audience	Criteria				Evaluation		Metrics	Output
		Pedagogical	Usability	Reusability	Metadata	Qualitative	Quantitative		
LORI 1.5 *	Reviewers	✓	✓	✓	✓	✓	✓	✓	Evaluation and Score
LOEM ***	Reviewers	✓	✓	✗	✗	✓	✓	✓	
WBLT-S ****	Learners	✓	✓	✗	✗	✓	✓	✓	
WBLT-T ****	Teachers	✓	✓	✗	✗	✓	✓	✓	
SUS **	All users	✗	✓	✗	✗	✓	✓	✓	
LOM Metadata Quality Evaluation Model	Software systems	✗	✗	✗	✓	✗	✓	✓	
Interaction Quality Evaluation Model	Software systems	Estimation of overall quality based on learners' interactions		✗	✗	✗	✓	✓	

* Extended with new quality metrics ** Extended with comments *** Extended with comments and quality metrics
**** Extended with contextual information and quality metrics

Some enhancements were made to the original evaluation models. A new field for general comments was included in those manual evaluation models that lack of qualitative evaluation (i.e. in LOEM and SUS). Furthermore, the WBLT-S and WBLT-T evaluation models were enriched with contextual information, including user demographic data (age and gender), usage scenario (e.g. classroom, online course, self-directed learning), grade and/or subject where the Learning Object was used, and purpose of using the Learning Object (e.g. introducing a topic, refreshing a topic, evaluating a topic). Finally, quality metrics were implemented for all Learning Object evaluation models. On the one hand, new quality metrics were defined for the

LORI evaluation model. On the other hand, quality metrics were defined for LOEM, WBLT-S and WBLT-T in order to calculate overall quality scores based on the evaluations performed according to these models. All the metrics provided by LOEP yield scores as decimal numbers on a 0-10 scale. It is worth mentioning that no modifications were made to the original criteria defined by the Learning Object evaluation models, and that the modifications were made only to extend the evaluation models with contextual information, general comments and/or quality metrics. In addition to these enhancements to the evaluation models, an optional field for proposing an overall score in a 0-10 scale for the evaluated Learning Objects was added to the web forms of the evaluation models targeted to reviewers (LORI and LOEM) and SUS.

Each of the seven Learning Object evaluation models supported by the current version of LOEP (and listed in Table 5.1) is described in the following sections. For each evaluation model, its criteria and quality metrics are described. Furthermore, it is worth pointing out that LOEP has been designed to be easy to extend with new evaluation models and metrics. Therefore, any interested party (e.g. LORs, institutions or researchers) can add, with little effort, new models and metrics to evaluate and measure the quality of Learning Objects. Future plans for the LOEP platform include implementing new evaluation models like UNE 71362 [261], [280], which is currently being developed as a standard for the quality evaluation of e-Learning resources (see section 2.6 for further details).

A LOEP instance does not have to offer all the Learning Object evaluation models and quality metrics supported by LOEP, it can offer just the ones it needs or wants. LOEP provides a YAML configuration file where several settings of a LOEP instance can be specified, including the Learning Object evaluation models and quality metrics that will be available. Thereby, a LOEP instance can be tailored to a specific scenario of use.

5.3.2.1 LORI 1.5

LORI (Learning Object Review Instrument) is likely the most widely used Learning Object evaluation model. The latest version is LORI 1.5 [273], which considers the nine criteria (also termed LORI items) listed in Table 5.2. For each criterion, reviewers can enter ratings on a 5-point scale ranging from 1 (low) to 5 (high). Reviewers can skip criteria that they are unable to assess or that they do not feel qualified enough to rate by selecting the “Not applicable” option instead of a numerical rating. This can also be done for criteria that are judged not relevant to the Learning Object. Lastly, reviewers can also provide general comments or remarks that they consider necessary or relevant for an evaluation.

LORI 1.5 defines an overall quality metric that consists of the average rating of all criteria. Besides providing this metric, LOEP provides new quality metrics based on LORI whose definition and evaluation are included in this chapter. The following sections show the definition of all these LORI metrics as implemented in LOEP.

Table 5.2: LORI 1.5 Criteria

LORI Item	Description
1. Content quality	Veracity, accuracy, balanced presentation of ideas, and appropriate level of detail
2. Learning goal alignment	Alignment among learning goals, activities, assessments, and learner characteristics
3. Feedback and adaptation	Adaptive content or feedback driven by differential learner input or learner modelling
4. Motivation	Ability to motivate and interest an identified population of learners
5. Presentation design	Design of visual and auditory information for enhanced learning and efficient mental processing
6. Interaction usability	Ease of navigation, predictability of the user interface, and quality of the interface help features
7. Accessibility	Design of controls and presentation formats to accommodate disabled and mobile learners
8. Reusability	Ability to use in varying learning contexts and with learners from differing backgrounds
9. Standards compliance	Adherence to international standards and specifications

5.3.2.1.1 LORI Arithmetic Mean (LORI AM) Metric

A rateable criterion is a criterion that can be quantitatively measured and for which a numerical rating can be given. Arithmetic mean metrics calculate the overall quality score of a Learning Object evaluated according to a certain evaluation model as the arithmetic mean of the scores of all rateable criteria of that evaluation model, considering all these criteria equally important. These metrics use the following general equation to calculate the overall quality score (Q) of a Learning Object on a 0-10 scale based on the scores $\{s_1, \ldots, s_N\}$ given to each of the N rateable criteria of a certain evaluation model:

$$Q(\{s_1, \ldots, s_N\}) = \frac{10}{N \times (S_{MAX} - S_{MIN})} \times \sum_{i=1}^{N} (\, s_i - S_{MIN}\,) \;, \qquad Q \,\in\, [0{,}10] \tag{5.1}$$

where s_i is the average score given to the i-th rateable criterion of the evaluation model, and $[S_{MIN}, S_{MAX}]$ is the numerical scale on which s_i is provided

LOEP uses this general equation to implement arithmetic mean metrics. Thereby, the definition of arithmetic mean metrics for new evaluation models is practically automatic.

The s_i variable is the average score given to the i-th rateable criterion of the evaluation model. For automatic evaluation models, since Learning Objects are evaluated only once, s_i is simply the score automatically calculated for the i-th rateable criterion in that evaluation. However, in manual evaluation models Learning Objects can be evaluated multiple times by different people. In these cases, in order to obtain the overall quality score for the evaluated Learning Object, s_i is calculated as the average of the numerical ratings given to the i-th rateable criterion in all the evaluations of that Learning Object conducted according to the evaluation model to which s_i belongs.

Given that the LORI evaluation model considers 9 rateable criteria that are evaluated on a 1-5 scale, the LORI AM (LORI Arithmetic Mean) quality metric is defined as follows by particularizing Equation 5.1 for N=9, S_{MIN}=1, and S_{MAX}=5:

$$Q(\{s_1, \dots, s_9\}) = \frac{5}{18} \times \sum_{i=1}^{9} (s_i - 1) \ , \qquad Q \in [0,10] \tag{5.2}$$

where s_i is the average score given to the i-th item of LORI

5.3.2.1.2 LORI Weighted Arithmetic Mean (LORI WAM) Metric

Weighted arithmetic mean metrics calculate the overall quality score of a Learning Object evaluated with a certain evaluation model as the weighted arithmetic mean of the scores of all rateable criteria of that evaluation model, giving different importance to each criterion. These metrics use the following general equation to calculate the overall quality score (Q) of a Learning Object on a 0-10 scale based on the scores $\{s_1, \dots, s_N\}$ given to each of the N rateable criteria of a certain evaluation model:

$$Q(\{s_1, \dots, s_N\}) = \frac{10}{(S_{MAX} - S_{MIN})} \times \sum_{i=1}^{N} W_i \times (s_i - S_{MIN}) \ , \qquad Q \in [0,10] \tag{5.3}$$

where s_i is the average score given to the i-th rateable criterion of the evaluation model,
$[S_{MIN}, S_{MAX}]$ is the numerical scale on which s_i is provided,
$W_i \geq 0$ is the weight of s_i, and
$\sum_{i=1}^{N} W_i = 1$

LOEP uses this general equation to implement weighted arithmetic mean metrics. This equation can be particularized for a certain evaluation model by giving values to N, S_{MIN} and S_{MAX}. The resulting equations can be then used to define different quality metrics for a same evaluation model by using different vectors of weights $\{W_1, \dots, W_N\}$. In fact, the Equation 5.1 used to define arithmetic mean metrics is a particular case of Equation 5.3 for $W_i = \frac{1}{N} \ \forall i \in \{1, \dots N\}$. Thereby, multiple weighted arithmetic mean metrics for evaluation models can be easily defined and provided just by specifying different vectors of weights.

The LORI WAM (LORI Weighted Arithmetic Mean) quality metric is defined as follows by particularizing Equation 5.3 for N=9, S_{MIN}=1, and S_{MAX}=5:

$$Q(\{s_1, \dots, s_9\}) = \frac{5}{2} \times \sum_{i=1}^{9} W_i \times (s_i - 1) \ , \qquad Q \in [0,10] \tag{5.4}$$

where s_i is the average score given to the i-th item of LORI,
$W_i \geq 0$ is the weight of s_i, and
$\sum_{i=1}^{9} W_i = 1$

Based on the general LORI WAM quality metric, LOEP provides two specific metrics which have been defined by using two different vectors of weights: the "LORI collected weights" shown in Table 5.3, and the "LORI inferred weights" shown in Table 5.4. The LORI WAM metric that uses the collected weights is referred to as "LORI WAM CW", and the LORI WAM metric that uses the inferred weights is referred to as "LORI WAM IW".

The collected and inferred weights were obtained from a study on the use of the LORI evaluation model. In this study, 15 reviewers evaluated 209 Learning Objects published on the ViSH platform with LORI 1.5 by using LOEP. Of the 15 reviewers, 9 were educators, 4 were e-Learning experts and 2 were designers. A total amount of 740 LORI evaluations were generated. Further details on this study are included in section 5.4.4.1 of this chapter as well as in [385].

The collected weights were obtained through a survey among the reviewers who participated in the study. Reviewers rated the importance that each of the LORI items had for them on a 0-10 scale, being 0 worthless and 10 extremely valuable. In order to obtain the final collected weights shown in Table 5.3, the ratings were averaged over all reviewers and then were normalized to sum to one.

Table 5.3: LORI Collected Weights

LORI Item	Weight
1. Content quality	$W_1 = 0.1724$
2. Learning goal alignment	$W_2 = 0.1207$
3. Feedback and adaptation	$W_3 = 0.1138$
4. Motivation	$W_4 = 0.1414$
5. Presentation design	$W_5 = 0.1379$
6. Interaction usability	$W_6 = 0.1034$
7. Accessibility	$W_7 = 0.0655$
8. Reusability	$W_8 = 0.0759$
9. Standards compliance	$W_9 = 0.0690$

The inferred weights were obtained by using a multiple linear regression analysis. In this study, reviewers had the option to propose an overall score on a 0-10 scale for the Learning Objects together with their LORI evaluations. A total of 241 (32.6%) out of 740 evaluations included a proposed overall score. The idea to calculate a set of weights for the LORI items was to conduct a multiple linear regression analysis using the proposed score as the dependent variable and the scores of all LORI items on a 0-4 scale as independent variables. Thereby, the coefficients that produce the best fit of the weighted arithmetic mean of the scores of all LORI items against the proposed score can be estimated and normalized to obtain a set of weights. However, the range of values obtained in this study for the "standards compliance" criterion was too narrow to calculate a reliable estimation of its weight by using this multiple linear regression analysis.

All Learning Objects evaluated with LORI in this study received ratings of 4 or 5 in the standards compliance criterion according to the LORI guidelines. This fact was because all Learning Objects had been created using the ViSH Editor authoring tool available on the ViSH platform, and hence all of these Learning Objects were compliant with SCORM [110], had been described with IEEE LOM compliant metadata (ViSH requires published Learning Objects to be tagged with at least some essential metadata), and their HTML5 code was W3C compliant. A detailed description and evaluation of ViSH Editor is included in chapter 4 of this thesis. The rest of LORI items received ratings between 1 and 5, covering the full range of possible scores. Therefore, given that it was not possible to reliably estimate the weight W_9, the value of 0.0690 obtained in the collected weights was used as a reference. Thereby, in order to calculate the weights for the LORI items 1 to 8, the multiple linear regression analysis was conducted approximating W_9 to a value of 0.0690. Table 5.4 shows the obtained “inferred weights” and the results of the regression analysis.

Table 5.4: LORI Inferred Weights

LORI Item	Coefficient	p-value	Weight
1. Content quality	0.3828	< 0.001	$W_1 = 0.1475$
2. Learning goal alignment	0.1724	0.006	$W_2 = 0.0665$
3. Feedback and adaptation	0.3588	< 0.001	$W_3 = 0.1383$
4. Motivation	0.6299	< 0.001	$W_4 = 0.2427$
5. Presentation design	0.0141	0.8	$W_5 = 0.0054$
6. Interaction usability	0.3436	< 0.001	$W_6 = 0.1324$
7. Accessibility	0.2334	< 0.001	$W_7 = 0.0899$
8. Reusability	0.2814	< 0.001	$W_8 = 0.1084$
9. Standards compliance	-	-	$W_9 = 0.0689$
Regression Statistics			
R^2		0.987	
p-value		< 0.001	

5.3.2.1.3 LORI Pedagogical WAM (LORI PWAM) Metric

LORI items can be divided in two subsets: a subset of items related to pedagogical criteria that covers items 1 to 6, and a subset of items related to technological criteria that includes the items 7, 8 and 9. This fact is explained in the evaluation of LORI reported in section 5.4.4.1, which also shows that technological items should be rated by reviewers with deep technical knowledge such as e-Learning experts.

The LORI PWAM (LORI Pedagogical WAM) quality metric only takes into account those LORI items related to pedagogical criteria (i.e. items 1 to 6). LORI PWAM is defined based on the LORI WAM metric defined through Equation 5.4, by using a new vector of weights where $W_i = 0 \ \forall i \in \{7,8,9\}$. These weights used for the LORI PWAM metric, which are shown in Table 5.5, were obtained by normalizing the “collected weights” W_1 to W_6 to sum to one.

5.3.2.1.4 LORI Technological WAM (LORI TWAM) Metric

The LORI TWAM (LORI Technological WAM) quality metric only considers those LORI items related to technological criteria (i.e. items 7, 8 and 9). LORI TWAM is defined based on the LORI WAM metric defined through Equation 5.4, by using a new vector of weights where $W_i = 0 \; \forall i \in \{1, \dots, 6\}$. These weights used for the LORI TWAM metric, which are shown in Table 5.5, were obtained by normalizing the "collected weights" W_7, W_8 and W_9 to sum to one.

Table 5.5: Weights for the LORI PWAM and LORI TWAM Metrics

LORI Item	**Weight**	
	LORI PWAM	**LORI TWAM**
1. Content quality	$W_1 = 0.2183$	$W_1 = 0$
2. Learning goal alignment	$W_2 = 0.1529$	$W_2 = 0$
3. Feedback and adaptation	$W_3 = 0.1441$	$W_3 = 0$
4. Motivation	$W_4 = 0.1791$	$W_4 = 0$
5. Presentation design	$W_5 = 0.1746$	$W_5 = 0$
6. Interaction usability	$W_6 = 0.1310$	$W_6 = 0$
7. Accessibility	$W_7 = 0$	$W_7 = 0.3113$
8. Reusability	$W_8 = 0$	$W_8 = 0.3607$
9. Standards compliance	$W_9 = 0$	$W_9 = 0.3280$

5.3.2.1.5 LORI Orthogonal Metric

Based on the LORI PWAM and LORI TWAM metrics, it is possible to build new quality metrics by establishing non-linear relationships between the overall score of a Learning Object and the scores given to the pedagogical and technological items.

The LORI Orthogonal metric is an example of one of these metrics. It represents the scores yielded by LORI PWAM and LORI TWAM as two orthogonal vectors in a two-dimensional coordinate system, and calculates the overall score of a Learning Object as the modulus of the vector sum of these vectors on a 0-10 scale. Its equation is as follows:

$$Q(\{s_1, \dots, s_9\}) = Q(S) = \frac{\sqrt{2}}{2} \times \sqrt{PWAM(S)^2 + TWAM(S)^2}, \qquad Q \in [0,10] \tag{5.5}$$

where s_i is the average score given to the i-th item of LORI,
$PWAM(S)$ is the score calculated according to the LORI PWAM metric, and
$TWAM(S)$ is the score calculated according to the LORI TWAM metric

5.3.2.1.6 LORI Logarithmic Metric

This metric defines a logarithmic relationship according to the following equation:

$$Q(\{s_1, \dots, s_9\}) = Q(S) = \frac{PWAM(S) \times ln(A \times TWAM(S) + 1)}{ln(10 \times A + 1)}, \qquad Q \in [0,10] \tag{5.6}$$

where s_i is the average score given to the i-th item of LORI,
$PWAM(S)$ is the score calculated according to the LORI PWAM metric,
$TWAM(S)$ is the score calculated according to the LORI TWAM metric, and
$A > 0$

The key idea of this metric relies on the fact that technology features of a Learning Object (e.g. accessibility or standards compliance) can gradually increase its overall quality, but only to the extent that it has a high pedagogical quality. This way, a resource with an extremely poor pedagogical quality (e.g. a SCORM package with a blank page) will be rated with 0 regardless of its metadata or supported standards. This metric also penalizes resources with extremely low scores in the technological criteria. This way, in the extreme case that a resource cannot be accessed by any common device and is not compliant with any standard, it will be also rated with 0 regardless its content. The first points in the technological scale are given more importance than the last ones. That makes sense since when a Learning Object achieve a minimum technical specifications, the added value of incorporating new features is decreased. The parameter A enables to adjust the metric and set the desired quality threshold. In the LORI Logarithmic metric provided by LOEP the parameter A has a value of 2.

5.3.2.1.7 LORI Square Root Metric

This metric defines a square root relationship according to the following equation:

$$Q(\{s_1, \dots, s_9\}) = Q(S) = \sqrt{PWAM(S) \times TWAM(S)}, \qquad Q \in [0,10] \tag{5.7}$$

where s_i is the average score given to the i-th item of LORI,
$PWAM(S)$ is the score calculated according to the LORI PWAM metric, and
$TWAM(S)$ is the score calculated according to the LORI TWAM metric

This metric is quite similar to the LORI Logarithmic metric, since it also penalizes Learning Objects with extremely low scores in technological or pedagogical items. In this case, there is no parameter to adjust the metric, but for the values PWAM(S)=5 and TWAM(S)=5, the yielded overall score is 5 (out of 10).

5.3.2.2 LOEM

LOEM (Learning Object Evaluation Metric) allows reviewers to evaluate Learning Objects according to four distinct constructs: interactivity, design, engagement and usability [268]. In total, LOEM considers the 17 criteria listed in Table 5.6. When evaluating a Learning Object using LOEM, reviewers rate each of these criteria on a 3-point scale by using a scoring rubric. Each item follows its own scoring scheme (see [388] for details). Furthermore, the version of LOEM implemented in LOEP allows reviewers to provide general comments or remarks that they consider necessary or relevant for an evaluation.

Table 5.6: LOEM Criteria

Construct	LOEM Item
A. Interactivity	1. Meaningful interactions
	2. Overall control
	3. Multimedia adds learning value
B. Design	1. Consistency
	2. Layout
	3. Labeling
	4. Readability (look of text)
C. Engagement	1. Quality of feedback
	2. Attractive
	3. Graphics
	4. Learning mode (amount of multimedia)
	5. Motivation
D. Usability	1. Natural to Use
	2. Orientation
	3. Navigation cues
	4. Instructions
	5. Appropriate language level

LOEP provides a metric termed LOEM AM (LOEM Arithmetic Mean) to calculate overall quality scores for Learning Objects evaluated with LOEM by averaging the scores given to all LOEM items. Given that the LOEM evaluation model considers 17 rateable criteria that are evaluated on a 1-3 scale, the LOEM AM quality metric is defined as follows by particularizing Equation 5.1 for N=17, S_{MIN}=1, and S_{MAX}=3:

$$Q(\{s_1, \dots, s_{17}\}) = \frac{5}{17} \times \sum_{i=1}^{17}(s_i - 1) \ , \qquad Q \ \in \ [0,10] \tag{5.8}$$

where s_i is the average score given to the i-th item of LOEM

5.3.2.3 WBLT-S

WBLT-S (WBLT Evaluation Scale for Students) is an evaluation model that allows assessing the effectiveness of Learning Objects from a learner's perspective [9], [281]. WBLT stands for Web-Based Learning Tool and is a term used as a synonym of Learning Object. WBLT-S is intended to be applied by learners that have used Learning Objects in order to evaluate them according to three constructs: design, learning and engagement. In total, WBLT-S considers 13 criteria. Table 5.7 shows these criteria as provided by the version of WBLT-S implemented in LOEP. In this version, learners rate each criterion on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). Learners can also add comments about what they like and do not like about the Learning Objects. Besides, LOEP allows learners to specify contextual information (e.g. demographic data, usage scenario and purpose of using the Learning Object).

Table 5.7: WBLT-S Criteria

Construct	WBLT-S Item
A. Design	1. The learning object was well organized
	2. The learning object was easy to use
	3. The instructions in the learning object were easy to follow
	4. The help features of the learning object were useful
B. Learning	1. Working with the learning object helped me learn
	2. The feedback from the learning object helped me learn
	3. The graphics and animations form the learning object helped me learn
	4. The learning object helped teach me a new concept
	5. Overall, the learning object helped me learn
C. Engagement	1. I like the overall theme of the learning object
	2. I found the learning object to be engaging
	3. The learning object made learning fun
	4. I would like to use learning objects like this again

LOEP provides a metric termed WBLT-S AM (WBLT-S Arithmetic Mean) to calculate overall quality scores for Learning Objects evaluated with WBLT-S by averaging the scores given to all WBLT-S items. Given that the version of WBLT-S provided by LOEP considers 13 rateable criteria that are evaluated on a 1-7 scale, the WBLT-S AM quality metric is defined as follows by particularizing Equation 5.1 for N=13, S_{MIN}=1, and S_{MAX}=7:

$$Q(\{s_1, \dots, s_{13}\}) = \frac{5}{39} \times \sum_{i=1}^{13}(s_i - 1) \ , \qquad Q \in [0,10] \tag{5.9}$$

where s_i is the average score given to the i-th item of WBLT-S

5.3.2.4 WBLT-T

WBLT-T (WBLT Evaluation Scale for Teachers) is an evaluation model that allows assessing the effectiveness of Learning Objects from a teacher's perspective [9], [281]. WBLT-T is intended to be used by teachers that have employed Learning Objects in their lectures in order to evaluate them according to three constructs: design, learning and engagement. In total, WBLT-T considers 11 criteria. Table 5.8 shows these criteria as provided by the version of WBLT-T implemented in LOEP. In this version, teachers rate each criterion on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). Teachers can also add comments about their teaching experience: they can describe what the overall impact of the Learning Object in their teaching was, report the problems related to technology that they encountered while using the Learning Object, and give advice to future teachers about using Learning Objects in their lessons. Besides, LOEP allows teachers to specify contextual information (e.g. demographic data, usage scenario and purpose of using the Learning Object).

Table 5.8: WBLT-T Criteria

Construct	WBLT-T Item
A. Design	1. The learning object was easy for me to use
	2. The learning object was easy for students to use
	3. The students found the learning object instructions clear
B. Learning	1. The graphics and animations from the learning object helped students learn
	2. The learning object enhanced student learning
	3. The learning object helped clarify the concept(s) being taught
	4. Overall, it was beneficial to me the learning object for teaching
C. Engagement	1. The students were on task or focused when the learning object was being used
	2. The students liked the interactive quality of the learning object
	3. The students appeared to like the learning object
	4. Overall, the students were engaged when the learning object was being used

LOEP provides a metric termed WBLT-T AM (WBLT-T Arithmetic Mean) to calculate overall quality scores for Learning Objects evaluated with WBLT-T by averaging the scores given to all WBLT-T items. Given that the version of WBLT-T provided by LOEP considers 11 rateable criteria that are evaluated on a 1-7 scale, the WBLT-T AM quality metric is defined as follows by particularizing Equation 5.1 for N=11, S_{MIN}=1, and S_{MAX}=7:

$$Q(\{s_1, \dots, s_{11}\}) = \frac{5}{33} \times \sum_{i=1}^{11}(s_i - 1) \ , \qquad Q \ \in \ [0{,}10] \tag{5.10}$$

where s_i is the average score given to the i-th item of WBLT-T

5.3.2.5 SUS

The System Usability Scale (SUS) is a simple and reliable 10-item Likert scale giving a global view of subjective evaluations of systems usability [279]. SUS can be used to evaluate and measure the usability of any tool or system. Therefore, although SUS was not specifically designed for Learning Objects, it can be used to evaluate and measure Learning Object usability. Table 5.9 shown below exposes the 10 items of SUS. In the version of SUS implemented in LOEP, the word “system” has been replaced by “learning object”.

Table 5.9: SUS Items

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

SUS is intended to be used by the users (reviewers, learners or teachers) after they have had an opportunity to use the Learning Object being evaluated, but before any discussion takes place. Each of the 10 items of SUS should be answered by users on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Half of the items are positively worded and half are negatively worded. The version of SUS implemented in LOEP also allows users to provide general comments on the usability of the Learning Object being evaluated.

SUS defines a metric to yield an overall score on a 0-100 scale representing a composite measure of the overall usability of the system being evaluated (the definition of this metric can be found in the appendix A of this thesis). This metric calculates an overall score for each evaluation (i.e. for each user). In order to calculate overall scores based on SUS evaluations, LOEP provides a very similar metric termed "Global SUS", which is defined as follows:

$$Q(\{s_1, \dots, s_{10}\}) = \frac{1}{4} \times \left(\sum_{i \in \{1,3,5,7,9\}} (s_i - 1) + \sum_{i \in \{2,4,6,8,10\}} (5 - s_i) \right), \quad Q \in [0,10] \tag{5.11}$$

where s_i is the average score of the i-th item of SUS

The Global SUS metric has two differences with respect to the original metric defined by SUS. The first difference is that the scale in which the overall score is yielded is 0-10 instead of 0-100. The second difference is that the s_i variable is defined as the average score given to the i-th item over all SUS evaluations. Thereby, the Global SUS metric allows calculating overall scores taking into account all the conducted evaluations.

5.3.2.6 LOM Metadata Quality Evaluation Model

This evaluation model allows to automatically evaluate and measure the quality of metadata instances compliant with the IEEE LOM (Learning Object Metadata) [119] standard. Thereby, LOEP can automatically evaluate and measure the quality of the metadata for those registered Learning Objects whose metadata are LOM compliant. In order to evaluate the metadata of a Learning Object, a URL to the LOM metadata instance in XML format of that Learning Object must be provided. The metadata evaluation will be carried out as soon as this URL is provided (right after the registration of the Learning Object on LOEP if the URL of the metadata instance is provided at registration time).

The LOM Metadata Quality evaluation model considers five items: completeness, conformance, consistency, coherence, and findability. Table 5.10 shows a brief description of them (see [26] for further details). The score of these items is automatically calculated on a 0-10 scale by using five metadata quality metrics, one for each item. These metrics were defined based on five of the standard-agnostic metadata quality metrics proposed by Ochoa [26], which were tailored to the IEEE LOM standard, modified to yield normalized scores (on a 0-10 scale), particularized with specific weight vectors, and concretized to be ready to use by applications in real-world scenarios without any extra effort.

Table 5.10: LOM Metadata Quality Evaluation Model Criteria

Item	Description
1. Completeness	Degree to which the metadata instance contains all the information needed to have a comprehensive representation of the described Learning Object.
2. Conformance	Degree to which the metadata instance fulfils the requirements of a given community of users for a given set of tasks: find, identify, and select Learning Objects.
3. Consistency	Degree to which the metadata instance matches the IEEE LOM metadata standard definition.
4. Coherence	Degree to which all the fields of the metadata instance describe the same Learning Object in a similar way.
5. Findability	Ease with which the metadata instance can be found.

LOEP also provides the "LOM Metadata Quality" metric that allows calculating the overall score of a Learning Object as the average of the scores obtained by the five items of the LOM Metadata Quality evaluation model. Next sections provide the descriptions and definitions of the metadata quality metrics used to calculate the scores of the items (completeness, conformance, consistency, coherence and findability), as well as the description and definition of the LOM Metadata Quality metric used to calculate the overall scores.

5.3.2.6.1 LOM Metadata Completeness Metric

This metric measures the degree to which a LOM metadata instance contains all the information needed to have a comprehensive representation of the described Learning Object. The IEEE LOM standard [119] defines a total of 45 different main metadata fields grouped into 9 categories. Each LOM metadata field may be a simple data element or an aggregate data element that contains other metadata fields. Besides, some metadata fields can be repeated. Further details on the IEEE LOM standard are included in section 2.2.2.1 of this thesis. In total, LOM defines 77 different metadata fields, of which 19 are aggregate data elements and 58 are simple data elements. Within this chapter, those metadata fields that are simple data elements are referred to as "simple metadata fields".

The LOM Metadata Completeness metric measures the completeness of a LOM metadata instance by counting the number of simple metadata fields that contain a non-null value. In the case of metadata fields that can be repeated, the field is considered complete if at least one contains a non-null value. In order to give more importance to some metadata fields to the detriment of others, a vector of weights is incorporated. Equation 5.12 shown below expresses how the completeness scores are calculated on a 0-10 scale according to this metric.

$$Q(\{m_1, \ldots, m_N\}) = 10 \times \left(\sum_{i=1}^{N} W_i \times P(m_i) \right), \quad Q \in [0,10]$$

where $N = 58$ is the total number of simple metadata fields defined by LOM,
m_i is the i-th simple metadata field of the LOM metadata instance, (5.12)
$P(m_i)$ is 1 if m_i has a non-null value and 0 otherwise,
$W_i \geq 0$ is the weight of m_i, and
$\sum_{i=1}^{N} W_i = 1$

Table 5.11 shows the weights $\{W_1, \ldots, W_N\}$ used in this metric. The values shown in the "Metadata Field" column correspond to the numbers of the simple metadata fields as defined in the specification of the IEEE LOM standard. These weights were obtained through a survey of four reviewers of the ViSH platform with extensive expertise evaluating Learning Objects with LORI 1.5 and with a high level of knowledge of the IEEE LOM standard. Before filling out the survey, its goals were clearly explained to the reviewers. After that, reviewers were asked to reflect individually on the importance of the different LOM metadata fields, taking into account the usefulness of each metadata field to search, identify, select, acquire, classify, and distribute Learning Objects.

Table 5.11: Weights for the LOM Metadata Completeness Metric

Metadata Field	**Weight**	**Metadata Field**	**Weight**	**Metadata Field**	**Weight**
1.1.1	0.018226	4.1	0.034022	6.1	0.044957
1.1.2	0.036452	4.2	0.017011	6.2	0.025516
1.2	0.060753	4.3	0.027947	6.3	0.023086
1.3	0.049819	4.4.1.1	0.013366		
1.4	0.042527	4.4.1.2	0.007290	7.1	0.009721
1.5	0.049818	4.4.1.3	0.000000	7.2.1.1	0.007290
1.6	0.009721	4.4.1.4	0.000000	7.2.1.2	0.012151
1.7	0.015796	4.5	0.002430	7.2.2	0.008505
1.8	0.014581	4.6	0.009721		
		4.7	0.012151	8.1	0.004860
2.1	0.008505			8.2	0.004860
2.2	0.020656	5.1	0.018226	8.3	0.013366
2.3.1	0.012151	5.2	0.037667		
2.3.2	0.021871	5.3	0.009721	9.1	0.000000
2.3.3	0.014581	5.4	0.006075	9.2.1	0.007290
		5.5	0.029162	9.2.2.1	0.006075
3.1.1	0.006075	5.6	0.031592	9.2.2.2	0.006075
3.1.2	0.006075	5.7	0.037667	9.3	0.000000
3.2.1	0.003645	5.8	0.034022	9.4	0.008505
3.2.2	0.002430	5.9	0.047388		
3.2.3	0.000000	5.10	0.019441		
3.3	0.014581	5.11	0.010936		
3.4	0.003645				

Then, reviewers discussed together about the importance of the different LOM metadata fields. After this discussion, reviewers filled out the survey, in which they had to rate the importance of each of the 58 simple metadata fields defined by LOM on a 0-10 scale, being 0 worthless and 10 extremely valuable. For aggregate elements, reviewers were asked to assign 0-10 points to the aggregate element and then distribute these points among the simple metadata fields contained in it. Lastly, in order to obtain the final weights, the ratings given to the simple metadata fields were averaged over the four reviewers and then were normalized to sum to one. Table 5.11 shows the weights obtained for the 58 simple metadata fields defined by LOM. The weights for those metadata fields that are aggregate elements can be obtained by summing the weights of the simple metadata fields that they contain.

5.3.2.6.2 LOM Metadata Conformance Metric

This metric measures the degree to which a LOM metadata instance fulfils the requirements of a given community of users for a given set of tasks: find, identify and select Learning Objects. It is based on the idea that the usefulness of a metadata instance to find, identify and select Learning Objects depends heavily on the amount of unique information contained in the instance. For instance, Learning Objects whose metadata have non-common words are easier to find, users can differentiate Learning Objects more easily if their metadata instances are not similar, and users can make better selections if the instances provide better descriptions of the Learning Objects. More information can be found in [26]. The metric described in this section measures the conformance to the expectation of a community of a LOM metadata instance by measuring the information contained in that instance. Equation 5.13 shown below expresses how conformance scores are calculated on a 0-10 scale according to this metric.

$$Q(\{m_1, \dots, m_N\}) = 10 \times \left(\sum_{m_i \in C} W_{m_i} \times Q_C(m_i) + \sum_{m_i \in T} W_{m_i} \times Q_T(m_i) \right), \quad Q \in [0,10]$$

where $N = 58$ is the total number of simple metadata fields defined by LOM,
m_i is the i-th simple metadata field of the LOM metadata instance,
C is a subset of categorical LOM metadata fields,
T is a subset of free text LOM metadata fields, (5.13)
$Q_C(m_i)$ and $Q_T(m_i)$ are 0 if m_i has a null value, and otherwise are calculated on a 0-1 scale according to Equations 5.14 and 5.15 respectively,
$W_{m_i} \geq 0$ is the weight of m_i, and
$\sum_{m_i \in C} W_{m_i} + \sum_{m_i \in T} W_{m_i} = 1$

This metric differentiates between categorical and free text LOM metadata fields. Categorical metadata fields are simple metadata fields that can only take a value from a defined and finite vocabulary (e.g. language). The rest of simple metadata fields are free text fields (e.g. title and description). These fields take values that consist of text strings of one or more words.

Table 5.12 shows the free text and categorical metadata fields used by the LOM Metadata Conformance metric provided by the current version of LOEP, as well as the weights of each of these metadata fields. The values shown in the "Number" column correspond to the numbers of the simple metadata fields as defined in the specification of the IEEE LOM standard. The metric considers four free text metadata fields (value of the identifier, title, description and keywords) and one categorical metadata field (language). The weights were determined by consensus by the same group of four reviewers that were surveyed to obtain the weights for the metric described in the previous section.

Table 5.12: Weights for the LOM Metadata Conformance Metric

Free Text Metadata Fields				**Categorical Metadata Fields**		
Number	**Name**	**Weight**	**Threshold**	**Number**	**Name**	**Weight**
1.1.2	Identifier Entry	0.20	1.5	1.3	Language	0.15
1.2	Title	0.25	3.25			
1.4	Description	0.20	5.5			
1.5	Keyword	0.20	4.25			

The information contained in a categorical field m_c of a LOM metadata instance that has a non-null value is calculated on a 0-1 scale according to the following equation:

$$Q_C(m_c) = \left(1 - \frac{log\left(N_{m_c} + 1\right)}{log(N + 1)}\right), \qquad Q_C \in [0,1]$$

where N_{m_c} is the number of times that the value of m_c is present in that categorical metadata field in the whole repository, and (5.14)

$N \geq N_{m_c}$ is the total number of LOM metadata instances in the repository for which m_c has a non-null value

The information contained in a free text field m_t of a LOM metadata instance that has a non-null value is calculated on a 0-1 scale according to the following equation:

$$Q_T(m_t) = \begin{cases} 0, & f(m_t) < 0 \\ f(m_t), & 0 \leq f(m_t) \leq 1 \\ 1, & f(m_t) > 1 \end{cases}, \qquad Q_T \in [0,1]$$

where

$$f(m_t) = \frac{log\left(\sum_{i=1}^{L_{m_t}} TF\text{–}IDF(word_i, m_t)\right)}{Max_{m_t}} \qquad (5.15)$$

where $L_{m_t} \geq 1$ is the length in words of the free text metadata field m_t,

$word_i$ is the i-th word of m_t,

$TF\text{–}IDF(word_i, m_t)$ is calculated according to Equation 5.16, and

$Max_{m_t} > 0$ is a threshold value for m_t

The calculation of the information contained in a free text metadata field is performed by using the TF-IDF (Term Frequency-Inverse Document Frequency) function [389]. According to this function, the importance of a word in a document is proportional to the number of times that word appears in the document and inversely proportional to how frequently documents in the corpus contain that word. In Equation 5.15, the TF-IDF values of the words are calculated according to the following equation:

$$TF\text{–}IDF(W,T) = TF(W,T) \times IDF(W)$$

where $TF(W,T)$ is the number of occurrences of the word W in the text T, and $IDF(W)$ is calculated according to Equation 5.17 shown below (5.16)

$$IDF(W) = log\left(\frac{2+N}{1+N_W}\right)$$

where N_W is the number of Learning Objects in the repository whose LOM metadata contain the word W, and $N \geq N_W$ is the total number of Learning Objects in the repository (5.17)

The Max_{m_t} parameter used in Equation 5.15 is a threshold value used to normalize the TF-IDF values. This normalization is necessary to provide the final conformance scores on a 0-10 scale. Each free text metadata field used by the LOM Metadata Conformance metric has its own threshold. Ideally, Max_{m_t} should be the maximum value that the numerator of the $f(m_t)$ function used in Equation 5.15 can obtain for the free text metadata field m_t of a metadata instance in the whole repository. The current version of LOEP provides fixed values for the thresholds of all free text metadata fields used in the LOM Metadata Conformance metric. Table 5.12 shows these threshold values, which were obtained by calculating the maximum values obtained by a metadata instance in a dataset of around 1,000 LOM metadata instances of the ViSH platform. Future versions of LOEP will allow to automatically calculate these thresholds for each repository.

The keyword metadata field can be repeated. In this case, the value of the field is formed by concatenating the text strings of all the keyword metadata fields. Thereby, metadata conformance is calculated taking into account all keywords of the Learning Objects.

LOEP provides scheduled tasks to automatically obtain and store all the information needed by the LOM Metadata Conformance metric to calculate conformance scores for a given repository. For each repository, LOEP calculates the frequencies of each categorical metadata field (parameter N_{m_c} of Equation 5.14), the total number of LOM metadata instances for which each categorical metadata field is provided (parameter N of Equation 5.14), the frequencies of each word (parameter N_W of Equation 5.17), and the total number of Learning Objects (parameter N of Equation 5.17). These pre-calculated values are stored in the database and updated periodically. Thereby, LOEP can perform the calculations fast enough to apply them to each metadata instance at creation or update time.

5.3.2.6.3 LOM Metadata Consistency Metric

This metric estimates the consistency of a LOM metadata instance by measuring the degree to which it matches the definition of the IEEE LOM standard. There are four main ways in which the consistency of a LOM metadata instance can be broken:

- The metadata instance includes fields not defined in LOM.
- The metadata instance does not include fields that the community sets as mandatory.
- The metadata instance includes categorical fields (i.e. simple metadata fields that should contain values from a defined and finite vocabulary) whose values do not belong to the LOM vocabulary.
- The metadata instance includes categorical fields whose combination of values is inconsistent or not recommended by the IEEE LOM standard.

The LOM Metadata Consistency metric uses a set of rules in order to detect errors, problems and inconsistencies in the metadata instances. Table 5.13 shows the five rules used in the current version of LOEP and their corresponding weights. Future versions may incorporate new rules. According to this metric, the consistency of a LOM metadata instance is proportional to the number of rules satisfied by that instance. The consistency scores are calculated on a 0-10 scale according to the next equation:

$$Q(M) = 10 \times \left(\sum_{i=1}^{N_R} W_i \times S(rule_i, M) \right), \quad Q \in [0,10]$$

where M is the set of metadata fields of the LOM metadata instance,

$N_R = 5$ is the number of defined rules,

$rule_i$ is the i-th rule, (5.18)

$S(rule_i, M)$ is 1 if the LOM metadata instance satisfies $rule_i$ and 0 otherwise,

$W_i \geq 0$ is the weight of $rule_i$, and

$\sum_{i=1}^{N_R} W_i = 1$

Table 5.13: Rules used by the LOM Metadata Consistency Metric

	Rule Description	Weight
1	All fields of the metadata instance are defined in the IEEE LOM standard.	0.25
2	The metadata instance includes the following mandatory fields: identifier and title.	0.25
3	All completed categorical fields of the metadata instance contain values that belong to the LOM vocabulary.	0.25
4	If both “Structure” and “Aggregation Level” fields of the metadata instance are completed, the “Structure” field should be set to “atomic” if the “Aggregation Level” field is set to “1” and vice versa, and the “Structure” field should be set to “collection”, “networked”, “hierarchical” or “linear” if the “Aggregation Level” field is set to “2”, “3” or “4” and vice versa. Otherwise, the rule is satisfied.	0.125
5	If both “Typical Age Range” and “Context” fields of the metadata instance are completed, the “Typical Age Range” field should be set to at least 17 years if the “Context” field is set to “higher education”. Otherwise, the rule is satisfied.	0.125

5.3.2.6.4 LOM Metadata Coherence Metric

The LOM Metadata Coherence metric measures the degree to which all the fields of a LOM metadata instance describe the same Learning Object in a similar way. This measurement is made by calculating the semantic similarity between different metadata fields that describe the Learning Object. Equation 5.19 shown below expresses how the LOM Metadata Coherence metric calculates the coherence scores on a 0-10 scale.

$$Q(\{m_1, \dots, m_N\}) = 10 \times \left(\frac{\sum_{i=1}^{N} \sum_{j=1}^{N} \begin{cases} Similarity(m_i, m_j), \ i < j \\ 0, \ otherwise \end{cases}}{\frac{N \times (N-1)}{2}} \right), \ Q \in [0,10] \quad (5.19)$$

where N is the total number of considered free text metadata fields of the LOM metadata instance that describe the Learning Object,

m_i and m_j are, respectively, the i-th and j-th of these free text metadata fields, and

$Similarity(m_i, m_j)$ is 0 if m_i or m_j has a null value, and otherwise is calculated on a 0-1 scale by using the cosine similarity metric and the TF-IDF function according to Equation 5.20 shown below

$$Similarity(T_x, T_y) = \begin{cases} 0, \ if\ T_x \text{ and } T_y \text{ do not have words in common} \\ \dfrac{\sum_{i=1}^{N} TF\text{–}IDF(word_i, T_x) \times TF\text{–}IDF(word_i, T_y)}{\sqrt{\sum_{i=1}^{N} TF\text{–}IDF(word_i, T_x)^2} \times \sqrt{\sum_{i=1}^{N} TF\text{–}IDF(word_i, T_y)^2}}, \ \text{otherwise} \end{cases} \quad (5.20)$$

where N is the number of different words in the shortest text string between T_x and T_y,

$word_i$ is the i-th of these words, and

$TF\text{–}IDF$ values are calculated according to Equation 5.16

An alternative way, also provided by LOEP, of calculating the semantic similarity between the two text strings in Equation 5.20 is using all the different words in the text strings T_x and T_y instead of the words in the shortest text string. Nevertheless, although this alternative can be better to estimate the similarity between the two text strings, the approach used by default by the LOM Metadata Coherence metric is more appropriate to estimate the coherence between them.

The current version of LOEP calculates the coherence score of the LOM metadata instances by using exclusively their title and description metadata fields. Thereby, the LOM metadata instances of the Learning Objects whose title and description have similar words will have high coherence scores. The maximum value of 10 is achieved when all the words from one metadata field appear in the other. On the contrary, the minimum value of 0 is achieved when the two fields (title and description) have no words in common, or when one of them has not been completed. Thus, in addition to lack of coherence of the LOM metadata instances, low coherence scores may indicate poor titles or descriptions.

5.3.2.6.5 LOM Metadata Findability Metric

This metric measures the ease with which a LOM metadata instance can be found, and hence the ease with which the Learning Object described by that metadata instance can be found. It considers LORs as networks of Learning Objects, where those Learning Objects whose metadata instances have more linkages are easier to find. The measurement of the findability of a metadata instance is made by counting its number of linkages based on its keywords. Two metadata instances are considered to be linked when they have at least one common keyword. The “keyword” LOM metadata field was chosen to establish the linking between metadata instances because keywords are one of the main fields used by Learning Object search services, catalogues and recommender systems, as well as by other features to discover Learning Objects. The IEEE LOM standard allows including several keywords in a metadata instance (i.e. the keyword LOM metadata field can be repeated), so different linkages pointing from one instance can be established based on multiple keywords. Besides, in order to perform the comparisons required to establish the linkages, using keywords is easier and more reliable than using other metadata fields such as title or description. Moreover, different information can be expressed in the form of keywords including tags, categories of a catalogue, collections, etc. Therefore, the metric can be effectively used in many scenarios (including the ViSH platform). The LOM Metadata Findability metric calculates the findability score of a LOM metadata instance on a 0-10 scale according to the following equation:

$$Q(\{m_K\}) = 10 \times MIN\left(\frac{linkages(m_K)}{MaxLinkages} , 1 \right), \quad Q \in [0,10]$$

where m_K are the keywords defined through the keyword LOM metadata fields, $linkages(m_K)$ is the number of linkages of the metadata instance based on m_K (i.e. the number of LOM metadata instances in the repository that have at least one keyword in common), and $MaxLinkages \geq 1$ is a threshold value calculated as the 70th percentile of the number of linkages of a LOM metadata instance in the whole repository (5.21)

LOEP provides scheduled tasks to automatically obtain and store all the information needed by the LOM Metadata Findability metric to calculate the findability scores for a given repository. For each repository, LOEP calculates the number of linkages of each metadata instance (i.e. of each Learning Object), as well as the threshold $MaxLinkages$ (which always must have a minimum value of one). All these pre-calculated values are stored in the database and updated periodically, allowing LOEP to speed up the calculations of findability scores.

At present, findability scores are based on the usefulness of the keywords of the Learning Objects to find other Learning Objects of the same repository. A drawback of this approach is that Learning Objects without keywords always obtain a findability score of zero. Future versions of LOEP might consider using new fields for establishing the linkages.

5.3.2.6.6 LOM Metadata Quality Metric

This metric allows to calculate overall metadata quality scores for those registered Learning Objects whose metadata are LOM compliant considering the five items of the LOM Metadata Quality evaluation model: completeness, conformance, consistency, coherence and findability. According to the LOM Metadata Quality metric, the overall metadata quality score of a Learning Object is calculated as follows:

$$Q(M) = \sum_{i=1}^{5} W_i \times Q_i(M_i), \quad Q \in [0,10]$$

where M is the set of metadata fields of the LOM metadata instance of the Learning Object,
M_i is a subset of M that contains the metadata fields required by the corresponding metric to calculate $Q_i(M_i)$,
$Q_1(\mathrm{M_i}), \ldots, Q_5(\mathrm{M_i})$, are, respectively, the scores of the LOM metadata instance on a 0-10 scale calculated according to the metrics LOM Metadata Completeness (Equation 5.12), Conformance (Equation 5.13), Consistency (Equation 5.18), Coherence (Equation 5.19) and Findability (Equation 5.21),
$W_i \geq 0$ is the weight of $Q_i(M_i)$, and
$\sum_{i=1}^{5} W_i = 1$ (5.22)

The default vector of weights $\{W_1, \ldots, W_5\}$ used by the LOM Metadata Quality metric is the one that satisfies that $W_i = 1/5 \ \forall i \in \{1, \ldots, 5\}$. Therefore, overall metadata quality scores are calculated by averaging the scores calculated using the metadata quality metrics described above for the five items of the LOM Metadata Quality evaluation model: completeness, conformance, consistency, coherence and findability.

The scores calculated for a Learning Object according to the LOM Metadata Conformance, Coherence and Findability metrics depend on the repository (or system) to which the Learning Object belongs. The values of the parameters used in these metrics that depend on the repository of the Learning Object are automatically calculated by LOEP using scheduled tasks that are executed periodically. For those Learning Objects for which a repository has not been specified, scores are calculated by considering that these Learning Objects belong to a repository that contains all the Learning Objects registered on LOEP. Thereby, LOEP allows to calculate metadata quality scores for Learning Objects even if they do not belong to a repository.

5.3.2.7 Interaction Quality Evaluation Model

This evaluation model is based on learning analytics and allows to estimate the quality of Learning Objects based on the interactions that learners have with them. In order to generate an overall quality score for a Learning Object through this model, a set of learning analytics obtained from the interactions of the users with the Learning Object must be provided.

Table 5.14 includes a description of the three learning analytics required by the current version of the Interaction Quality evaluation model: time spent, permanency rate, and number of mouse clicks. The applications registered on LOEP can provide these learning analytics for their Learning Objects in an automatic way by using an API offered by LOEP (further details are provided in section 5.3.3.3). LOEP does not provide support to capture the interactions of the learners with the Learning Objects or to process the interaction data into learning analytics. These actions should be performed by the external applications registered on LOEP that want to automatically measure the quality of their Learning Objects according to the Interaction Quality evaluation model.

Table 5.14: Interaction Quality Evaluation Model Criteria

Item	Description
1. Time spent	Average time spent on the Learning Object per learner session, in seconds.
2. Permanency rate	Percentage of users that did not abandon the Learning Object in the first 30 seconds.
3. Number of mouse clicks	Average number of mouse clicks per learner session.

The metric used by this model to calculate the overall quality scores of Learning Objects based on the interactions that learners have with them is termed "Interaction Quality" and is defined as follows:

$$Q(t_s, p_r, n_c) = 10 \times \left(W_{t_s} \times s_{t_s}(t_s) + W_{p_r} \times s_{p_r}(p_r) + W_{f_c} \times s_{f_c}(n_c, t_s)\right), \quad Q \in [0,10]$$

where

$$s_{t_s}(t_s) = MIN\left(\frac{t_s}{Max_{t_s}}\ ,\ 1\right)$$

$$s_{p_r}(p_r) = MIN\left(\frac{p_r}{Max_{p_r}}\ ,\ 1\right)$$

$$s_{f_c}(n_c, t_s) = MIN\left(\frac{\left(\frac{n_c}{t_s/60}\right)}{Max_{f_c}}\ ,\ 1\right) \tag{5.23}$$

and where t_s, p_r, and n_c are, respectively, the learning analytics time spent, permanency rate, and number of mouse clicks as defined in Table 5.14,

$fc = \frac{n_c}{t_s/60}$ is the average frequency of mouse clicks per learner session expressed in clicks per minute,

$Max_{t_s} > 0$, $Max_{p_r} > 0$, and $Max_{f_c} > 0$ are, respectively, threshold values for t_s, p_r, and f_c,

$W_{t_s} \geq 0, W_{p_r} \geq 0$, and $W_{f_c} \geq 0$ are, respectively, the weights of t_s, p_r, and f_c, and

$$W_{t_s} + W_{p_r} + W_{f_c} = 1$$

The weights W_{t_s}, W_{p_r} and W_{f_c} and the default threshold values Max_{t_s}, Max_{p_r} and Max_{f_c} used by this metric are shown in Table 5.15. In addition to default threshold values, LOEP provides a scheduled task to automatically calculate specific threshold values for each repository. This task calculates, respectively, the threshold values Max_{t_s}, Max_{p_r} and Max_{f_c} as the 80th percentile of the t_s, p_r and f_c variables in the whole repository. Given that this task can be executed periodically, it is possible to use dynamic thresholds that are refreshed on a regular schedule.

The weights and default threshold values shown in Table 5.15 were calculated by using a dataset of around 150,000 sessions of learner interactions with 256 Learning Objects of the ViSH platform. On the one hand, the default threshold values were calculated by using the aforementioned task over this dataset. On the other hand, the weights were obtained through a multiple linear regression analysis by using the quality score of the Learning Objects calculated according to the LORI WAM CW metric as the dependent variable, and the scores $s_{t_s}(t_s)$, $s_{p_r}(p_r)$ and $s_{f_c}(n_c, t_s)$ as independent variables. The results of this regression analysis, as well as a detailed explanation and an evaluation of the Interaction Quality metric, are presented in the next chapter of this thesis.

Table 5.15: Weights and Default Threshold Values for the Interaction Quality Metric

Variable		Weight	Default Threshold Value
t_s	Time spent (in seconds)	$W_{t_s} = 0.303$	$Max_{t_s} = 524$
p_r	Permanency rate (%)	$W_{p_r} = 0.435$	$Max_{p_r} = 73$
f_c	Frequency of mouse clicks (in clicks/minute)	$W_{f_c} = 0.262$	$Max_{f_c} = 6$

5.3.2.8 New Evaluation Models and Quality Metrics

LOEP has been designed to be easy to extend with new Learning Object evaluation models and quality metrics. Tutorials about how to add new models and metrics are provided on the LOEP wiki available at http://github.com/agordillo/LOEP/wiki. For new evaluation models, LOEP can provide web forms generated automatically as well as graphs of results. Custom web forms and graphs can also be implemented. Furthermore, new metrics can be defined based on one or multiple evaluation models. The implementation of the generic metrics (defined according to Equations 5.1 and 5.3) used to implement the specific arithmetic mean and weighted arithmetic mean metrics can be easily reused to implement new metrics in LOEP. This can be very useful for implementing arithmetic mean and weighted arithmetic mean quality metrics for new evaluation models. All the metrics provided by LOEP can be reused, customized and adapted. Besides, compound metrics can be created by combining other metrics. As an example of this feature, LOEP provides a metric termed “LORIEM” that calculates the overall quality score of a Learning Object as the average between the scores calculated for that Learning Object according to the metrics LORI AM and LOEM AM. Therefore, in order to calculate quality scores according to this metric, Learning Objects need to be evaluated with the LORI and LOEM evaluation models. The LORIEM metric is defined as follows:

$$Q(S_{LORI}, S_{LOEM}) = \frac{Q_{LORI\ AM}(S_{LORI}) + Q_{LOEM\ AM}(S_{LOEM})}{2}, \quad Q \in [0,10] \tag{5.24}$$

where S_{LORI} and S_{LOEM} are, respectively, the set of average scores given to the 9 LORI items and the 17 LOEM items, and $Q_{LORI\ AM}(S_{LORI})$ and $Q_{LOEM\ AM}(S_{LOEM})$ are, respectively, the scores calculated according to the LORI AM and the LOEM AM metrics

This is just an example that illustrates what kind of metrics can be easily defined in LOEP by reusing the provided metrics. Many other different metrics can be defined by LORs. For instance, a LOR may use a metric to calculate quality scores based on peer reviews, learner evaluations and teacher evaluations by using the LORI, WBLT-S and WBLT-T AM metrics. If a LOR wants to give more importance to the quality of the metadata of the Learning Objects, it could define a new metric that calculates quality scores by combining the scores yielded by some LORI metric with those yielded by metadata quality metrics. Given that the Interaction Quality metric can be used to estimate the quality of Learning Objects based on the interactions that learners have with them, a LOR may use a metric that provides the score calculated according to some manual evaluation model for those Learning Objects that have been evaluated with that model, and the score estimated by the Interaction Quality metric for those Learning Objects that have not been evaluated yet.

5.3.3 Features

5.3.3.1 Features for Reviewers

After reviewers log in to LOEP, they are greeted with a homepage that contains a list of assignments. This list of assignments indicates the Learning Objects for which a reviewer has been designated as evaluator and the evaluation models according to which the evaluations of the Learning Objects should be performed. Assignments may also specify a deadline for the completion of the evaluations. If a reviewer cannot or does not feel qualified enough to evaluate an assigned Learning Object with the indicated evaluation model, such a reviewer can reject the assignment. Administrators are notified of the assignments' rejections, so they have the choice of reassigning these Learning Objects to other reviewers. Besides evaluating assigned Learning Objects, reviewers can browse the public Learning Objects registered in LOEP and evaluate any of them using any available manual evaluation model although they have not been specifically assigned to do so. Figure 5.3 shows a screenshot of LOEP when a reviewer is evaluating a Learning Object with LORI. A link to the Learning Object to be evaluated is included in the evaluation web forms in order to facilitate reviewers to access such a Learning Object.

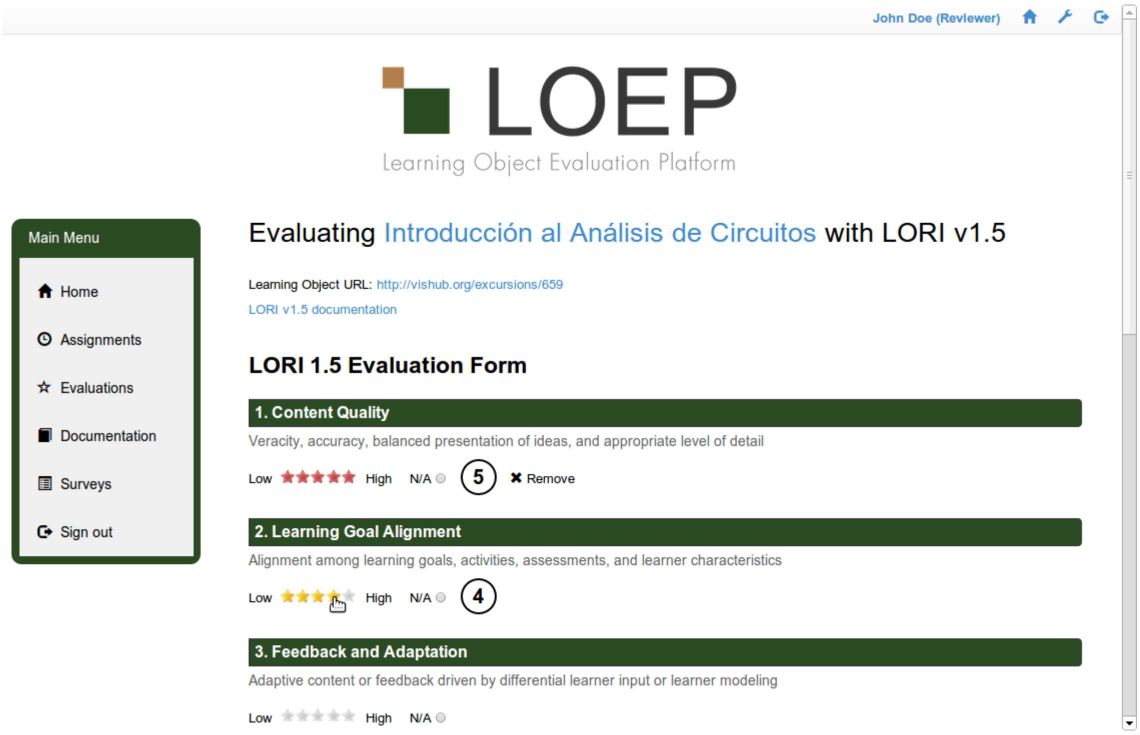

Figure 5.3: Evaluation of a Learning Object with LORI on the LOEP platform

Reviewers can view all the evaluations they have performed. However, they only can edit evaluations of open assignments (i.e. assignments whose deadlines have not yet expired) and those that they have performed on their own initiative. Thereby, the evaluations performed by reviewers as a consequence of assignments will remain unchanged after the deadlines of such assignments expire.

Reviewers have a profile page in which they can specify various information such as demographic data, field of expertise (teaching, educational technology or other), preferred language, known languages, and areas of interest and expertise. These data can be used to estimate the suitability of the reviewers to evaluate the different Learning Objects. Thereby, administrators can automatically assign the most suitable reviewers for a certain Learning Object and vice versa. Further details are included in next section.

Lastly, LOEP also provides documentation pages that can be used to provide reviewers with training materials, rubrics, printable scoring sheets and any other documents that might be useful for them. For instance, LOEP provides a documentation page for the LORI evaluation model that allows users to download the official LORI user manual and a printable version of the LORI evaluation form.

5.3.3.2 Features for Administrators

A wide range of features are available for administrators in a LOEP instance. On LOEP, there is a special type of administrator termed “super administrator”. Super administrators are administrators with additional privileges that mainly enable them to appoint new administrators (by granting the role to existing users or by inviting new people) and dismiss existing administrators. In general, the features for administrators described in this section are available both for regular and for super administrators.

Figure 5.4 shows the homepage of LOEP for administrators. This page shows the most recent activity of the platform, including the last updated assignments and evaluations, and the last registered Learning Objects.

A LOEP instance may be configured according to three different registration policies: “only register” (users can freely register, invitations are disabled), “only invitation” (users need to be invited to register), and “hybrid” (users can freely register but they can also be invited). If users can freely register, the role that these users will have by default in the platform should also be specified in the configuration. If invitations are enabled, administrators can invite new users to join to a LOEP instance as guests or reviewers. They also have the power to appoint new reviewers by granting the role to existing users and to cancel accounts of regular users (i.e. guests and reviewers). Super administrators can also invite, appoint and dismiss administrators.

Administrators can add new Learning Objects and register new applications in a LOEP instance, as well as to manage and edit the existing Learning Objects and applications. Section 5.3.3.3 describes the features provided by LOEP for registered applications. Super administrators can also edit and delete existing evaluations. More features that LOEP provides to administrators are described in the following sections.

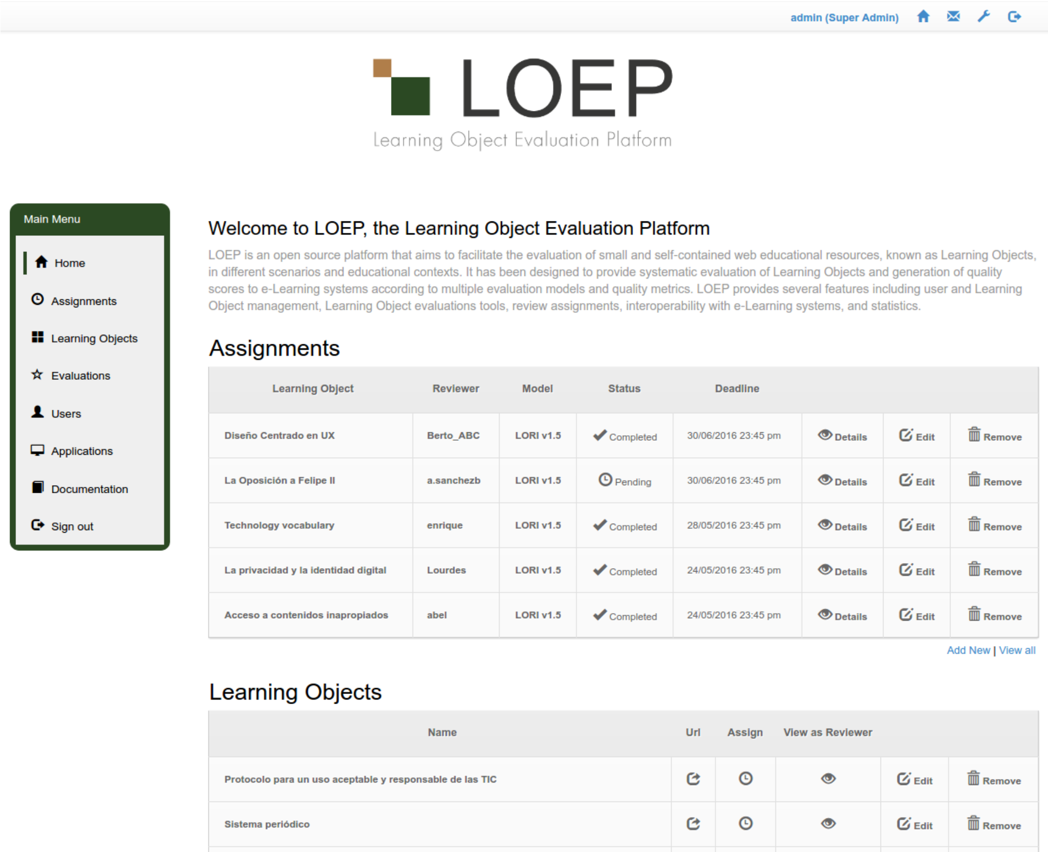

Figure 5.4: Homepage of an administrator on the LOEP platform

5.3.3.2.1 Assignments

On LOEP, administrators can create assignments to request reviewers to evaluate Learning Objects according to certain evaluation models in two ways: manually and automatically using different matching algorithms. In both cases, administrators have to select the Learning Objects to be evaluated, the reviewers who will be asked to carry out the evaluations, and the evaluation models according to which the evaluations of the Learning Objects should be performed. Optionally, administrators can write a description and specify a deadline for the assignments. In the manual procedure, administrators have to indicate manually which reviewers will evaluate each Learning Object. For each combination of reviewers and Learning Objects, administrators should fill and submit a different web form. In the automatic procedure, administrators have to specify the desired number of evaluations per Learning Object, and the strategy to match the Learning Objects with the reviewers in order to automatically distribute the assignments. Only one web form is required to be filled and submitted. At present, LOEP supports the following three matching strategies:

- *Prioritize workload balancing with random matching.* This strategy ensures that all reviewers will have to evaluate almost the same quantity of Learning Objects. At most, a reviewer will have to evaluate one more Learning Object that the others. When using this basic strategy, the matching is done randomly.
- *Prioritize workload balancing with best-effort matching.* Same as the above strategy, but now the matching is done using a best-effort approach. Each Learning Object assigned to a reviewer is selected based on its suitability for that reviewer. This suitability is automatically calculated based on the user profile of the reviewer and the metadata of the Learning Object according to Equation 5.25. When using this best-effort strategy, several rounds are carried out to distribute all the Learning Objects among the reviewers. In each round, each reviewer is matched with the most suitable Learning Object among the available ones.
- *Prioritize reviewer suitability.* In this strategy, instead of looking for the most suitable Learning Objects for each reviewer, the most suitable reviewers are assigned to each Learning Object. Unlike the above strategies, this one does not distribute the workload equally.

The suitability score of a matching between a Learning Object LO and a reviewer U is calculated on a 0-100 scale according to the following metric:

$$S_{LO-U}(LO,U) = W_L \times s_L(LO,U) + W_K \times s_K(LO,U) \;, \quad S_{LO-U} \in [0,100] \tag{5.25}$$

where $s_L(LO,U)$ is the language suitability score calculated according to Equation 5.26, $s_K(LO,U)$ is the keywords suitability score calculated according to Equation 5.27, and $W_L = 0.8$ and $W_K = 0.2$ are, respectively, the weights of $s_L(LO,U)$ and $s_K(LO,U)$

$$s_L(LO,U) = \begin{cases} 100, & if\ LO\ is\ in\ the\ preferred\ language\ of\ U \\ 90, & if\ LO\ is\ in\ a\ language\ known\ by\ U \\ 0, & otherwise \end{cases}, \quad s_L \in [0,100] \tag{5.26}$$

$$s_K(LO,U) = \begin{cases} 0, & N_{LO_k} + N_{U_k} = 0 \\ 100 \times \left(\frac{2 \times N_{C_k}}{N_{LO_k} + N_{U_k}}\right), & N_{LO_k} + N_{U_k} > 0 \end{cases}, \quad s_K \in [0,100] \tag{5.27}$$

where N_{LO_k} and N_{U_k} are, respectively, the number of keywords of LO and U, and N_{C_k} is the number of common keywords between LO and U

For Learning Objects, the language and keywords are obtained from their metadata. For reviewers, these data are obtained from their user profiles. The keywords of the reviewers used to calculate suitability scores are those that they provide as areas of interest and expertise.

5.3.3.2.2 External Evaluations

In addition to assignments to request reviewers registered on LOEP to evaluate Learning Objects, administrators can create links to allow external users to evaluate Learning Objects without registering on LOEP. Besides the Learning Object to be evaluated, several settings can be specified for these links: if the link is going to be active indefinitely or for a limited time period (in this case the number of hours for which the link will remain active can also be defined), if the link can be used to submit one or multiple evaluations of the Learning Object, and the evaluation model according to which the evaluation (or evaluations) of the Learning Object will be performed. Each generated link leads to a page that shows the evaluation web form corresponding to the evaluation model and Learning Object specified for that link. This page can be embedded in external websites and shared through its link. Each link is associated with a unique session token that determines the specific actions that can be performed through it. Thereby, a link generated to evaluate a certain Learning Object with a specific evaluation model cannot be used to evaluate other Learning Objects or to evaluate the same Learning Object with other evaluation models. Furthermore, if the settings of the link specify that it can be used only once, the link will be disabled after the submission of the first evaluation.

This feature enables external users to evaluate specific Learning Objects registered in a LOEP instance through the use of links. It can be very useful, for instance, to obtain feedback from students and teachers about Learning Objects used in VLEs such as LMSs and MOOC providers. The links to evaluate Learning Objects can be shared as resources or activities in the VLEs, through forums or via email. The external evaluations can also be very useful to allow external reviewers and experts to collaborate by performing occasional evaluations without registering on LOEP. For example, an expert on copyright law could be invited to evaluate a Learning Object about that topic.

5.3.3.2.3 Learning Object Evaluation Data

Administrators can view detailed information on the Learning Objects registered in a LOEP instance including their metadata, assignments and data related to their registration such as their scope and owner (in the LOEP instance). Besides all this information, administrators can view all the evaluation data of the Learning Objects.

Firstly, administrators can view all the performed evaluations of the Learning Objects. For each evaluation of a Learning Object, administrators can view the used evaluation model, the author, the completion date, and all data provided in the evaluation web form, including the scores given to all criteria and the provided comments. Super administrators can also modify the evaluations.

Secondly, LOEP provides for each Learning Object a table that shows all the scores calculated for that Learning Object based on their evaluations using different quality metrics. Figure 5.5 illustrates how the scores of a Learning Object are presented to administrators in the LOEP platform. For each score, LOEP indicates its value, the metric used to calculate it, and the evaluation models used by such a metric.

Lastly, LOEP also provides for each Learning Object a series of graphs that summarize the results of the performed evaluations. For each evaluation model, LOEP provides a graph that shows the average score obtained by the Learning Object for each criterion of that evaluation model. Figure 5.6 shows six graphs obtained in a LOEP instance for a Learning Object evaluated with LORI, LOEM, WBLT-S, WBLT-T, the Metadata Quality evaluation model, and the Interaction Quality evaluation model.

All the data of the Learning Objects (including their evaluation data) can be downloaded by the administrators in XLSX format, so they can be processed using spreadsheet software such as Microsoft Excel or LibreOffice Calc.

Metric	Evaluation Models	Score
Interaction Quality	**Interaction Quality**	8.1
LOEM Arithmetic Mean	**LOEM**	7.65
LORI Arithmetic Mean	**LORI v1.5**	8.39
LORI WAM CW	**LORI v1.5**	8.59
LOM Metadata Quality	**Metadata Quality**	8.15
WBLT-S Arithmetic Mean	**WBLT-S**	7.96
WBLT-T Arithmetic Mean	**WBLT-T**	9.24

Figure 5.5: Scores provided by the LOEP platform for a Learning Object

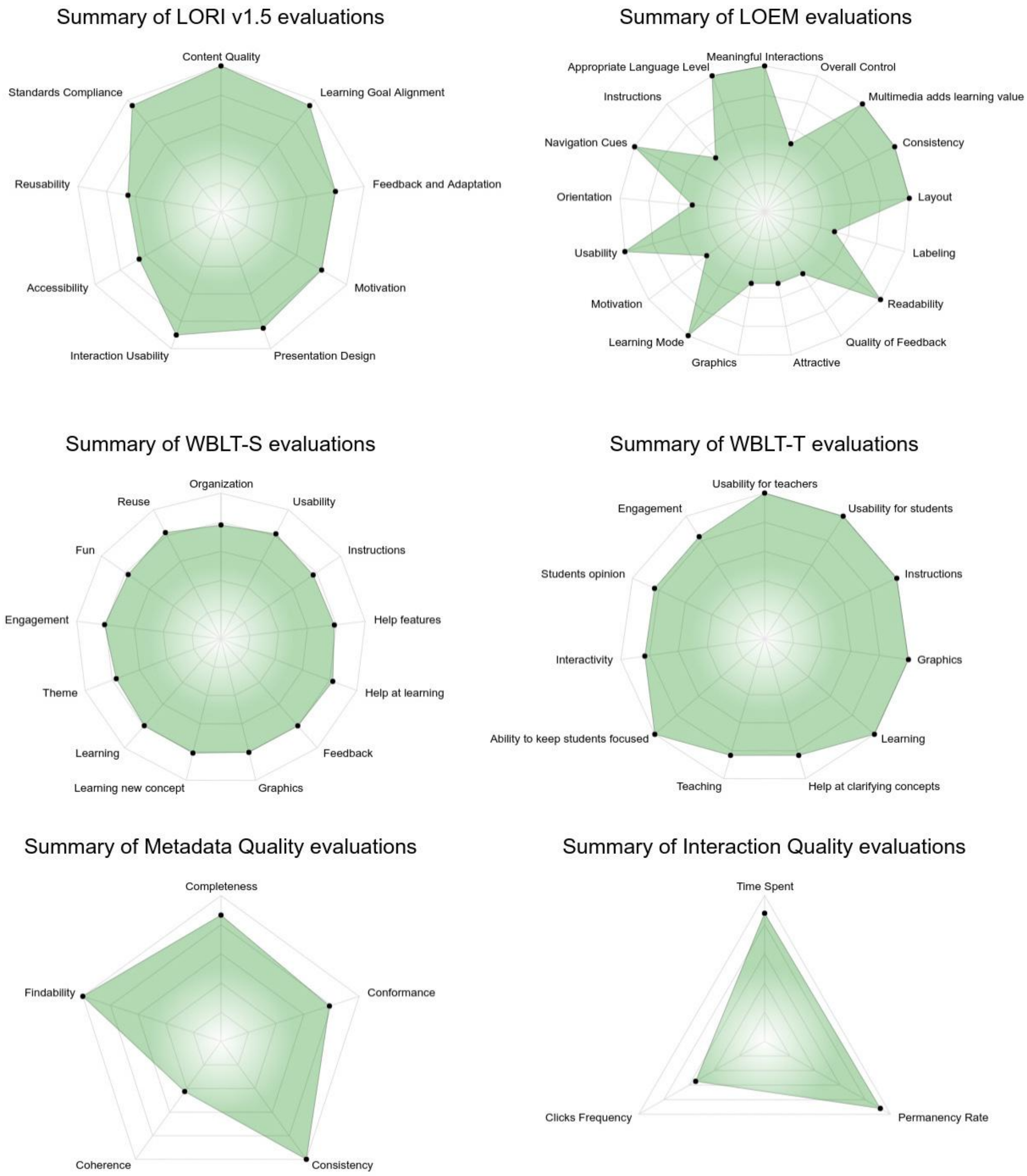

Figure 5.6: Result graphs generated by the LOEP platform for a Learning Object

5.3.3.2.4 Learning Object Search and Statistics

Other useful feature of LOEP is the search tool. This tool allows administrators to search for Learning Objects registered on LOEP. Searches can be done for a particular repository or in the whole LOEP database. Besides allowing to search for Learning Objects by name, the LOEP search tool allows to search for Learning Objects that include or do not include specific elements (e.g. text, images, videos, quizzes, ...), and to search for Learning Objects that have been or have not been evaluated with certain evaluation models. For instance, an administrator can search for Learning Objects registered in a LOEP instance that belong to a specific repository, that contain quizzes but not videos, and that have been evaluated with LORI and WBLT-S but not with WBLT-T. The user interface of the search tool is yet somewhat limited in this LOEP version, but it gives super administrators the option to write SQL (Structured Query

Language) queries in the web form to perform complex searches. The data of all Learning Objects included in the search results can be downloaded in XLSX format. Administrators can perform several actions over the Learning Objects retrieved by the search tool. These actions can be performed over all retrieved Learning Objects or over a subset. The available actions are:

- *Create assignments.* Administrators can create assignments to request reviewers to evaluate the selected Learning Objects. The creation of these assignments can be done by using the manual or automatic procedure as was previously described.
- *Calculate aggregated statistics.* Administrators can get aggregated data for a certain group of Learning Objects. For each group, LOEP provides the average score calculated by each metric, and the average score of each item of each evaluation model. Only those metrics for which all Learning Objects have scores and those evaluation models with which all Learning Objects have been evaluated are considered. Average scores calculated by the metrics are provided through tables (like the one in Figure 5.5) and the average scores of the items of each evaluation model are represented through graphs (like the ones in Figure 5.6). The aggregated data can be downloaded in XLSX format.
- *Compare.* Administrators can also compare Learning Objects based on their scores obtained for the different metrics and items of the evaluation models. Comparisons can only be made for those metrics and evaluation models for which all Learning Objects have evaluation data. Figure 5.7 illustrates a comparison between two Learning Objects based on the LORI evaluation model.

Name	LORI Arithmetic Mean	LORI WAM CW
Evaluación de Usabilidad y UX	8.54	8.62
Agujeros Negros	7.83	8.11

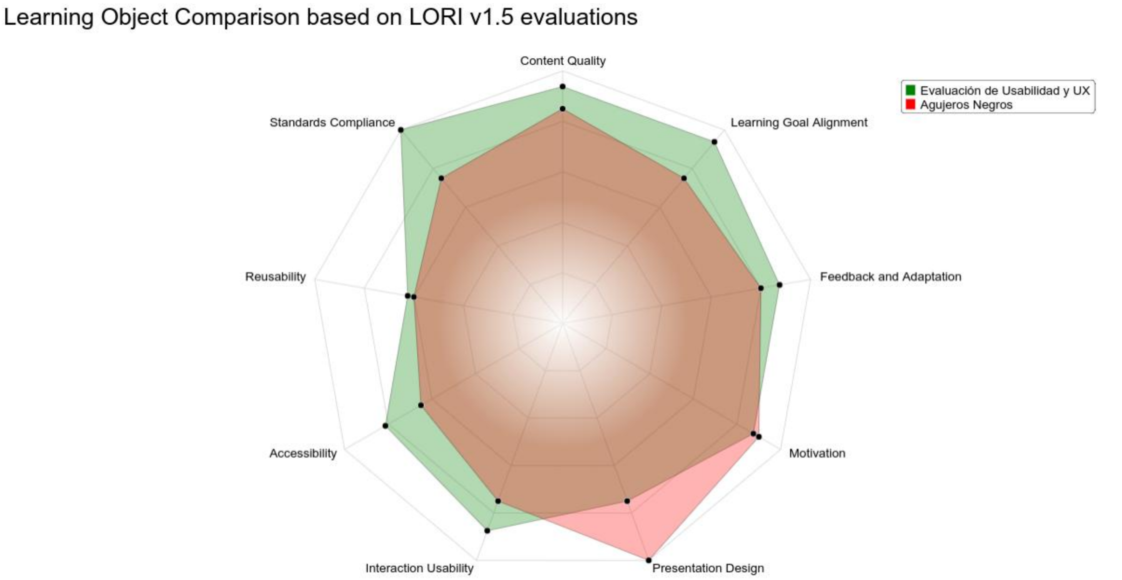

Figure 5.7: Learning Object comparison based on LORI on the LOEP platform

5.3.3.3 Features for Applications

External applications such as LORs, LMSs, MOOC providers or any other type of e-Learning system can be registered in a LOEP instance by an administrator. To register an application, administrators must indicate a unique name, which will be used by LOEP as identifier. Optionally, a callback URL can be specified for an application. In this case, LOEP will notify the application of different events related to their Learning Objects. An authentication token is automatically generated for each registered application. This token can be used by the applications to log in to LOEP on their own behalf. Registered applications have the same permissions as the administrator who registered them.

LOEP provides an API in order to facilitate registered applications to use a LOEP instance. This API is composed of two different REST APIs: "LOEP Learning Object API" and "LOEP Session Token API". Both of them use HTTP basic authentication (which can be used over HTTP or HTTPS). The credentials that applications should use are their name and their authentication token provided by LOEP. The specifications of all APIs provided by LOEP are available at its wiki: http://github.com/agordillo/LOEP/wiki.

The LOEP Learning Object API allows applications to register, update and delete Learning Objects in a LOEP instance, as well as to get information on their Learning Objects including quality scores. Applications can register Learning Objects according to three scopes: public, protected and private. If Learning Objects are registered publicly, reviewers will be able to evaluate them immediately. Otherwise, an administrator should create assignments to assign the reviewers. Future versions will allow applications to automatically create assignments for new Learning Objects according to different strategies. Through the LOEP Learning Object API, applications can provide to LOEP the information required to perform the metadata evaluations. The LOM Metadata Quality evaluation model allows applications to evaluate and measure the quality of the LOM metadata of their Learning Objects. Since one of the items of this model represents the degree to which the metadata instances match the definition of the IEEE LOM standard, LOEP can also be used by applications to validate their LOM metadata. Moreover, applications can also use the LOEP Learning Object API to provide learning analytics in order to enable the evaluation of their Learning Objects based on the interactions that users had with them by using the Interaction Quality evaluation model. At present, a custom data model is used to represent the learning analytics. The documentation of this data model can be found on the LOEP wiki. Future versions of LOEP might consider to use an e-Learning standard like IMS Caliper Analytics [165] for these representations.

The LOEP Session Token API allows registered applications to generate session tokens that can be later used for different actions such as requesting evaluation web forms (and submit their corresponding evaluations) and showing results of evaluations through graphs. Different parameters can be specified for a session token such as the specific action that it allows to perform, if the token will be active indefinitely or for a limited time period (and the period of validity in this case), and if the token can be used to perform one or multiple actions. By using the LOEP Session Token API, applications can enable their end users to evaluate Learning Objects directly from their website by using the evaluation models and web forms provided by LOEP. Applications can also use this API to show in their websites the results of the evaluations to their end users by using the graphs generated by LOEP.

As mentioned above, LOEP notifies those applications for which a callback URL has been specified of different events related to their Learning Objects. In order for the notifications generated by a LOEP instance to be received by a registered application, that application should implement a specific API whose base URL should be its callback URL specified in the LOEP instance. This API is termed “LOEP Callback API” and its specification is included on the LOEP wiki. The LOEP Callback API is expected to use HTTP basic authentication (over HTTP or HTTPS). The requests made by LOEP to these APIs include in the authentication header the name and authentication token of the corresponding application. By using the LOEP API and the LOEP Callback API, it is possible to establish a bidirectional communication between an application and a LOEP instance. The LOEP Callback API allows applications to receive new evaluation data (e.g. scores) of their Learning Objects as soon as these data are generated. In the current version of LOEP, evaluation data are provided using a custom data model (documented in the wiki). Applications are free to decide how to use and store these data. The development of an interoperable metadata model that enables to represent, store, manage, share and reuse evaluation data of Learning Objects is a current need in the TEL field. Future plans for LOEP include the definition of a metadata model to satisfy this need. An interesting option could be to define this model through a LOM application profile.

An example of the use of the LOEP API and the LOEP Callback API in a LOR can be found in chapter 3 of this thesis, which describes in detail the ViSH platform, including its evaluation system which was developed relying on the use of LOEP. Furthermore, in the source code repository of ViSH available at http://github.com/ging/vish/wiki, it can be found implementations of the client-side LOEP API and the server-side LOEP Callback API.

Other useful feature for applications is that they can implement their own evaluation models and quality metrics with little effort. Although the evaluation models and quality metrics supported by LOEP can be used to evaluate Learning Objects in most scenarios and contexts, applications are free to use their own implementations. For example, an application could develop evaluation models and quality metrics tailored to specific types of educational resources such as educational video games or intelligent tutoring systems.

Finally, it is worth pointing out that the source code of LOEP is open source, documented and publicly available at the GitHub repository http://github.com/agordillo/LOEP. Therefore, any interested party can customize the system and implement its own features.

5.3.4 Scenarios of Use

5.3.4.1 Implementation of Quality Control Mechanisms

The ultimate goal of LOEP is to facilitate e-Learning systems the systematic evaluation and measurement of the quality of Learning Objects by using reliable evaluation models and quality metrics, in order to allow them to implement effective quality control mechanisms. Throughout this chapter, the different features of LOEP have been described. This section aims to illustrate how these features can be used to implement different quality control mechanisms in an e-Learning system, concretely in a LOR. Figure 5.8 shows a generic scenario in which a LOR has used LOEP to implement a certain quality control mechanism. When a contributor of the LOR submits a new Learning Object, the following steps are performed:

1. The LOR registers the new Learning Object on LOEP by using the LOEP API.
2. The Learning Object is automatically evaluated in LOEP by those automatic evaluation models for which the required data has been provided. Suppose in this case that the LOR has provided the URL to the LOM metadata instance in XML format of the Learning Object. Thus, the Learning Object is evaluated according to the LOM Metadata Quality evaluation model and an overall quality score on a 0-10 scale is generated according to the LOM Metadata Quality metric.
3. LOEP notifies the LOR of this evaluation by using the LOEP Callback API. LOEP sends in this notification the scores calculated for the five items of the LOM Metadata Quality evaluation model (i.e. completeness, conformance, consistency, coherence, and findability) and the overall quality score calculated according to the LOM Metadata Quality metric.
4. The LOR receives and stores the evaluation data of the new Learning Object. At this point, the LOR could take a decision on whether or not to accept the Learning Object for publication. Suppose in this case that the LOR does not take any decision based on the results of the metadata quality evaluation.

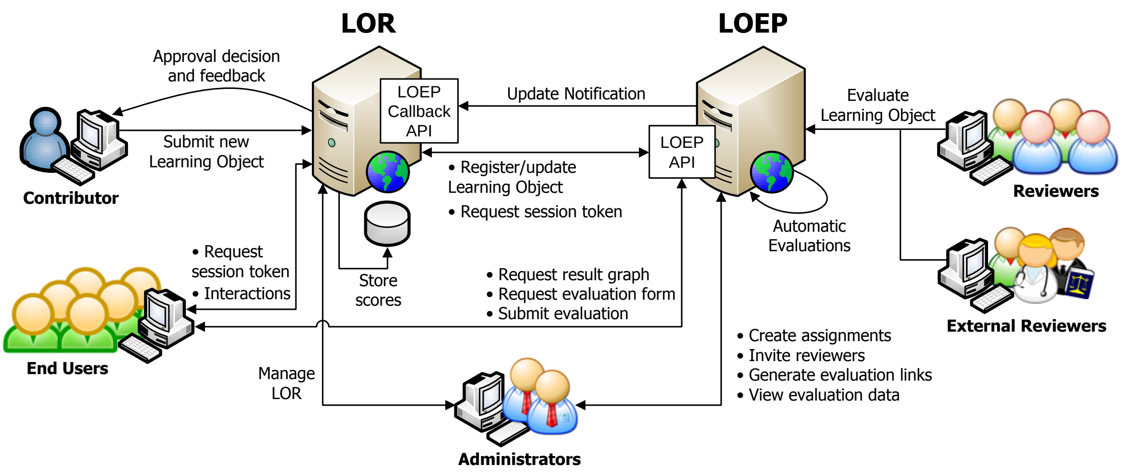

Figure 5.8: Implementation of quality control mechanisms using LOEP

5. Once the submitted Learning Object has been registered on LOEP, there are three different ways in which it can be evaluated by reviewers:
    a. If the LOR registers the Learning Object on LOEP with public scope, reviewers can evaluate it from the moment of its registration using any available manual evaluation model.
    b. Administrators can create assignments to request reviewers registered on LOEP to evaluate the Learning Object according to certain evaluation models.
    c. Administrators can create links to allow external reviewers to evaluate the Learning Object without registering on LOEP.

    The LOR should decide which way or combination of ways to use. Suppose in this case that a member of the LOR staff log in to LOEP as administrator, and creates assignments for the submitted Learning Object with the automatic procedure specifying the following parameters: all reviewers, the LORI evaluation model, four evaluations per Learning Object, and the "prioritize reviewer suitability" strategy. Thereby, the four most suitable reviewers are requested to evaluate the submitted Learning Object with LORI.
6. Each reviewer, in order to complete his/her new assignment, evaluates the Learning Object with LORI.
7. Each time the Learning Object is evaluated, LOEP calculates its new quality scores. In this case, since reviewers perform the evaluations with LORI, LOEP calculates scores by using all the available LORI metrics. After that, LOEP sends the LOR the evaluation data of the Learning Object. These data include for each evaluation model:
    a. The total number of completed evaluations.
    b. The number of completed, pending and rejected assignments.
    c. The average value given to each item of the evaluation model.
    d. The comments provided by the evaluators.
    e. All scores that were calculated by using metrics based on the evaluation model.
8. Each time the LOR receives a notification with new evaluation data, it stores and processes these data. The LOR can take a decision on whether or not to accept the Learning Object for publication on each notification. Many different quality control policies can be implemented. For instance, the LOR can wait until the Learning Object has three LORI evaluations, and then automatically accepts it if its score calculated according to the LORI WAM CW metric is higher or equal than five, and rejects it otherwise. The LOR could also define their own metrics by using the scores sent by LOEP. Other option for the LOR could be to allow its administrators to manually make the decision based on the available evaluation data. It is also possible for the LOR to send feedback to the contributor (e.g. the comments of the reviewers). Suppose in this example that the Learning Object has achieved an overall quality score higher than five and that the LOR approves its publication.

9. Once the Learning Object has been published, the end users of the LOR can access and interact with it, as well as to evaluate it. The LOR could use for the evaluations of their end users any of the evaluation models provided by LOEP, or implement their own one in LOEP. Suppose in this example that the end users of the LOR are mainly learners, and therefore the LOR opts to use WBLT-S. When a LOR end user evaluates a Learning Object the following steps are performed:
    a. A LOEP session token is requested to the LOR from the web browser of the user.
    b. The LOR requests a session token to LOEP by using the LOEP API.
    c. LOEP sends to the LOR a new session token which allows to perform a single WBLT-S evaluation of the Learning Object.
    d. The LOR return the LOEP session token to the web browser of the end user.
    e. The web browser of the end user uses this token to request to LOEP the WBLT-S evaluation form for the Learning Object, and displays this form.
    f. The end user fills out the WBLT-S web form and sends it.
    g. LOEP stores the new evaluation data and notifies the LOR, which takes the actions it deems appropriate.
10. The LOR can show to their end users the results of the quality evaluations of the published Learning Objects. On the one hand, it can use the evaluation data sent by LOEP to show the results in any way it wants. On the other hand, it can use the LOEP API to show the results using the graphs generated by LOEP for each evaluation model. In this case, the web browser of the end users obtains a session token in the same way as described above, and uses it to request to LOEP the desired graphs for a Learning Object. Figure 5.6 shows graphs generated by LOEP for six different evaluation models.

The case described above is just an example of the wide variety of quality control mechanisms that can be implemented with LOEP. In this example, the LOR had a quality control policy that required the Learning Objects to be evaluated before being published in order to guarantee a minimum quality level. Nevertheless, many LORs, especially those that are OER repositories, allow publishing Learning Objects whatever their quality because they are not able to evaluate all submitted Learning Objects. Thus, these LORs need different quality control mechanisms. LOEP has also been designed with these scenarios in mind. Next, an example is provided to illustrate how LOEP enables to implement quality control mechanisms in these cases.

Suppose now that the LOR of the first example has not enough reviewers to evaluate all submitted Learning Objects in an acceptable time frame (or has no reviewers at all), and hence it decides to accept all submitted Learning Objects. In this new situation, the LOR can use LOEP to implement different quality control mechanisms such as the following:

- The LOR can use the WBLT-S evaluations performed by its end users to stop distributing low quality Learning Objects. For instance, the LOR could retract all Learning Objects evaluated by more than three users whose quality scores calculated according to the WBLT-S AM metric were below five. The LOR could also opt not to retract any Learning Object, but give more visibility to the ones with higher quality.
- The LOR can combine the end user evaluations with peer review. Instead of retracting a Learning Object when it receives poor evaluations from end users, these Learning Objects could be assigned to reviewers to be evaluated. The final decision on stopping the distribution of Learning Objects would be made based on the results of the reviewers' evaluations. For instance, the LOR could retract all Learning Objects whose LORI scores (calculated using some of the supported LORI metrics) were below five. Although this mechanism needs reviewers, their workload is significantly reduced because they only need to evaluate those Learning Objects with poor evaluations from end users. The LOR could recruit reviewers from its user community. A recent survey showed that teachers, in general, are willing to contribute by becoming accredited reviewers [53].
- The LOR can use the Interaction Quality evaluation model to automatically estimate the quality of the published Learning Objects based on the interactions that end users have with them. In order to implement a quality control mechanism based on this model, the LOR needs to capture the interaction data of the end users, and process these data into the learning analytics required by the model: time spent, permanency rate, and number of mouse clicks. Once these learning analytics are calculated, the LOR can send them to LOEP through the LOEP API. Immediately after receiving the learning analytics, LOEP calculates the interaction quality scores and sends them to the LOR. The LOR can use these quality scores to implement its quality control mechanism. For instance, it could retract or manually review those Learning Objects with more than a certain number of significant interactions whose interaction quality score was below a threshold. Other option is to give more visibility to the Learning Objects with higher quality scores, but using the WBLT-S and/or LORI scores for those Learning Objects that have been evaluated by end users and/or reviewers, and the interaction quality scores for those Learning Objects that have not been evaluated yet. The major advantage of this mechanism is its high scalability. However, its implementation is complex and laborious since it requires capturing and processing data about the interactions of the end users with the Learning Objects.

5.3.4.2 Enhancement of Features in Learning Object Repositories

Besides facilitating the implementation of quality control mechanisms, LOEP aims to allow e-Learning systems to enhance their features for searching and discovering Learning Objects. In the above scenario represented in Figure 5.8, the LOR stores in its database the quality scores of the evaluated Learning Objects calculated according to the different quality metrics. These scores can be used to enhance several of the features typically offered by LORs (see section 2.4 for a review on LOR features). Next, some examples of how the quality scores provided by LOEP can be used to enhance specific LOR features are described:

- *Search services*. Quality scores can be used to provide quality-based sorting of the search results. Thereby, Learning Objects with higher quality are displayed first. This ranking strategy has been adopted by LORs such as MERLOT [275], [276] and eLera [283]. Furthermore, the quality scores can be used to create compound ranking metrics that combine quality with other indicators such as similarity to the search query terms, similarity with the user profile, or popularity indicators. Examples of ranking metrics for Learning Objects based on the integration of quality with other indicators can be found at [219], [220]. Another example can be found in chapter 3 of this thesis, which describes the search service of the ViSH platform. In this case, the ranking metric uses scores provided by LOEP.
- *Recommender Systems*. These systems can use quality scores of Learning Objects to provide better recommendations. Chapter 7 of this thesis describes how a Learning Object recommender system uses quality scores provided by LOEP.
- *Catalogues*. Many LORs offer a catalogue that allows users to browse Learning Objects. In those cases where Learning Objects created by the community can be automatically included in the catalogue, the LOR can use quality scores to filter low quality Learning Objects (see chapter 3 for an example). Thereby, only the better resources of the LOR are advertised in the catalogue. The filtering of low quality Learning Objects may be useful for any feature or system intended to distribute Learning Objects, including search services and recommender systems.
- *Metadata Validation*. The LOM Metadata Consistency metric measures the degree to which metadata instances match the definition of the IEEE LOM standard. According to this metric, all Learning Objects whose metadata are not compliant with LOM receive a score of zero. Thus, LORs can use the consistency scores to validate LOM metadata. An example of how scores provided by LOEP were used to evaluate the metadata quality of the Learning Objects created by an authoring tool is shown in chapter 4.

5.3.4.3 Research on Learning Object Quality

LOEP can also be a useful tool for research on Learning Object quality. It provides features to collect, store, visualize and download evaluation data, search Learning Objects by several criteria (e.g. type of content included and evaluation models used), calculate aggregated statistics for groups of Learning Objects, and compare Learning Objects based on their evaluation data. Therefore, LOEP can be used to conduct studies on quality indicators, evaluation models, quality metrics, quality control mechanisms, learning effectiveness, and acceptance of Learning Objects. An example of a study on Learning Object quality indicators in which LOEP was used can be found in chapter 4 of this thesis. This study analyzed the influence of the presence of two types of resources on the quality of the Learning Objects created with a specific authoring tool.

5.4 Evaluation and Results

5.4.1 Quantitative Analysis

As was mentioned in the overview section, the LORs ViSH [56] and EducaInternet [60] use a LOEP instance to evaluate their Learning Objects. This LOEP instance has been used for more than three years in ViSH and more than two years in EducaInternet. This section presents the results of a quantitative analysis conducted in this LOEP instance in order to provide empirical evidence of the use of LOEP to evaluate Learning Objects in real scenarios. The data for this analysis were obtained from the database of the LOEP instance and correspond to 28 February 2017. Table 5.16 shows the results of the quantitative analysis.

Table 5.16: Results of the Quantitative Analysis conducted in the LOEP Instance

	Repository		
	ViSH	**EducaInternet**	**All**
Total number of evaluated Learning Objects	1,681	965	2,646
Learning Objects automatically evaluated with the LOM Metadata Quality evaluation model	1,681	965	2,646
Learning Objects automatically evaluated with the Interaction Quality evaluation model	1,487	845	2,332
Learning Objects evaluated by reviewers	318	76	394
Learning Objects evaluated by end users	108	37	145
Total number of performed evaluations	5,330	2,684	8,014
Automatic evaluations of metadata quality	1,681	965	2,646
Automatic evaluations based on interaction data	1,487	845	2,332
Evaluations performed by reviewers	1,047	224	1,271
Evaluations performed by end users	1,115	650	1,765
Total number of created assignments	1,076	244	1,320
Completed assignments	1,047	224	1,271
Pending assignments	16	20	36
Rejected assignments	13	0	13
Total number of calculated quality scores	3,931	2,001	5,932

First off, in order to understand how the LOEP instance was used by ViSH and EducaInternet, it is necessary to explain the quality control mechanism of these LORs, which was implemented relying on LOEP. ViSH and EducaInternet provide registered users with an authoring tool called ViSH Editor that allows them to create Learning Objects in the form of Interactive

Presentations (see chapter 4 for further details about ViSH Editor). Users can publish these Learning Objects in the LORs. All of them are accepted for publication immediately after their submission. Once a user publishes an Interactive Presentation created with ViSH Editor, this Learning Object can be evaluated by end users with WBLT-S and WBLT-T. The WBLT-S evaluation model is intended to be used by those end users who are learners, and WBLT-T is intended to be used by those end users who are teachers. In addition to the evaluations from end users, ViSH and EducaInternet have a team of reviewers dedicated to evaluating the Learning Objects published by their users using LORI. Two members of the team of reviewers also operate as LOEP administrators and create the assignments to distribute the workload. The LORs also automatically measure the metadata quality of all published Interactive Presentations by using the LOM Metadata Quality evaluation model. The end users of the LORs can view in their web portals the results of the quality evaluations of the Learning Objects through the graphs provided by the LOEP instance. Based on the scores calculated using the LORI WAM CW, WBLT-S AM and WBLT-T AM metrics, the LORs calculate an overall quality score for each evaluated Learning Object. Non evaluated resources receive a default overall quality score of 0.5 out of 1. Overall quality scores are then used by different features of the LORs including the search services, the recommender system and the catalogue. Thereby, the LORs give more visibility to those evaluated Learning Objects with higher quality. Besides, warnings are automatically generated for those Learning Objects whose overall quality score is below a certain threshold. The LOR administrators use these warnings to detect low quality Learning Objects and stop their distribution. Lastly, the LORs capture data about the interactions of the end users with the Interactive Presentations and process these data into learning analytics, which are sent to the LOEP instance and used to calculate quality scores using the Interaction Quality metric. Further details about how LOEP is used in these LORs are provided in chapter 3.

The results of the quantitative analysis conducted in the LOEP instance used by ViSH and EducaInternet provide evidence that LOEP has succeeded in allowing the LORs to systematically evaluate and measure the quality of their Learning Objects. The LOEP instance allowed to evaluate 2,646 Learning Objects, perform more than 8,000 evaluations, and generate around 6,000 quality scores. All Learning Objects were automatically evaluated with the LOM Metadata Quality evaluation model. Of these 2,646 evaluated Learning Objects, 2,332 (88.1%) had enough interaction data to be evaluated with the Interaction Quality evaluation model, 394 (14.9%) were evaluated by reviewers, and 145 (5.5%) were evaluated by end users. The percentage of peer-reviewed Learning Objects is similar to others reported in the literature for existing LORs. For instance, Hanley [390] reported that around a 14% of the materials available in MERLOT had been peer reviewed. The low percentage of Learning Objects evaluated by end users suggests that the LORs should consider the implementation of incentive mechanisms to motivate users to evaluate resources. The results of the quantitative analysis show that a total of 8,014 evaluations were performed, of which 2,646 (33.0%) were automatic evaluations of metadata quality, 2,332 (29.1%) were quality evaluations based on interaction data, 1,271 (15.9%) were evaluations performed by the reviewers, and 1,765 (22.0%) were evaluations performed by end users. When a Learning Object is evaluated in LOEP with an automatic evaluation model, only one evaluation is performed. Thus, the number of evaluations performed with these models coincides with the number of Learning Objects evaluated by them. Regarding the evaluations performed by reviewers, results indicate that each peer-reviewed Learning Object was evaluated, on average, by 3.23 reviewers. Lastly, with regard to the end user evaluations, the data showed that a small percentage of the evaluated Learning Objects received most of the evaluations. A more detailed analysis of the data revealed that the evaluations from end users followed the Pareto principle (20/80 rule): the 20% of the Learning Objects evaluated by end users received around the 80% of the end user evaluations.

5.4.2 Evaluation of the User Acceptance

An online survey was conducted among the reviewers registered on the LOEP instance used by ViSH and EducaInternet to collect general feedback about LOEP. There were a total of 18 reviewers registered on the LOEP instance: 6 e-Learning experts, 9 educators and 3 designers. Surveys were collected for 17 reviewers. Thereby, the survey sample consisted of 17 reviewers, 10 males and 7 females, 23 to 43 years of age (M=31.0, SD=5.3), of which 5 were e-Learning experts, 9 were educators, and 3 were designers. Table 5.17 shows the main results of the survey including for each question the mean value (M) and the standard deviation (SD).

Table 5.17: Results of the LOEP Survey (N=17)

Question	M	SD
What is your overall opinion of the LOEP platform? 1 (awful) – 5 (excellent)	4.3	0.5
How would you describe the experience of learning to use LOEP? 1 (very difficult) – 5 (very easy)	4.2	0.8
Please indicate your level of agreement on each of the following statements about LOEP 1 (strongly disagree) - 5 (strongly agree)		
LOEP makes my job as a reviewer easy	4.6	0.6
I have improved my ability to judge the quality of Learning Objects after using LOEP	4.1	0.9
I think my assignments were suitable according to my profile	3.8	1.1
The documentation is easy to find	4.3	0.9
The documentation is truthful, accurate, well presented, and has the appropriate level of detail	3.8	0.8
LOEP can be very useful for Learning Object Repositories, Learning Management Systems and educational content providers	4.4	0.5
LOEP can be very useful for educational institutions	4.1	1.0
Would you recommend LOEP to others?	**Yes**	**No**
	100%	0%

The results of the survey show that reviewers had a good overall opinion of LOEP (M=4.3, SD=0.5) and found LOEP easy to use (M=4.2, SD=0.8). Reviewers also indicated that LOEP made their jobs as reviewers easy (M=4.6, SD=0.6), and that LOEP was helpful to improve their ability to judge Learning Object quality (M=4.1, SD=0.9). The results of the question about assignments (M=3.8, SD=1.1) suggest that the features that LOEP provides to administrators to create assignments are suitable. Finally, it is worth pointing out that the results show that reviewers strongly believed that that LOEP can be very useful for LORs and other e-Learning systems such as LMSs (M=4.4, SD=0.5), as well as for educational institutions (M=4.1, SD=1.0). Therefore, it is not surprising that all reviewers answered that they would recommend the use of the LOEP platform.

5.4.3 Usability Evaluation

Besides the survey whose results are presented in the above section, the 17 reviewers filled out a SUS questionnaire in order to evaluate the usability of LOEP. Table 5.18 shows the results of this questionnaire, including the overall SUS score.

Table 5.18: Results of the SUS Questionnaire for LOEP (N=17)

	M	**SD**
SUS Score 0 – 100	84	8.4
SUS items 1 (strongly disagree) - 5 (strongly agree)		
1. I think that I would like to use this system frequently	4.4	0.8
2. I found the system unnecessarily complex	1.1	0.3
3. I thought the system was easy to use	4.4	1.1
4. I think that I would need the support of a technical person to be able to use this system	1.7	0.9
5. I found the various functions in this system were well integrated	4.6	0.5
6. I thought there was too much inconsistency in this system	1.2	0.4
7. I would imagine that most people would learn to use this system very quickly	4.2	0.6
8. I found the system very cumbersome to use	1.5	0.7
9. I felt very confident using the system	4.2	0.6
10. I needed to learn a lot of things before I could get going with this system	2.8	1.3

The results of the SUS questionnaire show that, in general, reviewers had a good opinion on the overall usability of LOEP and that they perceived the platform as easy to use. The overall usability score recorded a mean of 84 out of 100. All positively worded items were rated above 4.1, while all negatively worded items were rated below 1.8 with the exception of the item 10, which obtained a mean of 2.8 on a 1-5 scale. This is because reviewers had to learn how to use the LORI evaluation model before beginning to evaluate Learning Objects.

5.4.4 Evaluation of Learning Object Evaluation Models and Quality Metrics

5.4.4.1 Experiment A: use of LORI to evaluate a collection of Learning Objects in a LOR

A study was conducted in order to evaluate the usefulness of the LORI evaluation model. The participants of this study were 15 reviewers registered on the LOEP instance used by ViSH and EducaInternet. At the beginning of the study, reviewers studied the LORI user manual corresponding to version 1.5, and received a four-hour training session on how to evaluate Learning Objects using LORI 1.5 and how to use the LOEP platform to perform the evaluations. After that, a set of 209 Learning Objects of the ViSH platform was distributed among the 15 reviewers in such a way that each Learning Object was assigned at least to 3 different reviewers and each reviewer was requested to evaluate approximately the same number of Learning Objects. This distribution was done by creating assignments on the LOEP platform. All the Learning Objects involved in this study had been created by the users of the ViSH platform using the ViSH Editor authoring tool. These Learning Objects were notably varied in terms of content and quality. Reviewers had four months to evaluate the whole set of Learning Objects. Email support was available throughout the duration of the study. Over these four months, the team of reviewers evaluated the 209 Learning Objects with LORI 1.5 generating a total amount of 740 evaluations. Finally, the reviewers filled out a survey about LORI. Table 5.19 summarizes the results of this survey.

Table 5.19: Results of the LORI Survey (N=15)

Question	M	SD
Please indicate your level of agreement on each of the following statements about LORI 1 (strongly disagree) - 5 (strongly agree)		
LORI is an excellent tool for evaluating the quality of Learning Objects	4.2	0.8
The LORI user manual is truthful, accurate, well presented, and has the appropriate level of detail	4.1	0.9
The training session on LORI was truthful, accurate, well presented, and had the appropriate level of detail	3.9	0.7
Please indicate your comfort level rating Learning Objects on the following LORI items 1 (very uncomfortable) - 5 (very comfortable)		
1. Content quality	4.2	0.7
2. Learning goal alignment	4.1	1.1
3. Feedback and adaptation	3.9	1.0
4. Motivation	4.3	0.8
5. Presentation design	4.4	0.6
6. Interaction usability	3.9	0.6
7. Accessibility	2.9	1.0
8. Reusability	3.1	1.2
9. Standards compliance	3.3	1.3

The sample of the survey consisted of 15 reviewers, 9 males and 6 females, 23 to 43 years of age (M=30.8, SD=5.6), of which 4 were e-Learning experts, 9 were educators, and 2 were designers. The results show that reviewers perceived LORI as a useful tool for evaluating the quality of Learning Objects. Furthermore, the results suggest that reviewers were satisfied with the documentation (i.e. the LORI user manual) and the provided training session on how to use LORI and LOEP. Regarding the comfort level rating the different LORI items, reviewers felt more comfortable rating items related to pedagogical criteria (items 1 to 6) than rating items more related to technological criteria (items 7, 8 and 9). The explanation for this is that non-technical reviewers had difficulties to judge items related to technological criteria. This fact becomes clear in the results presented in Table 5.20, where respondents were divided in two groups: technical reviewers (e-Learning experts) and non-technical reviewers (educators and designers). These results show that reviewers without deep technical knowledge did not felt very comfortable rating LORI items related to technological criteria such as “accessibility” (M=2.5, SD=0.8), “reusability” (M=2.8, SD=1.1), and “standards compliance” (M=2.9, SD=1.3). The fact that around 27% of the evaluations carried out by the educators lacked of some of these three items, reinforces the idea that usually non-technical reviewers are unable or do not feel qualified enough to judge these criteria. This conclusion is consistent with the findings of other studies. For instance, [284] reported that reviewers lacked the knowledge of metadata and accessibility standards needed to use LORI. Similarly, in [391], the original LORI items that dealt with accessibility and standards compliance were removed because the participants lacked the necessary knowledge to provide an assessment in both of those areas.

According to the LORI guidelines, it could be argued that the reusability item is not a pure technological criterion since it is focused on educational reusability. However, in practice, the ability of a Learning Object to be reused in varying learning contexts and with learners from different backgrounds strongly relies on technological aspects. Reviewers need a deep knowledge about the different technologies in which Learning Objects are provided in order to suitably judge to what extent they can be customized (e.g. by using authoring tools), translated, or integrated into other Learning Objects or e-Learning systems, and how much effort is needed to do so. The empirical data obtained in this study sustain this fact.

Table 5.20: Comfort Level of Reviewers Rating Technological LORI Items

Please indicate your comfort level rating Learning Objects on the following LORI items 1 (very uncomfortable) - 5 (very comfortable)	**Technical Reviewers (N=4)**		**Non-Technical Reviewers (N=11)**	
	M	**SD**	**M**	**SD**
7. Accessibility	4.0	0.8	2.5	0.8
8. Reusability	3.8	1.5	2.8	1.1
9. Standards compliance	4.5	0.6	2.9	1.3

In conclusion, to reliably evaluate a Learning Object with LORI, it should not only be reviewed by educators with knowledge of its subject, but also by at least one technician or e-Learning expert. The results of the study presented in this section confirm the existing differences between the pedagogical and technological LORI criteria. Based on this fact, it seems reasonable to define quality metrics by dividing LORI items into pedagogical and technological items, as was done in some of the metrics proposed in this chapter. The results of the study also suggest that future versions of LORI should consider replacing the reusability item for two different items: “Pedagogical Reusability” and “Technological Reusability”. This way, educators could focus on pedagogical reusability while technicians take care of the technological constraints. The overall reusability score could be calculated based on the scores given to these two items in order to offer a reliable and truthful measurement of reusability.

As was mentioned in the description of the LORI metrics, the weight vectors used for the LORI WAM CW and LORI WAM IW metrics were obtained from this study. The weights used for LORI WAM CW were obtained through a survey among the reviewers, and the weights used for LORI WAM IW were obtained by using a multiple linear regression analysis. Details are included in the description of the LORI WAM metric.

5.4.4.2 Experiment B: use of quality metrics to provide quality-based sorting of Learning Objects and to filter low quality Learning Objects

An experiment was conducted in order to determine if the quality metrics provided by LOEP can be effectively used to provide quality-based sorting of Learning Objects to users, as well as to effectively distinguish between high quality and low quality Learning Objects. The experiment evaluated all the metrics based on the LORI evaluation model that are described in this chapter, and the metrics used to calculate overall quality scores with the automatic evaluation models LOM Metadata Quality and Interaction Quality.

A total of 10 teachers participated in this experiment. These participants were asked to simulate a search for physics teaching resources in a LOR. A list of 12 randomly sorted Learning Objects about physics was presented to the participants as the results of this fictitious search. The 12 Learning Objects were selected among the 209 Learning Objects of the ViSH platform that had been evaluated with LORI 1.5 by a team of 15 reviewers in the experiment A. On the one hand, Learning Objects with diverse quality were selected in order to cover the maximum possible range of scores. On the other hand, some Learning Objects with similar quality were also selected to reliably measure the accuracy of the metrics. Firstly, participants were required to rate each of the 12 Learning Objects of the list in terms of their pedagogical quality on a scale from 0 (lowest) to 10 (highest). Participants were also requested to give ratings lower than five to those Learning Objects that they felt were not of high enough quality to be used as educational resources. After that, the participants were required to reorder the list of Learning Objects according to their pedagogical quality, placing the Learning Object with higher quality in the first position and the Learning Object with lower quality in the last one. This way, a human-generated ranking of the Learning Objects was obtained in the experiment. Then, the metrics evaluated in the experiment (i.e. all LORI metrics, the LOM Metadata Quality metric, and the Interaction Quality metric) were used to reorder the list. Thereby, a ranking of the Learning Objects was obtained for each metric. Finally, the ranking calculated for each metric was compared against the human-generated ranking. In order to measure the difference between the human-generated ranking and each of the rankings obtained by using the metrics, the Kendall tau coefficient [392], [393] was used. This coefficient measures the degree of correspondence between two rankings. If two rankings are identical, the Kendall tau coefficient is equal to 1, and if they are in inverse order, the Kendall tau coefficient is equal to -1. Thereby, a ranking metric that sorts the Learning Objects randomly would obtain on average a Kendall tau coefficient of zero. Table 5.21 shows the Kendall tau coefficients obtained for each of the metrics evaluated in this experiment.

Table 5.21: Results of the Quality Metrics Evaluation

Metric	Rank Correlation		Scores					Accuracy	Filtering Success Rate
	Kendall tau	2-tailed p-value	SD	Range	Error M	Error SD	Error Max		
LORI Metrics									
LORI AM	0.91	< 0.001	2.4	80%	0.6	0.6	1.8	1.6	100%
LORI WAM CW	0.88	< 0.001	2.7	86%	0.6	0.6	1.9	1.6	100%
LORI WAM IW	0.94	< 0.001	2.6	86%	0.7	0.5	1.6	1.6	100%
LORI PWAM	0.88	< 0.001	3.0	95%	0.7	0.7	2.0	1.6	100%
LORI TWAM	0.55	0.016	1.6	57%	1.4	1.1	3.6	5.6	83%
LORI Orthogonal	0.91	< 0.001	2.0	67%	0.9	0.8	2.1	0.9	100%
LORI Logarithmic (A=2)	0.85	< 0.001	2.9	90%	0.6	0.4	1.3	1.6	92%
LORI Square Root	0.76	< 0.001	2.5	85%	0.6	0.6	1.9	1.4	100%
LOM Metadata Quality	0.36	0.115	0.5	18%	2.6	2.5	8.2	6.6	67%
Interaction Quality	0.61	0.007	2.5	84%	1.5	1.1	3.8	2.2	92%

Besides the Kendall tau coefficients, other parameters were calculated in order to evaluate the quality metrics. As a measurement of how well the metrics distributed the scores, the standard deviation of the scores and the covered range of scores were calculated for each metric. The larger this standard deviation and range are, the better is the metric at distributing scores. Score errors were calculated as the difference between the scores calculated by the metrics and the average scores given by the users. The smaller the error is, the more reliable is the metric. The “accuracy” parameter indicates the minimum difference that should exist between the average scores (given by the users) of two Learning Objects to ensure that the metric is capable of sorting the list of Learning Objects with zero error. The smaller the accuracy is, the more capable is the metric at sorting Learning Objects with similar scores. In the experiment, participants gave ratings higher or equal to five to those Learning Objects they considered acceptable to be used for education. Similarly, metrics can define a quality threshold and reject (or filter) those Learning Objects scored below it. In this experiment, all quality thresholds were set to five. The “filtering success rate” parameter shows the percentage of Learning Objects for which the metric produced the same result as the users when deciding if the Learning Object should be accepted or not (i.e. if the Learning Object should be filtered or not).

Considering the obtained Kendall tau coefficients, it can be stated that all the presented quality metrics based on LORI, except the LORI TWAM metric, were very effective in providing quality-based sorting of Learning Objects to teachers. This proves that LORs can effectively use quality metrics that calculate scores based on Learning Object evaluations performed by reviewers to sort by quality the Learning Objects they distribute. The efficacy of this approach to sort Learning Objects by quality is directly dependent on the validity of the evaluation model used to generate the quality scores [273]. Thus, it can be concluded that LORI is a reliable model for evaluating Learning Object quality. Nevertheless, it is worth noting that there will always be differences between the rankings desired by end users and the rankings generated by LORI metrics, since these metrics calculate scores based on the LORI criteria, which are different from the criteria considered by most end users.

For all LORI metrics except LORI TWAM, the covered range of scores were higher or equal to 80% (except for the LORI Orthogonal metric that obtained a range of 67%), the average score error was below 1.0, and the accuracy was below or equal than 1.6. The results achieved by the LORI AM metric were very similar to those achieved by the LORI WAM CW and LORI WAM IW metrics. The only notable difference was that the LORI WAM metrics were slightly better at distributing scores. Further experiments are needed to determine the advantages of using an appropriate set of weights for the LORI criteria. The LORI PWAM metric obtained very positive results in this experiment. This is comprehensible since participants were required to rate the Learning Objects in terms of pedagogical quality. Furthermore, most educators do not pay attention to technological criteria (or are not aware or their importance) when rating Learning Objects. Nevertheless, this metric could achieve much worse results if it was used alone in other situations. Results indicate that the LORI Orthogonal metric was effective to sort Learning Objects by quality, but the covered range of scores was very narrow. The LORI Logarithmic and LORI Square Root metrics were found useful to penalize Learning Objects with extremely low technological or pedagogical scores. The LORI Logarithmic metric achieved the smallest score error and the second widest range.

The LORI TWAM metric, which is based on technological criteria, was found ineffective to sort Learning Objects by quality. The high value recorded by the accuracy parameter (5.6) denotes that this metric is unable to effectively differentiate Learning Objects according to their pedagogical quality. Something similar happened with the LOM Metadata Quality metric, which was found absolutely ineffective to provide quality-based sorting of Learning Objects. These facts point out that measures of reusability or metadata quality should not be used as measures of overall quality of Learning Objects. Despite the LORI TWAM metric is not very useful alone, it can be used to build better quality metrics (e.g. the LORI Logarithmic metric). Although the scores calculated according to the LOM Metadata Quality metric cannot (or should not) be used as overall quality scores, this metric can be used to develop metadata evaluation services, which are essential for LORs. The better the metadata of the Learning Objects of a LOR are, the easier is for users to find and hence to reuse these Learning Objects.

The Interaction Quality metric, which automatically calculated the quality scores of the Learning Objects based on the interactions that end users had with them, obtained satisfactory results regarding its effectiveness in providing quality-based sorting of Learning Objects. The obtained Kendall tau coefficient of 0.61 was satisfactory, but significantly lower than those obtained by the quality metrics based on LORI (except LORI TWAM). Results show that the Interaction Quality metric performed well at distributing scores, calculated scores with a moderate error (M=1.5, SD=1.1), and achieved an acceptable accuracy. In summary, the effectiveness of the metric in sorting Learning Objects by quality was satisfactory, but notably lower than the effectiveness that can be achieved by using LORI quality metrics. The Interaction Quality metric was defined as a predictive metric to estimate scores calculated according to the LORI WAM CW metric (see next chapter for further details). Therefore, since the Interaction Quality metric can predict LORI WAM CW scores with a certain error, it was expected that it was capable of sorting Learning Objects by quality but not as well as the LORI WAM CW metric.

The results of this experiment show that all LORI metrics (except LORI TWAM) and the Interaction Quality metric were effective to a lesser or greater extent in providing quality-based sorting of Learning Objects. Based on these results, it can be suggested that the scores calculated by these quality metrics can be used to enhance Learning Object search services. These services can use the quality scores directly to sort Learning Objects by quality or to create compound ranking metrics that combine quality with other indicators such as similarity to the search query terms, similarity with the user profile, or popularity indicators. Future experiments should investigate the benefits for Learning Object search services of using quality scores in compound ranking metrics.

The results obtained for the “filtering success rate” parameter show how effective was each metric in order to distinguish between high and low quality Learning Objects. The results indicate that all LORI metrics except LORI TWAM can be effectively used to filter low quality Learning Objects. Based on these results, it can be stated that when a Learning Object is scored higher or equal to five according to any of these LORI metrics, such a Learning Object can be considered of high enough quality to be used for education. The filtering success rate obtained for the Interaction Quality metric shows that, in this experiment, this metric was able in most cases to distinguish between high quality and low quality Learning Objects. Although these results suggest that the Interaction Quality metric can be effectively used to filter low quality Learning Objects, it should be taken into account that the error of the score calculated according to this metric can be very large for certain Learning Objects, since scores are automatically calculated based on the interactions of end users. Nevertheless, the obtained results were very positive considering that scores were calculated without human intervention.

5.4.4.3 Experiment C: use of quality metrics to enhance a Learning Object recommender system

Lastly, an A/B test was conducted on the ViSH platform for six months in order to determine if the quality metrics provided by LOEP can be effectively used to enhance Learning Object recommender systems. In this A/B test, the recommendations generated by the ViSH recommender system (hereafter ViSH RS) using quality scores were compared with the recommendations generated by the ViSH RS without using quality scores. The ViSH RS was developed based on a hybrid Learning Object recommendation model that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. The quality scores used by the ViSH RS are the overall quality scores calculated by ViSH for the Learning Objects. As was explained in section 5.4.1, these scores are calculated by using the LORI WAM CW, WBLT-S AM and WBLT-T AM metrics. The Learning Objects that have not been evaluated receive a default overall quality score of 0.5 out of 1. More details about how ViSH calculates these overall quality scores are included in chapter 3 of this thesis. Furthermore, chapter 7 describes the ViSH RS in detail.

On ViSH, when users reach the last slide of an Interactive Presentation created with the ViSH Editor Learning Object authoring tool, they can request recommendations to the ViSH RS by clicking on the “next slide” button. If a user requests recommendations, a new panel is popped up showing six recommended Interactive Presentations. Then, the user can access any of the Interactive Presentations or close the panel, thus rejecting the recommendations. This situation was chosen for the A/B test because it was the only one where an explicit acceptance or rejection of the recommendations is produced. A total of 7,521 recommendations generated during the six months of the test were analyzed. Each recommendation consisted of a ranked list of six Interactive Presentations. Of the 7,521 recommendations, around 60% were generated by the ViSH RS using quality scores, and around 40% were generated by the ViSH RS without using quality scores. Recommendations were compared in terms of acceptance rate, quality of the Learning Objects accessed through the recommendations, and time spent by the users on these Learning Objects. Table 5.22 shows the results of the A/B test.

Table 5.22: Results of the A/B Test of the ViSH Recommender System

	Recommendations generated using quality scores		**Recommendations generated without using quality scores**		**Chi-square test of independence**	
Number of recommendations					**X^2**	**p-value**
Total	4,591		2,930			
Accepted	1,258 (27.4%)		643 (21.9%)		79.8	< 0.001
	M	**SD**	**M**	**SD**	**Independent samples t-test p-value (2-tailed)**	
Accepted Learning Objects						
Quality score (0-10)	7.0	1.5	6.5	1.5	< 0.001	
Time spent (s)	162	232	95	217	< 0.001	

The acceptance rate obtained by the recommendations generated using quality scores (27.4%) was significantly higher than the one obtained by the recommendations generated without using quality scores (21.9%). A chi-square test of independence using an alpha level set at 0.05 was performed to determine if the acceptance rate of the recommendations was independent of the use of quality scores in the recommender system. The result of the chi-square test of independence was X^2=79.8 with p<0.001. Since X^2 is higher than the critical value of 3.8, the independence hypothesis is rejected. Thus, it can be stated that there is a statistically significant relationship between the acceptance rate of the recommendations and the use of quality scores in the recommender system. The recommendations generated using quality scores also outperformed those generated without using quality scores in terms of the quality of the Learning Objects whose recommendations were accepted, and in terms of the time spent by the users on these Learning Objects. Both differences were found to be statistically significant (p<0.001). These results show that the recommendations generated using quality scores made possible for users to discover better and more interesting Learning Objects. In conclusion, it can be stated that the quality scores provided by the LOEP platform can be effectively used to enhance recommender systems.

5.5 Conclusions

This chapter presents the results of the design, implementation and evaluation of LOEP, an open source web-based platform that provides systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. The main components and features of the system are described, as well as its main scenarios of use. Furthermore, the chapter describes one by one the Learning Object evaluation models and quality metrics supported by LOEP. A total of seven evaluation models are supported by the current version of LOEP: LORI 1.5 [273], LOEM [268], WBLT-S and WBLT-T [9], [281], SUS [279], and two new evaluation models, one termed "LOM Metadata Quality" which enables to automatically evaluate the quality of LOM compliant metadata instances, and other one termed "Interaction Quality" which enables to estimate the overall quality of Learning Objects based on the interactions that learners have with them. In addition to the two new evaluation models, the chapter proposes several new quality metrics for Learning Objects.

Several aspects of LOEP were evaluated. First, a quantitative analysis was conducted in a LOEP instance used by two LORs. The results of this analysis provide evidence that LOEP succeeded in allowing the LORs to systematically evaluate and measure the quality of their Learning Objects. Secondly, the user acceptance was evaluated with an online survey among the reviewers registered on the LOEP instance. The results of this survey show that reviewers had a good overall opinion of LOEP and found the system easy to use, and that they strongly believed that LOEP can be very useful for LORs and other e-Learning systems, as well as for educational institutions. Reviewers also indicated that LOEP made their jobs easy and helped them to improve their ability to judge the quality of Learning Objects. Furthermore, reviewers evaluate the usability of LOEP by using SUS questionnaires. The overall SUS score was 84. Finally, three experiments were conducted to evaluate some of the evaluation models and quality metrics supported by LOEP.

In the experiment A, the LORI evaluation model was used by a team of reviewers to evaluate a collection of Learning Objects of a LOR. The results of the experiment show that reviewers perceived LORI as a useful tool to evaluate the quality of Learning Objects. These results also reveal that reviewers without deep technical knowledge have difficulties to judge items related to technological criteria.

Experiment B evaluated the effectiveness of several quality metrics supported by LOEP in providing quality-based sorting of Learning Objects to users, as well as the effectiveness of these metrics in distinguishing between high quality and low quality Learning Objects. Results show that LOEP is able to provide quality scores that can be used to sort Learning Objects by quality as well as to filter low quality Learning Objects. Taking this into account, it was suggested that these quality scores can be used to enhance Learning Object search services. LORI proved to be an effective Learning Object evaluation model for those LORs that can have reviewers to evaluate the submitted Learning Objects. The results of experiment B also show that the Interaction Quality evaluation model provided by LOEP can enable the implementation of useful quality control mechanisms in those LORs that cannot evaluate all submitted Learning Objects using manual evaluation models. Other finding of this experiment is that measures of reusability or metadata quality should not be used as measures of overall quality of Learning Objects.

Experiment C consisted of an A/B test, which was conducted in a LOR for six months in order to determine if the quality metrics provided by LOEP can be effectively used to enhance

Learning Object recommender systems. In the A/B test, the recommendations generated by the recommender system of the LOR using quality scores provided by LOEP were compared with those generated by the same recommender system without using quality scores. The results of the A/B test show that the recommendations generated using quality scores statistically significantly outperformed those generated without using quality scores in terms of acceptance rate, quality of the Learning Objects accessed through the recommendations, and time spent by the end users on these Learning Objects.

In summary, the results of the evaluation presented in this chapter provide evidence that LOEP is an effective system to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems. Results also show that scores provided by LOEP can be effectively used to perform quality-based sorting of Learning Objects, to filter low quality Learning Objects, and to generate better Learning Object recommendations.

The first part of the first research question of this chapter can be answered as follows: “The quality of Learning Objects can be effectively evaluated, measured and transformed into quality scores that can be understood by humans and automatically processed by information systems by using appropriate Learning Object evaluation models, quality metrics and systems”. The validity of the quality scores strongly depends on the evaluation model and quality metric used to generate them. Nonetheless, there are other factors that also influence the validity of the quality scores. For instance, the results of the experiment A reported in this chapter suggested that to reliable evaluate a Learning Object with LORI, such a Learning Object should be evaluated both by educators with knowledge of its subject and by e-Learning experts. Regarding the second part of the first research question, it can be concluded, based on the results reported in this chapter, that the quality scores calculated by using appropriate Learning Object evaluation models, quality metrics and systems can be effectively used to filter low quality Learning Objects, and to enhance Learning Object search services as well as Learning Object recommender systems.

The second research question of this chapter can be answered by enumerating and describing those features that had to be implemented in LOEP to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems. Firstly, a system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems should support multiple evaluation models and quality metrics. The evaluation models should be targeted to different audiences such as reviewers, learners, teachers and end users, and should be able to evaluate Learning Objects according to different criteria such as pedagogical quality, usability, reusability and metadata quality. Furthermore, given that using automatic evaluation models (i.e. models that can be used without human intervention) can bring several benefits in certain scenarios, the implementation of these models should be considered. Whenever possible, Learning Object evaluation systems should rely on evaluation models and quality metrics that have been effectively tested. In this regard, section 2.6 of this thesis provides a comprehensive review of the most relevant Learning Object evaluation models and quality metrics that have been proposed. Moreover, this chapter proposes two new Learning Object evaluation models and several new quality metrics. Besides implementing existing evaluation models and quality metrics, Learning Object evaluation systems should allow the implementation of new models and metrics. Thereby, e-Learning systems will be able to define their own models to evaluate Learning Objects in specific contexts for which the existing models are not appropriate.

Other key feature that a Learning Object evaluation system should have is interoperability with e-Learning systems. A possible option is to use web APIs to establish the communication between the systems. A Learning Object evaluation system should allow the Learning Objects of the e-Learning systems to be evaluated by appointed reviewers, end users of the e-Learning systems, invited users, and automatic evaluation models. Regarding the evaluations from appointed reviewers, one useful feature is to allow administrator users to create assignments in order to distribute the evaluations among the reviewers. These assignments could be created manually, or in an automatic way using different matching algorithms that take into account the profile of the reviewers and the metadata of the Learning Objects. The use of the evaluation system should be transparent for the end users of the e-Learning systems. Thus, these users should be able to evaluate the Learning Objects directly from the e-Learning systems. Other feature that should be considered is to allow the description of the context in which the evaluated Learning Objects have been used to be saved together with the evaluation data. For evaluations performed according to automatic evaluation models, the evaluation system should allow e-Learning systems to provide all required data. For instance, if an evaluation system implements the models proposed in this chapter to automatically measure metadata quality and to automatically estimate the quality of Learning Objects based on the interactions of the end users, such an evaluation system should allow e-Learning systems to provide the metadata of the Learning Objects as well as the needed interaction data. A Learning Object evaluation system should also allow e-Learning systems to obtain, store and use the quality evaluations and scores generated by it, as well as any other evaluation data that may be useful. Thereby, the e-Learning systems could use these evaluation data to implement quality control mechanisms, enhance their features to search and discover Learning Objects, and implement new services. This feature also allows e-Learning systems to integrate the results of the quality evaluations in the metadata of the evaluated Learning Objects.

Lastly, other features that could be useful for Learning Object evaluation systems are the visualization and downloading of evaluation data, Learning Object search by evaluation criteria, generation of statistics on quality evaluations and scores, and comparison of Learning Objects based on evaluation data.

This chapter makes three main contributions. The first contribution is the LOEP open source platform, which is the first system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. LOEP fully supports the evaluation stage of the Learning Object life cycle and can be used by e-Learning systems in many different scenarios and contexts. Besides, it resolves the limitations of existing Learning Object evaluation tools. The work presented in this chapter shows that LOEP is capable of providing systematic evaluation of Learning Objects to e-Learning systems in an open, low cost, reliable and effective way. Furthermore, LOEP has proven to be able to allow e-Learning systems to implement quality control mechanisms and enhance features to search and discover Learning Objects. Therefore, LOEP can help to overcome one of the major barriers to the use and adoption of Learning Objects: the need for LORs to have tools, models and metrics to systematically evaluate and measure the quality of Learning Objects in order to implement effective quality control mechanisms and enhance features to search and discover Learning Objects. Moreover, the development of LOEP has allowed to identify a wide range of features that should be considered in the implementation of systems aimed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems. Therefore, the work exposed in this chapter can drive future development of better Learning Object evaluation systems.

The second contribution of this chapter is the proposal of new evaluation models and quality metrics for Learning Objects. These models and metrics were implemented in LOEP but can be implemented in other systems too. Regarding LORI, the most widely used Learning Object evaluation model, this chapter proposes new quality metrics as well as different weight vectors for the LORI items, a contribution that has been demanded by some researchers [293]. Quality metrics for other existing evaluation models are also proposed. Besides, the chapter proposes two new evaluation models, one to automatically evaluate the metadata quality of Learning Objects, and one to estimate the quality of Learning Objects based on the interactions that learners have with them.

The last contribution of this chapter is the evaluation of several evaluation models and quality metrics for Learning Objects, which provided insights into the benefits for LORs of evaluating Learning Objects, a research topic on which not much work has been done. The results of the evaluation presented in this chapter show that the quality of Learning Objects can be effectively evaluated, measured and transformed into quality scores if appropriate evaluation systems, models and quality metrics are used, and that these quality scores can be effectively used to filter low quality Learning Objects, and to enhance Learning Object search services as well as Learning Object recommender systems.

Chapter 6

A Quality Metric for Learning Objects based on Learning Analytics

Open Educational Resources (OER) have emerged as one of the cornerstones of open education. One of the main barriers hampering their use and adoption is the lack of sustainable and effective quality control mechanisms in OER repositories. Evaluation approaches such as peer review have not been sufficiently scalable to keep up with the fast pace of open content creation by the user community. This chapter presents a new approach grounded on learning analytics to estimate the quality of Learning Objects based on the interactions that learners have with them in open environments. A study was conducted in which 146,291 sessions of learner interactions with 256 Learning Objects distributed through an OER repository were analyzed. A total of 11 learner-Learning Object interaction variables were considered in the study. The quality of the Learning Objects was measured by using LORI (Learning Object Review Instrument). In order to investigate the relationships between the learners' interactions with Learning Objects and the quality of these Learning Objects, as well as to define a predictive quality metric, linear regression analyses were used. The results show that there is a relationship between interactions and quality, and that it is possible to estimate with a moderate error the quality of Learning Objects based on the interactions that learners have with them. Moreover, the results point out that the proposed predictive quality metric can be used in OER repositories to automatically detect low quality Learning Objects. Lastly, this chapter describes the implementation of the predictive metric in an OER repository.

6.1 Introduction

Open Educational Resources (OER) have emerged as one of the cornerstones of open education due to their potential to provide better learning experiences with fewer resources and democratize education by providing universal and equal access to knowledge [201]. The term OER was first defined in 2002 at a UNESCO conference as "the open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes" [194]. Nowadays, the most used definition is the following: "OER are digitised materials offered freely and openly for educators, students and self-learners to use and re-use for teaching, learning and research" [195], [196] (see section 2.3.3 for further details). OER are typically created in the form of Learning Objects in order to maximize their reuse and sharing potential. Other advantage of Learning Objects that should be taken into account is that they can provide more detailed tracking of the interactions of the learners with the learning content. Not all OER are Learning Objects and vice versa, but all open Learning Objects are OER. Therefore, those Learning Object Repositories that distribute open Learning Objects can be considered OER repositories as well. A comprehensive review on Learning Objects, including their relation with OER, is included in section 2.3 of this thesis.

The number of OER available to users has grown dramatically in recent years, mainly because many OER repositories allow anyone to contribute by creating and publishing their own resources. Nevertheless, there are still some barriers hampering the use and adoption of the OER. One of the main barriers is the lack of effective quality control mechanisms in OER repositories [195], [258]. Teachers need some assurance of quality of OER before incorporating them into their teaching, and hence they point to the lack of quality control as a problem when using OER made by others [53]. This need for quality assurance can be even more important for students in learner-centred or self-directed educational settings where they are expected to select their own learning resources, due to the risk of them being misinformed by inaccurate content, or of wasting time with poor instructional designs [284]. Other problem that confirms the need of controlling and measuring the quality of OER is the difficulty that users have in finding suitable e-Learning resources in repositories [43]–[45]. In order to address these needs, OER repositories are implementing different quality control mechanisms [39]. This trend is endorsed by the results of the survey of 59 well-known Learning Object Repositories conducted by Tzikopoulos, Manouselis and Vuorikari [48], which identified 27 repositories that followed some quality control policy, and 23 repositories that had some resource evaluation/rating or review policy. The approaches used by OER repositories to control content quality can be classified mainly in three types [195]: reputation-based approaches, peer review, and community-based mechanisms. In the first case, the brand or reputation of an institution is used to persuade the user that the resources offered by the repository are of good quality. This approach is not appropriate for the OER movement because it can only be applied to materials elaborated by institutions and not to resources contributed by the members of the user community. When using peer review, one or more accredited reviewers evaluate the quality of the resources submitted to the repository. Based on these evaluations, an administrator can decide whether the resources should be accepted for publication or not. This is one of the most popular approaches. Examples of this are the repositories MERLOT [275], [276] and OpenStax CNX (formerly Connexions) [208], [209]. The main problem of peer review is that it is costly in time and does not scale to keep up with the fast pace of open content creation by the user community. A clear example of this fact is that in MERLOT only around 14% of the available resources have been peer reviewed [390]. For this reason, some repositories opt to allow the publication of resources without pre-publication reviews, and to evaluate these resources after publication in order to give more visibility to those with higher quality, for instance, by showing them in the first positions of the search results. The last approach consists of using the interactions of the end users in order to determine the quality of the resources offered by the repository. These interactions may be explicit or implicit. A repository may directly ask users to evaluate content by using online rubrics or rating scales, or may use the number of visits or the number of times resources have been bookmarked or shared on social networks as quality indicators. Clements, Pawlowski and Manouselis [39] indicated that the future trend of Learning Object Repositories that distribute OER is to heavily rely on community-based quality control mechanisms, and they recommended developers of Learning Object Repositories to take a mixed approach for quality assurance by combining peer review and community-based quality control mechanisms.

Some studies have emphasized the importance of seeking new ways of estimating the quality of OER in a sustainable manner [202], [258]. OER repositories need sustainable solutions capable of providing quality assurance for large quantities of resources [39]. This chapter studies the possibility of using learning analytics in order to estimate the quality of Learning Objects based on the interactions that learners have with them in open environments such as OER repositories [394]. The final goal is to define a metric that allows, based on the learners' interactions, to automatically predict the quality that a reviewer would have assigned to a Learning Object if such a reviewer would have evaluated it. Learning analytics can be defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" [297]. Their use cases and benefits are numerous and varied [302]. The learning analytics cycle is comprised of four steps [299]:

1. *Learners' interactions*. The learners interact with e-Learning systems, typically Virtual Learning Environments (VLEs), and with e-Learning resources.
2. *Capture of data*. Data about the learners and their interactions are captured.
3. *Generation of analytics*. Data captured in step 2 are processed into learning analytics in order to provide some insight into the learning process.
4. *Interventions*. Lastly, the learning analytics are used to drive one or more interventions that have some effect on learners.

Further details can be found in the review of the state of the art of learning analytics provided in section 2.7 of this thesis.

Although there are many studies that have addressed learners' interactions with VLEs [97]–[103], there has been scarce research on learners' low-level interactions with Learning Objects. In this regard, Miller and Soh [306] analyzed 1,335 sessions of students with interactive Learning Objects in order to identify a set of significant predictors of learning. The results of this study found that interaction data such as the number of clicks and the time students spend on Learning Objects are significant indicators of learning. In the study conducted by Feng, Heffernan and Koedinger [307], data from 494 students who had interacted with Learning Objects for several months were collected and used to predict their scores on a test. Results showed that learners' interaction data such as the time taken to answer questions, the number of hint requests and the number of attempts were negatively correlated with test scores, while total time spent on Learning Objects was positively correlated. Another relevant work is the one of Muñoz-Merino et al. [289], which presents a generic methodology to determine the effectiveness of students when interacting with e-Learning resources in online courses. This methodology was applied to four particular SPOCs for calculating the effectiveness of videos and self-graded exercises. Effectiveness of videos was calculated as a function of the percentage of video watched by the students while effectiveness of exercises was calculated as a function of the number of times they were solved by the students. The final goal of the measures of effectiveness of the e-Learning resources was to provide feedback to the teachers. A limitation of these three studies ([289], [306], [307]) is that they analyzed student interactions with e-Learning resources with a very particular structure, and therefore it is questionable whether their findings can be generalized to other resources. None of the studies on this topic published so far have analyzed the interactions of learners with Learning Objects in OER repositories, nor have proposed predictive metrics to estimate the quality of Learning Objects based on learners' interactions. These two issues are addressed in this chapter, which reports on a study that investigated the relationships between the learners' interactions with Learning Objects in open environments and the quality of the Learning Objects, and that defined and evaluated a predictive metric to estimate the quality of Learning Objects based on the interactions that learners have with them.

The structure of this chapter is as follows. Next section shows the objective and research question of this thesis covered by the chapter. Section 6.3 describes the research methodology of the study reported in this chapter. Section 6.4 presents the results of the study, including the definition and evaluation of the predictive metric. An implementation of the predictive metric in an OER repository is described in section 6.5. Finally, section 6.6 closes the chapter summarizing the main conclusions.

6.2 Objectives

This chapter tackles the following objective of the thesis:

- *Propose and evaluate new quality metrics for Learning Objects. This goal includes the conception, proposal and evaluation of a predictive metric to estimate the quality of Learning Objects based on the interactions that learners have with them.*

More specifically, this chapter describes, proposes and evaluates a predictive metric based on learning analytics to estimate the quality of Learning Objects based on learners' interactions.

Furthermore, the following research question of the thesis is addressed in this chapter:

- *Is there any relationship between the learners' interactions with a Learning Object and its quality? And if so, is it possible to estimate the quality of Learning Objects based on the interactions that learners have with them?*

The question is answered based on the results of the reported study.

6.3 Research Methodology

The study reported in this chapter has two main goals. The first one is to analyze the learners' interactions with Learning Objects in an OER repository in order to identify which of the interaction data may be significant predictors of the quality of the Learning Objects. The second goal consists of defining and evaluating a predictive metric to estimate the quality of open Learning Objects based on the interactions that learners have with them. By achieving these two goals, the study aims to answer the research question stated in the previous section.

For the study, 146,291 distinct sessions of learner interactions with Learning Objects were analyzed. These sessions involved a total of 256 different Learning Objects. All these Learning Objects were published under open licenses on the ViSH platform [56], which provides an OER repository. A detailed description of ViSH is provided in chapter 3 of this thesis. The Learning Objects had been created by the users of the ViSH community by using an authoring tool called ViSH Editor available on the ViSH platform. This authoring tool allows registered users to create Learning Objects in the form of Interactive Presentations by using and combining different types of resources such as text, images, audios, videos, self-graded questions, PDF documents, SCORM [110] and IMS content packages [113], web applications, Flashcards, Virtual Tours, Enriched Videos, etc. Thereby, although the Learning Objects were created with the same tool, they were varied in terms of content and instructional design. Further details about the ViSH Editor authoring tool can be found in chapter 4 of this thesis. On the ViSH platform, the Learning Objects created with ViSH Editor can be downloaded as SCORM packages so that they can be integrated into Moodle as well as in other SCORM compliant VLEs. Therefore, users accessed the Learning Objects both through the ViSH platform and through VLEs. Interaction data were automatically captured by the Learning Objects. These Learning Objects sent the interaction data of each learner session to the ViSH tracking system, which stored them in the ViSH database (see chapters 3 and 4 for further details). The 146,291 sessions of learner interactions analyzed in this study correspond to a period of 7 months between 1 September 2014 and 31 March 2015. The profile of the learners who used the Learning Objects was very diverse. Some learners used the Learning Objects in subjects of primary, secondary and higher education, while others used Learning Objects in MOOCs or to learn in a self-taught way. Of the 256 Learning Objects involved in the study, 35 (13.7%) were targeted to primary education students, 114 (44.5%) to secondary education students, 50 (19.5%) to higher education students, and 57 (22.3%) were not targeted to any specific educational level.

In order to evaluate the quality of the Learning Objects involved in this study, the LORI (Learning Object Review Instrument) [273] evaluation model was used. More specifically, it was used LORI 1.5, the latest version of LORI, which considers the following nine criteria (also termed LORI items): content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, reusability, and standards compliance. When using LORI, reviewers have to rate each item using a 5-point scale. Further details about LORI can be found in section 2.6 of this thesis. As quality metric to calculate the quality scores of the Learning Objects, the "LORI Weighted Arithmetic Mean" metric proposed and validated in chapter 5 of this thesis was used. This metric calculates the overall score of a Learning Object on a 0-10 scale as the weighted arithmetic mean of all LORI items scores, giving different importance to each criterion. The used weights were those obtained through a survey among the ViSH reviewers (i.e. the collected weights as termed in chapter 5). Each Learning Object was evaluated by at least three reviewers.

In order to study the relationships between the learners' interactions with Learning Objects and the quality of these Learning Objects, linear regression analyses were used. The linear regression analysis technique is used to model a dependent variable through a linear combination of one or more independent variables. When only one independent variable is used, the technique is called simple linear regression analysis. When more than one independent variable is used, it is called multiple linear regression analysis. In this study, the independent variables (hereafter interaction variables) were learning analytics obtained from the data about the interactions between the learners and the Learning Objects, and the dependent variable was the quality of the Learning Objects measured through the LORI evaluation model. Linear regression is more appropriate than correlations for identifying significant predictors and building predictive models. Different examples of the use of linear regression for these purposes can be found in the literature [97], [306], [307]. In this study, simple linear regression analyses were used to individually study the relationship between each interaction variable and the quality of the Learning Objects, and then a multiple linear regression analysis was used in order to define a predictive quality metric based on the identified significant interaction variables.

6.4 Results

A total of 11 learner-Learning Object interaction variables were analyzed in the study. Table 6.1 shows the results of the simple linear regression analyses for these 11 interaction variables, including for each of them the Pearson correlation coefficient, the regression coefficient, and the p-value.

Table 6.1: Correlation and Regression Coefficients between Interaction Variables and Learning Object Quality

Interaction Variable	Pearson Correlation Coefficient	Regression Coefficient	p-value
Average total time spent by the learners on the Learning Object	0.32	0.0019	< **0.001**
Average time spent by the learners on each slide (i.e. on each resource) of the Learning Object	0.19	0.0013	**0.002**
Average minimum time spent by the learners on one slide	0.19	0.0013	**0.002**
Average maximum time spent by the learners on one slide	0.27	0.0016	< **0.001**
Average percentage of visualized slides	0.10	- 0.0063	0.094
Average number of mouse clicks	0.40	0.0843	< **0.001**
Average number of answered quizzes	0.31	1.3612	< **0.001**
Total number of visits to the Learning Object	0.19	0.0001	**0.002**
Permanency rate: percentage of users that did not abandon the Learning Object in the first 30 seconds	0.48	0.0515	< **0.001**
Return rate: percentage of registered users that returned to the Learning Object after the first use	0.00	- 0.0003	0.950
Favorites rate: percentage of registered users that bookmarked the Learning Object as favorite	0.27	0.0373	< **0.001**

* All time variables are expressed in seconds, and averages are calculated by averaging learner sessions

Of the 11 learner-Learning Object interaction variables that were analyzed, 9 were identified as significant predictors of quality (p-value < 0.05). These variables are indicated in bold in the table. Positive regression coefficients were obtained for the 9 significant interaction variables. Therefore, the answer to the first part of the research question is that, in general, there is a relationship between some interactions of the learners with a Learning Object and its quality.

Once identified which of the interaction variables are significant predictors of quality, these interaction variables were used as a basis for defining a predictive quality metric by using a multiple linear regression analysis. Since the quality scores of Learning Objects are calculated on a 0-10 scale according to the used LORI metric, it was necessary to define new normalized variables for the predictive quality metric. Each of these normalized variables was defined as the minimum value between 1 and the value obtained by dividing the original interaction variable by a threshold value. Thereby, the normalized interaction variables always take values between 0 and 1. In this study, the threshold value for each variable was calculated as the 80th percentile of the variable for all the observed Learning Objects. A total of three normalized interaction variables were used to define the predictive quality metric: normalized average time spent, normalized permanency rate, and normalized average frequency of mouse clicks. These interaction variables were chosen because they are independent among them, can be relatively easily calculated by VLEs, and allowed to achieve a satisfactory goodness of fit. To force the regression line to pass through the origin, its constant was set to zero. Table 6.2 summarizes the results of the multiple linear regression analysis.

Table 6.2: Regression Coefficients and Weights of the Interaction Variables of the Predictive Quality Metric

	Interaction Variable	**Regression Coefficient**	**p-value**	**Weight**
s_{t_s}	Normalized average time spent (in seconds)	2.71	< **0.001**	0.303
s_{p_r}	Normalized permanency rate	3.90	< **0.001**	0.435
s_{f_c}	Normalized average frequency of mouse clicks (in clicks per minute)	2.35	< **0.001**	0.262
Regression Statistics				
R^2		0.950		
p-value		< **0.001**		

The value of the coefficient of determination R^2 obtained in the multiple linear regression analysis show that 95% of the variability of the quality of the Learning Objects can be explained by the three considered interaction variables: normalized average time spent, normalized permanency rate, and normalized average frequency of mouse clicks. The p-value (significance value of the F-statistics) indicates that the regression is statistically significant. Furthermore, the results of the multiple linear regression analysis also show that all regression coefficients are statistically significant at the 0.05 level.

Based on the regression coefficients obtained in the multiple linear regression analysis, a weight was calculated for each of the three interaction variables in such a way that all weights sum to one. These weights, which are shown in Table 6.2, were used to define the predictive metric to estimate the quality of Learning Objects based on the learners' interactions according to the following equation:

$$Q(s_{t_s}, s_{p_r}, s_{f_c}) = 10 \times (0.303 \times s_{t_s} + 0.435 \times s_{p_r} + 0.262 \times s_{f_c}), \quad Q \in [0,10] \tag{6.1}$$

where s_{t_s}, s_{p_r}, and s_{f_c} are, respectively, the values on a 0-1 scale of the interaction variables "normalized average time spent", "normalized permanency rate", and "normalized average frequency of mouse clicks" listed in Table 6.2

This metric allows to calculate the quality score on a 0-10 scale for a given Learning Object based on the values of the normalized interaction variables s_{t_s}, s_{p_r} and s_{f_c}. These values can be calculated based on the non-normalized interaction variables t_s (average total time spent by the learners in the Learning Object), p_r (permanency rate), and n_c (average number of mouse clicks) listed in Table 6.1, according to the following equations:

$$s_{t_s}(t_s) = MIN\left(\frac{t_s}{Max_{t_s}}, 1\right) \tag{6.2}$$

where $Max_{t_s} > 0$ is the 80th percentile of the variable t_s in the whole repository to which the Learning Object belongs

$$s_{p_r}(p_r) = MIN\left(\frac{p_r}{Max_{p_r}}\ ,\ 1\right)$$

where $Max_{p_r} > 0$ is the 80th percentile of the variable p_r in the whole repository to which the Learning Object belongs (6.3)

$$s_{f_c}(n_c, t_s) = MIN\left(\frac{\left(\frac{n_c}{t_s/60}\right)}{Max_{f_c}}\ ,\ 1\right)$$

where $fc = \frac{n_c}{t_s/60}$ is the average frequency of mouse clicks per learner session expressed in clicks per minute, and (6.4)

$Max_{f_c} > 0$ is the 80th percentile of the variable f_c in the whole repository to which the Learning Object belongs

The interaction variables t_s , p_r and n_c are learning analytics that can be calculated for each Learning Object by using data about the learners' interactions with the Learning Object. Thus, in order to use this metric, OER repositories need to capture the interactions of the learners with the Learning Objects and process the interaction data into learning analytics.

Figure 6.1 shows, for each of the 256 Learning Objects involved in this study, the quality score measured through LORI and the quality score estimated through the predictive metric by using interaction data. The figure also includes a trend line. The mean square error of the prediction (calculated by comparing predicted and actual quality scores) was 2.41. The mean error was 1.24 with a standard deviation of 0.93. It can be concluded, therefore, that the metric allowed to estimate the quality of Learning Objects with a mean square error of 2.41. The second part of the research question can be answered based on these results as follows: "it is possible to estimate, with a moderate error, the quality of Learning Objects based on the interactions that learners have with them in open environments".

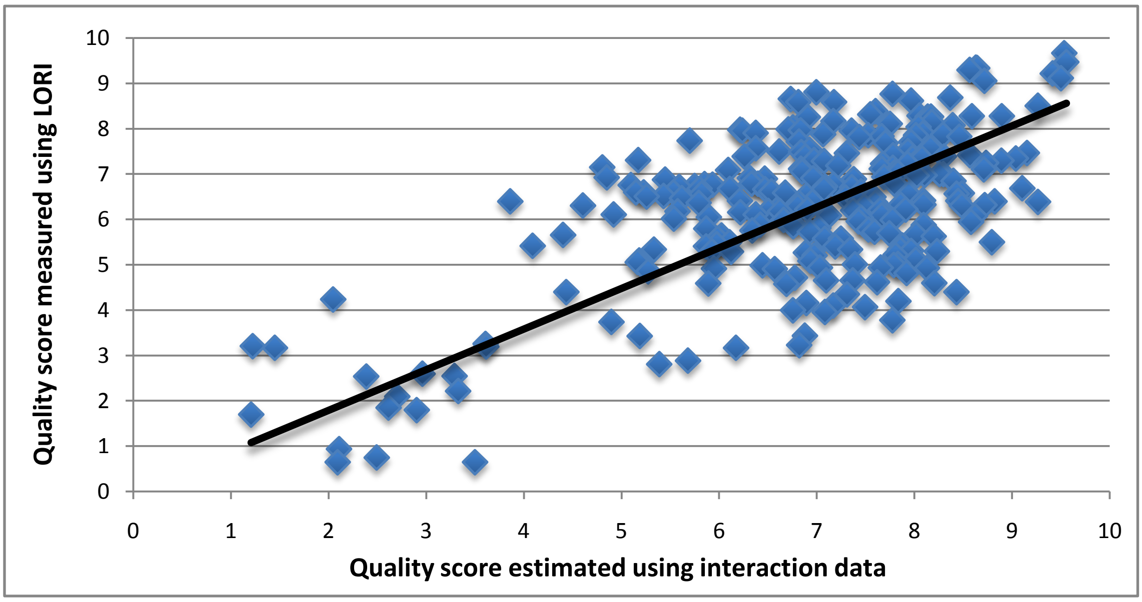

Figure 6.1: Estimated and actual quality scores of the Learning Objects

Finally, the effectiveness of the proposed predictive metric in distinguishing between high quality and low quality Learning Objects was evaluated. When a Learning Object is scored higher or equal to five according to the LORI Weighted Arithmetic Mean quality metric used in this study, such a Learning Object can be considered of high enough quality to be used for education. Further details on this LORI metric can be found in [385] as well as in chapter 5 of this thesis. The predictive metric correctly differentiated between high quality Learning Objects (LORI quality score ≥ 5) and low quality Learning Objects (LORI quality score < 5) in the 90% of the cases. In view of these results, it can be suggested that the predictive quality metric is highly reliable in identifying low quality Learning Objects.

The results of this study prove that there was a relationship between the quality of the Learning Objects of an OER repository and the interactions that learners had with such Learning Objects. The results show that learners tended to spend more time on Learning Objects of higher quality. This was expected because higher quality resources have better content, have higher capacity to motivate and generate interest, are better designed, and are easier to use, which cause learners to spend much more time using and exploring these resources. Interaction data such as the average number of mouse clicks or the average number of answered quizzes were also identified as predictors of quality. This fact points out that high quality Learning Objects can foster active learning. The permanency rate (defined as the percentage of users that do not abandon the Learning Object in the first 30 seconds) has a strong relationship with the quality. This is understandable in an open environment such as an OER repository where many users freely browse for learning resources and only consume those that interest them and have the quality that they deem acceptable. If a user accesses a very poor quality learning resource, it is more than likely that such a user abandons the resource in a short period of time. The results of the study also found that users tended to bookmark as favorites in more occasions the Learning Objects of higher quality. This fact reveals a certain alignment between the opinions of the users and the results of the evaluations carried out by the reviewers through LORI. According to the obtained results, there was hardly any relationship between the total number of visits to the Learning Objects and their quality. The regression coefficient obtained for this interaction variable was almost zero. This is because the number of visits depends heavily on other factors such as advertising, the topic of the resource, and the context of use. For instance, the Learning Objects used in MOOCs receive much more visits than those Learning Objects used in traditional courses regardless their quality. For this reason, OER repositories should not use popularity measures such as the number of visits as quality indicators. A possible alternative for OER repositories is to use the favorites rate, which has proven to be a significant predictor of quality. The average percentage of visualized slides was not identified as a significant predictor of quality. This could be due to the fact that in this study some low quality Learning Objects contained only one slide, thus always recording visualization percentages of 100%.

Lastly, the return rate (defined as the percentage of registered users that return to the Learning Object after the first use) was also not identified as a significant predictor of quality. In general, Learning Objects are small e-Learning resources in terms of the time needed by learners to complete them. Typically, Learning Objects are intended to be completed by a learner in a single uninterrupted period of time of less than one or two hours. In this study, the Learning Objects to which learners returned most frequently were not those of higher quality, but could have been those in which learners did not achieve the learning objectives during the first session or simply those used in several lessons.

The findings of this study are somewhat related with others reported by previous studies. For example, Miller and Soh [306] identified the number of clicks and the time spent by students on Learning Objects as significant predictors of learning. Feng, Heffernan and Koedinger [307] reported that total time spent on Learning Objects was positively correlated with learner performance. Lastly, Agudo-Peregrina, Iglesias-Pradas, Conde-González and Hernández-García [97] found positive correlation between student-content interactions and academic performance in online courses. Nevertheless, it should be pointed out that the study reported in this chapter investigated the relationships of the learners' interactions with the quality of Learning Objects, and not directly with the academic performance. A reasonable hypothesis is that if two Learning Objects address the same learning objectives, the Learning Object with higher quality will be more effective in terms of academic performance. However, the validation of this hypothesis is out of the scope of this work. Other fact that should be noted is that this study analyzed the learners' interactions with Learning Objects in the context of an OER repository. Therefore, the findings of this study can only be applied to OER repositories. Nonetheless, the characteristics of the OER repository and the large sample size of the study suggest that the findings can be generalized to other similar open environments. The relationships between the learners' interactions with Learning Objects and the quality of the Learning Objects can be radically different in closed environments such as private LMSs, or even in different open environments such as MOOC platforms where resources are exclusively consumed in the context of online courses. Therefore, future studies should investigate these relationships in new environments.

This study proposes a predictive metric that allows to estimate with a moderate error the quality of Learning Objects based on the interactions that learners have with them in OER repositories. Three independent interaction variables were considered to define the predictive metric: normalized average time spent, normalized permanency rate, and normalized average frequency of mouse clicks. In order for the time spent variable to be independent of the permanency rate, this time should be calculated considering only those users who do not abandon the Learning Object in the first 30 seconds. The frequency of mouse clicks was used instead of the total number of mouse clicks because this way the interaction variable is independent of the time spent. The rest of interaction variables were not used for different reasons. First, “average percentage of visualized slides” and “return rate” were excluded because they were not identified as significant predictors of quality. The “total number of visits to the Learning Object” was also excluded because its regression coefficient was almost zero. Second, the other time variables (average time spent on each slide, and maximum and minimum time spent on one slide) were excluded because they are not independent of the total time spent. The average number of answered quizzes was identified as a strong significant predictor of quality. However, this interaction variable only makes sense for those Learning Objects that contain quizzes. Thus, this variable was not considered in the definition of the predictive metric because the goal of the study was to propose a generic metric that could be applied to any Learning Object. Thereby, the findings can be generalized to all Learning Objects. A common limitation of previous studies (e.g. [289], [306], [307]) is that they analyzed interactions with e-Learning resources with a very particular structure, and therefore it is questionable whether their findings can be generalized to other resources. In this regard, an interesting future work would be to improve the predictive model by using clustering analysis to classify Learning Objects into different types so that specific metrics could be applied to each of them. This way, a specific metric that also takes into account the number of answered quizzes could be applied to those Learning Objects that contain quizzes. Finally, the favorites rate was also not taken into account to define the predictive metric even though it was identified as a significant predictor of quality. The reason for this was to propose a metric that could be used in open VLEs, even if these systems do not allow users to register or do not provide a favorites feature.

The results of the study also show that the predictive metric was effective in distinguishing between high quality and low quality Learning Objects. More specifically, the metric correctly differentiated between high quality and low quality Learning Objects in the 90% of the cases. A related work can be found in [259], where Cechinel, da Silva Camargo, Sicilia and Sánchez-Alonso presented an approach for Learning Object Repositories to automatically classify web-based Learning Objects between good and not good using only intrinsic features of the Learning Objects such as their number of links, words, images, videos, scripts or files for downloading. In this work, a total of 63 models of artificial neural networks were evaluated using Learning Objects of MERLOT [275]. Quality scores obtained from the evaluations of the MERLOT reviewers were used as the basis to determine the quality of the Learning Objects. Results showed that 16 (25.4%) of the models presented accuracies below 50% (worse than random decisions), 33 (52.4%) presented accuracies between 50% and 59.9%, and 14 (22.2%) presented accuracies greater than 60%. The maximum accuracy obtained by a model was 75%. The accuracy of 90% obtained in this study notably outperforms those obtained in the previously cited work. This fact suggests that quality estimations of Learning Objects based on user interaction data are better than those based on intrinsic features.

The proposed quality metric allows VLEs (such as OER repositories that allow users to use the offered e-Learning resources directly from the web platform) to calculate a quality score for each Learning Object by using the following interaction data: average total time spent by the learners on the Learning Object, permanency rate, and average number of mouse clicks. These interaction data are learning analytics that VLEs can calculate based on the interactions of the users with the Learning Objects. The time spent and the permanency rate can be easily obtained by the VLEs independently of the type of e-Learning resources involved. However, obtaining the number of mouse clicks requires the e-Learning resources to capture interactions of the learners with the content and send the interaction data to the VLE. In this regard, Learning Objects can provide a detailed tracking of the learners' interactions with the content and send the interaction data to the VLEs by using e-Learning standards such as SCORM [110] and xAPI [111]. Next section provides an example of how to implement the proposed quality metric in an open VLE.

6.5 Implementation

In order to validate the approach of estimating the quality of Learning Objects based on the interactions that learners have with them in open environments, the quality metric for Learning Objects based on learning analytics proposed in this chapter was implemented in an OER repository. Concretely, the implementation was made in the ViSH e-Learning platform. Figure 6.2 represents the different systems and processes involved in the generation of the quality scores for the Learning Objects through the use of the proposed quality metric.

ViSH is a web-based e-Learning platform to create and distribute Learning Objects. It consists of a Learning Object Repository enriched with features such as authoring tools, open licensing, a Learning Object evaluation system, a recommender system, and a social network. ViSH can be considered an OER repository since it requires all Learning Objects to be published under open licenses. A full description of ViSH is given in chapter 3 of this thesis.

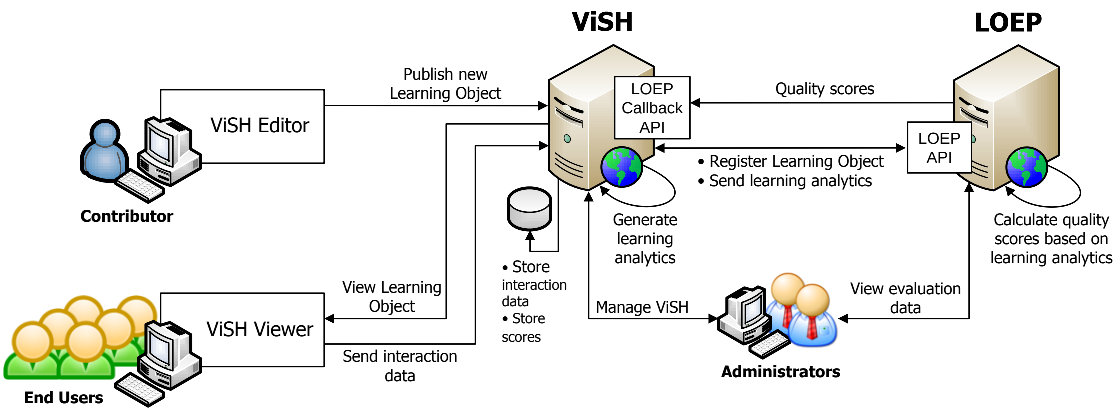

Figure 6.2: Implementation of the Learning Object quality metric based on learning analytics

As was previously explained, the ViSH platform provides an authoring tool called ViSH Editor that allows registered users to create Learning Objects in the form of Interactive Presentations. This authoring tool consists of two main components: an editor (termed ViSH Editor) and a player (termed ViSH Viewer). ViSH Editor is a client-server web application that allows users to create the Learning Objects and publish them on the ViSH platform. ViSH Viewer is a player implemented as a fully client-side web application that allows users to show the Learning Objects created with ViSH Editor in a web browser and interact with them. The use of ViSH Viewer is completely transparent for end users. The end users can access the Learning Objects created with ViSH Editor and published on the ViSH platform from any device with an HTML5 compatible web browser without any installation being needed. Further details of the ViSH Editor authoring tool are provided in chapter 4 of this thesis.

The last system involved in the generation of the quality scores is LOEP, a web-based platform that communicates with ViSH in order to provide it with systematic evaluation of Learning Objects and generation of quality scores. Chapter 5 of this thesis describes LOEP in detail.

Next, this section describes the steps followed from the time a Learning Object is created with ViSH Editor until the ViSH platform obtains the quality scores for that Learning Object calculated based on the interactions that end users had with it.

1. A contributor creates a new Learning Object by using the ViSH Editor authoring tool and publishes this Learning Object on the ViSH platform. On ViSH, Learning Objects are published immediately after their submission.
2. ViSH registers the new Learning Object on LOEP. On this platform, the Learning Object can be evaluated by appointed reviewers or by using automatic evaluation models. Suppose in this case that no evaluation is performed at this time.
3. Once the Learning Object has been published, the end users of ViSH can access and interact with it. The interaction data of each session (i.e. of each uninterrupted period of time a user is accessing the Learning Object) are automatically captured by the Learning Object. More specifically, the interaction data are captured by the ViSH Viewer application that displays the content of the Learning Object. Captured interaction data include among others the total time spent on the Learning Object and the total number of mouse clicks. The interaction data of each session are sent by ViSH Viewer to the tracking system of the ViSH platform just before the user closes the web browser.
4. When the tracking system of ViSH receives the data of a session of end user interactions with the Learning Object, it stores these interaction data in the ViSH database.
5. ViSH periodically processes the stored interaction data in order to generate learning analytics. For each Learning Object, ViSH generates all the learning analytics listed in Table 6.1. These analytics include the three learning analytics required by the Learning

Object quality metric proposed in this chapter: average total time spent by the learners on the Learning Object, permanency rate, and average number of mouse clicks.

6. Once the learning analytics have been generated, ViSH sends them to LOEP.
7. When LOEP receives the learning analytics of the Learning Object (i.e. the learning analytics obtained from the interactions of the end users with the Learning Object), it calculates a quality score on a 0-10 scale for the Learning Object by using the quality metric proposed in this chapter. Thus, quality scores are calculated according to Equation 6.1. The threshold values for all the variables (i.e. the parameters Max_{t_s}, Max_{p_r} and Max_{f_c}) are automatically and periodically calculated by LOEP as the 80th percentile of the variables in the whole repository.
8. Immediately after calculating the quality score for the Learning Object, LOEP sends this quality score to the ViSH platform.
9. Finally, ViSH receives and stores in its database the quality score of the Learning Object calculated based on the interactions that end users had with it.

At this point, an OER repository could use the quality scores for different purposes such as implementing a quality control mechanism or improving features to search and discover Learning Objects. For instance, since the proposed quality metric has been found effective in identifying low quality Learning Objects, it could be used to generate warnings in order to facilitate administrators of OER repositories to detect low quality Learning Objects and stop their distribution. In the case of ViSH, administrators can view and download the evaluation data of the Learning Objects on the LOEP platform. They can also calculate aggregated statistics and compare Learning Objects based on their evaluation data. Figure 6.3 illustrates the evaluation data provided by LOEP for a Learning Object for which a quality score has been calculated by using the proposed quality metric based on learning analytics.

Metric	Evaluation Models	Score
Interaction Quality	**Interaction Quality**	7.29

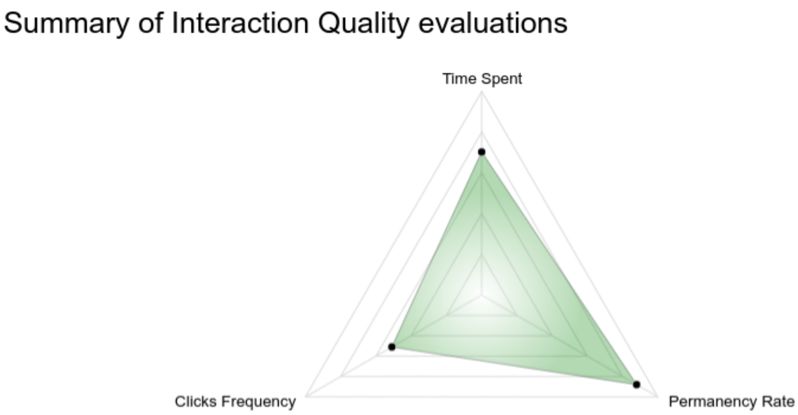

Figure 6.3: Evaluation data obtained from interactions provided by LOEP for a Learning Object

The generated learning analytics as well as the quality scores calculated based on them can also be used to provide feedback to contributors about the estimated quality of the Learning Objects they submit or create. In the case of ViSH, some learning analytics are used to provide feedback to authors about the Learning Objects they have created with ViSH Editor.

Examples of features of OER repositories that could be enhanced with quality scores include search services, recommender systems and catalogues. Concrete examples of how quality scores can be used in OER repositories for the benefit of end users can be found in chapters 3 and 5 of this thesis. The results of an experiment reported in chapter 5 show that the quality metric for Learning Objects based on learning analytics proposed in this chapter and implemented in the ViSH platform was, to a certain extent, effective in providing quality-based sorting of Learning Objects as well as in distinguishing between high and low quality Learning Objects. Notwithstanding, the experiment concluded that this effectiveness was notably lower than the effectiveness that can be achieved by using LORI quality metrics (see experiment B of chapter 5 for details).

It is worth noting that the quality scores calculated based on learning analytics can be used alone or in combination with quality scores obtained through other evaluation models. For instance, an OER repository may use LORI quality scores for those Learning Objects that have been evaluated by reviewers with LORI, and the quality scores obtained based on the interactions of the end users for those Learning Objects that have not been evaluated but that have enough interaction data to do so. Thereby, OER repositories can implement a mixed approach for quality assurance by combining peer review and a community-based quality control mechanism, a recommendation that has been made by some researchers [39].

The implementation described in this section shows that it is possible for OER repositories to implement sustainable quality control mechanisms based on user interactions. The results of this chapter and the results of experiment B of chapter 5 show that the proposed quality metric for Learning Objects based on learning analytics is, to some extent, effective in estimating Learning Object quality, in providing quality-based sorting of Learning Objects, and in distinguishing between high quality and low quality Learning Objects. Therefore, it can be suggested that quality control mechanisms implemented based on this metric can be moderately effective. The systems involved in the implementation of the proposed quality metric address the four steps of the learning analytics cycle. Firstly, the learners interact with the Learning Objects created with ViSH Editor through the ViSH platform. Secondly, the interaction data are captured by ViSH Viewer and sent to ViSH. Thirdly, ViSH processes the interaction data into learning analytics, and sends them to LOEP. Finally, LOEP generates quality scores for the Learning Objects based on these learning analytics and sends them to ViSH, where they can be used for the benefit of the end users. Thereby, the learning analytics cycle is closed. All the systems involved in the implementation of the proposed quality metric are open source.

The source code of ViSH and the source code of the server part of ViSH Editor are available at http://github.com/ging/vish, the source code of ViSH Viewer and the client part of ViSH Editor is available at http://github.com/ging/vish_editor, and the source code of LOEP is available at http://github.com/agordillo/LOEP. An interesting future work would be to develop a new open source learning analytics system, which generates the learning analytics from the captured interaction data and calculates the weights (which are obtained from the regression coefficients) and the threshold values used by the metric in a dynamic way. Thereby, the functionalities related to learning analytics could be migrated to a new system dedicated exclusively to the processing and management of learning analytics.

6.6 Conclusions

This chapter presents a new approach based on learning analytics to estimate the quality of Learning Objects based on the interactions that learners have with them in open environments. Firstly, the chapter reports a study that analyzed 146,291 distinct sessions of learner interactions with 256 different Learning Objects distributed through an OER repository. A total of 11 learner-Learning Object interaction variables were considered in the study (see Table 6.1). The quality of the Learning Objects was measured by using the LORI evaluation model. Each of the Learning Objects involved in the study was evaluated by at least three reviewers. Simple linear regression analyses were used to individually study the relationship between each interaction variable and the quality of the Learning Objects. After that, a multiple linear regression analysis was used in order to define a predictive quality metric based on the identified significant interaction variables.

The results of the study show that 9 of the 11 analyzed interaction variables were identified as significant predictors of quality. The predictive quality metric was defined considering three interaction variables: normalized average time spent, normalized permanency rate, and normalized average frequency of mouse clicks. The results of the multiple linear regression analysis show that 95% of the variability of the quality of the Learning Objects can be explained by the three considered interaction variables. The mean square error of the prediction, calculated by comparing predicted and actual quality scores, was 2.41. Thus, it was concluded that the proposed quality metric is able to estimate, with a moderate error, the quality of Learning Objects based on the interactions that learners have with them in open environments. Besides, the results indicate that the proposed quality metric can be used by OER repositories to automatically detect low quality Learning Objects.

Finally, in order to provide evidence that OER repositories can implement sustainable quality control mechanisms based on end user interactions, this chapter describes the implementation of the proposed predictive quality metric in an OER repository. The results of an experiment show that this implementation of the metric was, to a certain extent, effective in providing quality-based sorting of Learning Objects as well as in distinguishing between high and low quality Learning Objects. Nonetheless, the experiment concluded that this effectiveness was notably lower than the one that can be achieved by using quality metrics based on LORI.

In summary, the work presented in this chapter shows that the proposed quality metric for Learning Objects based on learning analytics can be used by OER repositories to implement sustainable quality control mechanisms with an acceptable effectiveness, as well as to enhance features to search and discover Learning Objects. The approach to control content quality based on learning analytics that the proposed metric enables to implement, unlike peer review, is scalable enough to keep up with the fast pace of open content creation by the user community. This approach allows to automatically detect, with high reliability, low quality Learning Objects based on the learners' interactions. An OER repository can generate warnings to notify its administrators each time a low quality Learning Object is detected. This way, administrators can decide if the distribution of these Learning Objects should be stopped or not. Previous studies had already proved that it is possible to extract pedagogically meaningful information from student interaction data and provide valuable feedback based on this information by using predictive models [99], but this had not been done in the context of an OER repository. OER repositories also have the option to use the quality scores yielded by the quality metric based on learning analytics to implement a completely automated quality control mechanism that does not require human intervention. For instance, they can automatically retract all Learning Objects that obtain a quality score below a certain threshold and for which interaction data of a minimum number of sessions of learner interactions have been processed. Quality control mechanisms of this kind have high scalability and hence are appropriate for OER repositories with large quantities of resources. A limitation of the quality evaluation approach based on learning analytics proposed in this chapter is that Learning Objects cannot be evaluated before being published. Another aspect to consider is that this approach only applies to Learning Objects and not to other educational resources with lower tracking capabilities. Furthermore, its implementation can be complex and laborious since it requires capturing and processing data about the interactions of the learners with the Learning Objects.

Regarding the research question addressed in the chapter, it can be concluded that, in general, in open environments such as OER repositories, there is a relationship between some interactions of the learners with a Learning Object and the quality of such a Learning Object, and it is possible to estimate, with a moderate error, the quality of Learning Objects based on the interactions that learners have with them. The issue of how many sessions of learner interactions a Learning Object needs to have in order to reliably estimate its quality has not been addressed. Future studies should not only address this issue, but also the applicability of the results reported in this chapter to other open environments in which Learning Objects are freely used.

The main contribution of this chapter is the proposal of a quality metric for Learning Objects based on learning analytics. The proposed quality metric allows OER repositories to automatically estimate the quality of Learning Objects based on the interactions that learners have with them. Thereby, the evaluation stage of the Learning Object life cycle can be supported in a sustainable way. Therefore, the metric helps to address one of the major barriers that hamper the use and adoption of open Learning Objects: the lack of sustainable and effective quality control mechanisms in OER repositories. Besides, the metric can be used to enhance features of OER repositories to search and discover Learning Objects such as search services, catalogues and recommender systems. This chapter makes another important contribution by investigating the relationships between the learners' interactions with Learning Objects and the quality of the Learning Objects. A total of 9 out of 11 learner-Learning Object interaction variables were identified as significant predictors of quality. For the first time, these findings provide a theoretical basis for the selection of relevant data about the interactions between learners and Learning Objects in OER repositories.

Chapter 7

A Hybrid Recommendation Model for Learning Object Repositories

Learning Objects play an essential role in the distribution of educational content. These resources are typically distributed through Learning Object Repositories (LORs), which can facilitate users to find suitable Learning Objects by using Recommender Systems (RSs). This chapter presents a hybrid Learning Object recommendation model for LORs that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. The chapter also describes how two RSs have been implemented based on this model for two different LORs: ViSH and Europeana. For each implementation, the covered use cases, the used knowledge sources, and how the recommendation process was applied are described. The two RSs were evaluated in terms of accuracy, utility, user satisfaction and usability. Besides, an A/B test was conducted on ViSH to compare, in the context of a real-world application, the recommendations generated by the RS with random suggestions. Results show that the RSs had a satisfactory accuracy, were perceived as useful, achieved high user satisfaction, were easy to use, and were able to generate recommendations that significantly outperformed random recommendations.

7.1 Introduction

Learning Objects play an essential role in the distribution of educational content. The key difference of Learning Objects with other types of e-Learning resources is that they are designed to improve reusability, which saves time and reduces production costs. In order to facilitate their search and discovery, Learning Objects are tagged with metadata which include information such as their title, description, language, keywords and creation date. This information is usually stored in a structured way according to a metadata standard such as IEEE LOM [119] or Dublin Core [120]. Further details can be found in the review on Learning Objects provided in section 2.3 of this thesis.

Learning Objects are typically distributed through Learning Object Repositories (LORs), a type of web-based digital library used for storing, distributing, discovering and retrieving e-Learning resources. Besides offering Learning Object search services, many LORs offer additional features that allow users to create personal accounts, browse Learning Objects by different criteria, bookmark Learning Objects, rate and comment on Learning Objects, view and download metadata, or use educational tools [47], [48]. Examples of popular LORs that are currently available are MERLOT [275], Europeana [57], OpenStax CNX (formerly

Connexions) [208], [209], LRE [133], and the ODS portal [131], [132]. More examples of LORs can be found in recent surveys and studies [47]–[50], which have identified more than 100 different LORs. The amount of resources available in LORs has grown enormously in recent years, causing users to have difficulty in finding relevant and quality content. Many works have referred to this difficulty that users have in finding suitable Learning Objects in the different LORs available on the Web [43]–[45]. In order to face this problem, LORs can adopt some measures such as the development of easy to use search tools [44], the adoption of ranking metrics [218]–[221], the implementation of quality control mechanisms [39], and the use of Recommender Systems (RSs) [42], [315]–[317], [320]–[330].

RSs are software tools that provide suggestions for items likely to be of use to a user [308], [309]. Based on the techniques used to generate the recommendations different types of RSs can be distinguished [308], [309]. These recommendation techniques differ from each other mainly on the knowledge sources and the recommendation algorithms used. In general, RSs can be classified into the following types:

- *Content-based.* The system learns to recommend items that are similar to the ones that the user liked or found interesting in the past. Recommendations are generated based on the features associated with the items and the ratings and/or actions of the user.
- *Collaborative filtering.* These systems generate item recommendations using only information about ratings or usage from different users.
- *Demographic.* This type of systems recommends items based on the demographic profile of the user. Thus, recommendations are generated based on demographic information such as language, country, age, gender, etc.
- *Knowledge-based.* Knowledge-based recommenders suggest items to the users based on inferences about their needs and preferences.
- *Community-based (social).* These systems provide recommendations of items based on the preferences of the user's friends and contacts.
- *Hybrid.* Hybrid RSs are those that combine two or more techniques to generate the recommendations. Different types of hybrid RSs have been identified based on the type of combination used [309], [310].

RSs can also be classified as proactive or reactive. Proactive RSs differ from reactive RSs in that they automatically provide (or push) recommendations to the users, without explicit requests or actions from them. Furthermore, those RSs that incorporate contextual information (e.g. time, location, current activity of the user or device used) into the recommendation process are called “context-aware recommender systems” [313], [314]. In TEL (Technology-Enhanced Learning) environments, these RSs also usually take into account educational resources that are relevant to the user [314]. Further details on RSs can be found in section 2.8 of this thesis. Besides, that section provides a review of related work on RSs for LORs.

There are numerous recent studies on the use of RSs in e-Learning systems in order to facilitate users the search and discovery of educational resources based on their needs and preferences [42], [330]. Nevertheless, despite the number of RSs proposed for recommending educational resources, a closer look to the current status of the development and evaluation of these RSs reveals that many of them still remain at a design or prototyping stage of development, that many have not been evaluated through trials that involved human users, and that there is a lack of evaluation studies in the context of real-world applications [330]. This lack has also been evidenced in a recent survey of 235 articles on RSs for TEL [334], which found that 40% of them did not reported evaluations of the RSs, and that only around 13% of them reported evaluations through real life testing (i.e. evaluations where real users use the RS under normal conditions over a long period of time). Besides, the survey found that, in many cases, the real life testing was conducted using a prototype implementation of the RS. Only 3 out of the 235 surveyed TEL RSs were evaluated using offline experiments, user studies and real life testing. The survey concluded by stating that there is need for more real life testing of TEL RSs, and that these systems should also be evaluated from the user perspective. With regard to the second issue, several user-centred methods have been developed for evaluating RSs [332], [333]. The main reason why many evaluations are performed on prototypes is because implementing a real-world RS is much more complex than implementing a prototype [395]. When a RS is implemented in a real scenario the environment plays a crucial role. In this regard, [395] proposes to study the environment based on three dimensions: the users, the data used to generate the recommendations (i.e. the knowledge sources), and the overall application into which the RS is going to be integrated. Besides the lack of evaluations of RSs in real scenarios, there is also a lack in the literature of studies evaluating a same recommendation model in different scenarios.

This chapter presents a hybrid Learning Object recommendation model for LORs [396], as well as the implementation and evaluation of two RSs based on this model and applied to two LORs: ViSH [56] and Europeana [57]. For each of these RSs, the accuracy, utility, user satisfaction and usability were evaluated. Moreover, an A/B test was conducted on ViSH to compare the recommendations generated by the RS with random suggestions. Thereby, this chapter contributes to the state of the art of TEL RSs by describing a recommendation model for LORs with distinguishing features, by evaluating the model in two different scenarios, and by providing a complete evaluation of the model in the context of a real-world application.

The organization of the chapter is as follows. Next section shows the objective and research question of this thesis covered by the chapter. Section 7.3 presents the recommendation model. Section 7.4 describes the RSs implemented for ViSH and Europeana based on this model and section 7.5 reports the results of their respective evaluations. Finally, the last section finishes with the conclusions of the chapter.

7.2 Objectives

The following objective of the thesis is addressed in this chapter:

- *Design a recommendation model for Learning Object Repositories, implement a Learning Object recommender system based on it and evaluate this system in a real environment.*

Next section presents the design of a hybrid recommendation model for LORs. The section after that describes how a Learning Object RS for ViSH has been implemented based on this model. Lastly, section 7.5 reports the results of an evaluation of this RS in the context of ViSH. Additionally, this chapter provides a description and evaluation of a RS for Europeana.

The chapter also covers the following research question of the thesis:

- *What kind of recommendation model is suitable for implementing Learning Object recommender systems? Which factors need to be contemplated in their implementation?*

This question is answered based on the results of the design, implementation and evaluation of the two RSs for ViSH and Europeana presented in the chapter.

7.3 Recommendation Model

The recommendation model for LORs proposed in this chapter is represented in Figure 7.1. It is a hybrid recommendation model that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. The model allows to generate proactive recommendations of sets of N Learning Objects.

7.3.1 Use Cases

The recommendation model was designed to support a wide variety of use cases by taking into account the most common activities and features of the LORs. Another factor that was considered was the accesses by anonymous users (i.e. users that have not registered or logged in) who do not have a user profile. This is an important factor since typically there are many accesses from anonymous users in LORs. For instance, on the ViSH platform around 80% of the accesses are performed by non-logged users [396]. Next, the three main use cases of the recommendation model are described.

7.3.1.1 Recommend a list of Learning Objects to a particular user

This is the most common use case. By supporting this use case, a RS can be used, for instance, to show recommendations to users on the homepage, on the user profile page, or in situations in which there is no contextual information. For an anonymous user the recommendations are generated based on the quality and popularity scores of the Learning Objects. If the user is logged in, the profile of such a user can also be used to generate the recommendations. For anonymous users there is also the possibility of generating a virtual user profile throughout the browsing session.

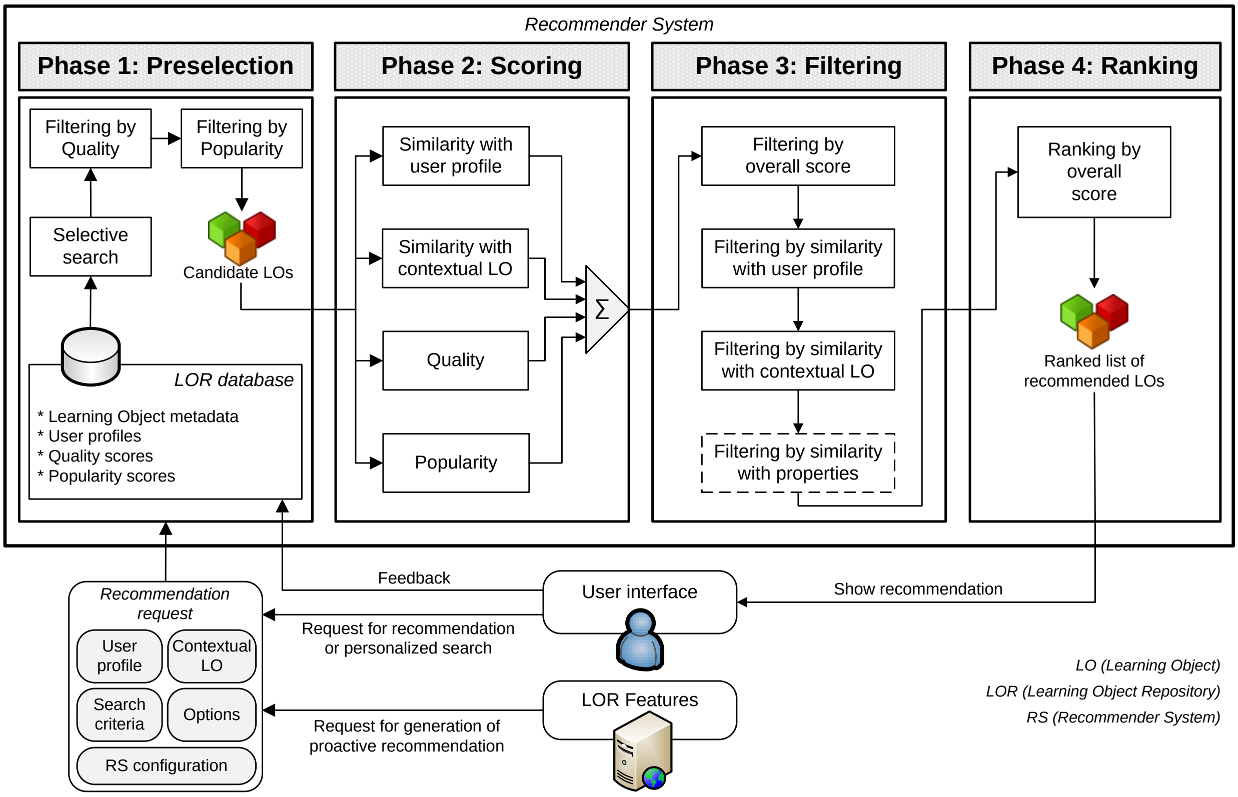

Figure 7.1: Hybrid recommendation model for Learning Object Repositories

7.3.1.2 Recommend to a user Learning Objects similar to other one

Recommending Learning Objects similar to the one the user is viewing is another typical use case. In these situations, the RS can use the Learning Object the user is viewing (which is termed *contextual LO* in the model) to generate the recommendations. Both when accessing the page of the Learning Object as well as after finishing the viewing of the Learning Object are appropriate moments to show these recommendations [321]. It is worth pointing out that for a RS to be able to generate this type of recommendations, it should be context-aware, because it needs to know both the activity performed by the user (view a Learning Object) and the contextual Learning Object. In this use case, the recommendations of Learning Objects are generated based on the similarity with the contextual Learning Object, the quality and popularity scores, and the user profile in the case of identified users.

7.3.1.3 Perform a personalized search of Learning Objects

Although the recommendation model allows to generate proactive recommendations, it also allows a RS to be used in a reactive way to perform personalized searches of Learning Objects (or to respond to explicit recommendation requests from users). When performing a personalized search, the RS acts in a similar way to the first use case except that the recommended Learning Objects are selected from a subset that meets the search criteria.

7.3.2 Knowledge Sources

This section describes the different knowledge sources considered by the model in the recommendation process: Learning Object metadata, user profiles, quality scores, and popularity scores.

7.3.2.1 Learning Object metadata

The recommendation model models the Learning Objects by using properties included in their metadata. The specific properties to use will depend on the environment in which the RS operates. Some of the more common properties, included in the IEEE LOM [119] standard, are title, description, language and keywords. LORs can extend LOM by defining their own application profiles or can use other different metadata formats enabling this way the use of new properties (see section 2.2.2 for further details). The recommendation model allows to use properties of the following types: *text* (e.g. title, description), *number* (e.g. age), *date* (e.g. creation date), *vocabulary* (e.g. category in a catalogue, language), and *list of items of vocabulary type* (e.g. keywords). Within this context, “properties of vocabulary type” are those whose values belong to a defined and finite vocabulary, which can be static or dynamic (e.g. a LOR can have a vocabulary composed of all existing keywords or tags).

7.3.2.2 User profiles

Users are modelled through different types of properties. Within this context, the set of properties that models a user is termed “user profile”. On the one hand, a user profile can include demographic information such as the language, country and age of the user. On the other hand, a user profile can include information explicitly given by the user about his/her tastes and areas of interest. Lastly, a user profile can also include the Learning Objects that the user liked or found interesting in the past, as well as the ones that the user did not like or did not find interesting. Learning Objects are stored in the user profile according to the modelling explained in the above section (i.e. Learning Objects are stored as a set of properties obtained from their metadata). The Learning Objects can be stored together with a numerical rating or a binary variable that indicates the positive or negative opinion or interest of the user. The specific properties to use as well as the way of generating the user profiles will depend on the environment in which the RS operates. In addition to a list of Learning Objects, a user profile can be comprised of properties of the same types as those allowed for the Learning Objects (i.e. *text*, *number*, *date*, *vocabulary*, and *list of items of vocabulary type*). Regarding the way of generating the user profiles, a LOR may opt to obtain the Learning Objects of interest to a user through ratings, by using a favorites feature, or by considering the Learning Objects visited by the user during the browsing session. The recommendation model gives freedom to the LORs to use any of these approaches, even to choose which one of them to use depending on the user profile.

7.3.2.3 Quality scores

Many evaluation models have been proposed to evaluate the quality of Learning Objects such as LORI [273], WBLT-S and WBLT-T [9], [281], COdA [263], HEODAR [264], [265], and LOEI [267]. Besides, some LORs such as MERLOT [275], [276] and LRE [133] have defined their own evaluation models. Learning Object evaluation models can be characterized by several properties including intended audience (e.g. end users, reviewers, learners, teachers or software systems), evaluation criteria (pedagogical, usability, reusability and metadata), and context (e.g. a specific country or educational setting). Furthermore, some Learning Object evaluation models define quality metrics, which allow to quantitatively measure the quality of Learning Objects according to certain criteria. The use of these quality metrics allows to calculate quality scores for the evaluated Learning Objects. A Learning Object quality metric is characterized by the criteria it takes into account, the process it uses to calculate the quality score, and the scale in which the final numerical value is yielded. A comprehensive review on Learning Object evaluation, including descriptions of the most relevant Learning Object evaluation models and quality metrics, is included in section 2.6 of this thesis. Besides, several definitions of Learning Object quality metrics can be found in chapter 5. The recommendation model proposed in this chapter gives freedom to the LORs to choose the Learning Object quality metric to use. The only condition that the LOR must meet is that the quality scores yielded by the metric must be on a 0-1 scale.

7.3.2.4 Popularity scores

Learning Object popularity metrics aim to measure how much Learning Objects are used. These metrics calculate popularity scores for Learning Objects generally by using popularity indicators such as the number of times (or the frequencies with which) the Learning Objects are visited, download, bookmarked or shared. There are works in the literature about the use of popularity metrics for Learning Objects in search services of LORs [219], about the integration of Learning Object popularity indicators and quality indicators [220], and about the use of Learning Object popularity indicators to create popularity, ranking and recommendation metrics [221]. The recommendation model gives freedom to the LORs to choose the Learning Object popularity metric to use. As with the quality scores, the only condition that the LOR must meet is that the popularity scores yielded by the popularity metric must be on a 0-1 scale.

7.3.3 Recommendation Process

The recommendation process is comprised of six steps that are carried out sequentially: recommendation request, preselection phase, scoring phase, filtering phase, ranking phase, and visualization of the recommendation. All these steps are represented in Figure 7.1. Next sections describe each of these steps one by one.

7.3.3.1 Recommendation request

The process starts with a recommendation request that can be made by a user or that can be proactively generated by the LOR. This request indicates the user profile (if any), the contextual Learning Object (for the use case 2), and a set of options (e.g. the number N of desired recommendations). Furthermore, if the RS is going to be used to perform a personalized search (i.e. use case 3), the request should also include the search criteria. The request can also include configuration settings for the RS, such as the weights to be used in the phase 2 (i.e. the scoring phase) or the threshold values to be used by the filters in the phase 3 (i.e. the filtering phase). The idea is that the RS has a default configuration, but that it is flexible enough to allow end users to modify this configuration, either permanently (by specifying settings in their profiles) or for a single request.

7.3.3.2 Phase 1: Preselection

In a LOR with huge amounts of Learning Objects it is not feasible to process all of them in each recommendation request. The goal of this phase is to select from the LOR database an initial set of candidate Learning Objects that can be quickly processed in the next phases. If search criteria have been specified, the RS will obtain an initial set of candidate Learning Objects that meets with such search criteria, in the same way as traditional search engines. For instance, if search query terms are provided in the recommendation request, the RS can compare these terms with the text contained in the metadata of the Learning Objects and returns all Learning Objects that contain the same words. In the preselection of Learning Objects, in addition to quality and popularity filters, a series of preselection filters can be applied in the selective search. The specific filters to use will depend on the scenario of the LOR in which the RS operates. For example, a LOR may opt for recommending to users only those Learning Objects available in their languages. The candidate Learning Objects delivered by this phase are a set of Learning Objects that meet the preselection criteria (e.g. language, minimum quality score, ...) and whose size is less or equal to a maximum preselection size defined by the LOR. These candidate Learning Objects will be used in the next phases. After performing the filtering process in the preselection phase, the amount of candidate Learning Objects can be higher or lower than the permitted maximum size. If the amount is higher than the maximum, the final candidates will be chosen randomly (thus introducing some randomness in the recommendations). Otherwise, the LOR can choose between doing nothing and adding to the set of candidate Learning Objects (which can be empty) other Learning Objects following less restrictive criteria. Depending on the scenario, it could be useful for a LOR that users always receive recommendations in some situations regardless their suitability.

7.3.3.3 Phase 2: Scoring

In this phase, the partial scores and the overall score for each of the candidate Learning Objects delivered by the phase 1 are calculated. The higher the overall score of a Learning Object, the more likely is the Learning Object to be recommended. First, for each candidate Learning Object, a partial score is calculated for each recommendation criterion: similarity with user profile, similarity with contextual Learning Object, quality and popularity. The calculation of all partial scores is not mandatory. For anonymous users without profile the criterion "similarity with user profile" will be skipped, when there is no contextual Learning Object the second criterion will be omitted, and in the case that a LOR does not use quality and/or popularity metrics the other two criteria could also be omitted. In the worst case, if no source of information is available (i.e. there is no user profile, contextual Learning Object, quality scores or popularity scores), the RS will generate random recommendations based on the candidate Learning Objects. Thus, at least one source of information should be provided in each situation.

The metrics used by the RS to calculate the partial scores for the criteria "similarity with user profile" and "similarity with contextual Learning Object" are defined in section 7.3.4. The metrics used to calculate the partial scores for the criteria "quality" and "popularity" should be provided by the LOR. As was mentioned above, the recommendation model gives freedom to the LORs to choose the Learning Object quality and popularity metrics to use. The only condition that the LORs must meet is that the quality and popularity scores calculated by the metrics must be on a 0-1 scale.

The overall score for each candidate Learning Object is calculated by the RS as the weighted arithmetic mean of all its partial scores, giving different importance to each recommendation criterion. Both the partial scores and the overall score are calculated on a 0-1 scale. The relative importance of each criterion is specified by using a set of weights. These weights can have fixed values defined by the LOR or can have values specified by the users (in this case each user would have his/her own set of weights). Equation 7.1 shown below expresses how the overall score of a candidate Learning Object LO is calculated on a 0-1 scale by the RS in the scoring phase, when there is enough information to calculate all partial scores.

$$S(LO,U,CLO) = \begin{pmatrix} W_{Sim_U} \times Sim_{U-LO}(U,LO) + \\ W_{Sim_{CLO}} \times Sim_{LO-LO}(LO,CLO) + \\ W_Q \times Q(LO) + W_P \times P(LO) \end{pmatrix}, \qquad S \in [0,1] \tag{7.1}$$

where U is the profile of the user for which the recommendation is generated,
CLO is the contextual Learning Object as defined in the recommendation model,
$Sim_{U-LO}(U,LO)$ and $Sim_{LO-LO}(LO,CLO)$ are, respectively, the similarity scores
on a 0-1 scale between U and LO and between LO and CLO
calculated according to Equations 7.9 and 7.2,

$Q(LO)$ and $P(LO)$ are, respectively, the quality and popularity scores of LO calculated according to the quality and popularity metrics provided by the LOR,

$W_{Sim_U} \geq 0, W_{Sim_{CLO}} \geq 0, W_Q \geq 0,$ and $W_P \geq 0$ are, respectively, the weights of the recommendation criteria similarity with user profile, similarity with contextual Learning Object, quality, and popularity, and

$$W_{Sim_U} + W_{Sim_{CLO}} + W_Q + W_P = 1$$

As was indicated above, the RS does not calculate the partial scores for those recommendation criteria for which there is no enough information. The expression shown in Equation 7.1 is the one used when there is enough information to calculate the partial scores for all the criteria. In other cases, the terms of the equation corresponding to the omitted recommendation criteria should be dropped. For instance, if there is no contextual Learning Object, the addend "$W_{Sim_{CLO}} \times Sim_{LO-LO}(LO, CLO)$" must be dropped from the equation.

The output of this second phase is the set of candidate Learning Objects delivered in the phase 1, but including for each Learning Object an overall score and four partial scores, one for each recommendation criterion: similarity with user profile, similarity with contextual Learning Object, quality and popularity. For those partial scores that were not calculated, a value of zero is returned. Similarity scores for specific properties can also be provided.

7.3.3.4 Phase 3: Filtering

In this phase, the candidate Learning Objects can be filtered based on the scores calculated in the previous phase. It is possible to filter Learning Objects whose overall score is below a certain threshold value, as well as Learning Objects that do not have a minimum similarity with the user profile or the contextual Learning Object. It is also possible to apply filters to specific properties, for example, to discard those Learning Objects whose description has a similarity score with the contextual Learning Object lower than a certain value. Similarly to the scoring phase, only those filters that apply to the specific use case are used. For instance, if there is no contextual Learning Object, those filters that use it will be not applied. The specific filters to be used by the RS in the filtering phase will depend on the scenario of the LOR in which the RS operates. As with the weights used in the scoring phase, the threshold values of these filters can have fixed values defined by the LOR or can have values specified by the users. The output of this third phase is a subset of the candidate Learning Objects delivered in the phase 1 that meets the filtering criteria, including for each Learning Object its overall score calculated in the phase 2.

Although the phases 2 and 3 are conceptually represented as standalone phases that are carried out sequentially, in practice they can be conducted together in a single process in a more efficient way by applying the filters as soon as possible. Thereby, if a Learning Object is filtered, no more scores are calculated for it.

7.3.3.5 Phase 4: Ranking

Finally, the RS sort the candidate Learning Objects delivered by the filtering phase according to their overall score, and generates the final recommendation as a ranked list of the first N Learning Objects, where N is the number of desired recommendations specified in the recommendation request. If the parameter N has not been specified in the recommendation request, the RS can use a default value defined by the LOR. The output of this last phase is the output of the RS and consists of a ranked list of N recommended Learning Objects.

7.3.3.6 Visualization of the recommendation

In the last step of the recommendation process, the ranked list of recommended Learning Objects generated by the RS is shown in the user interface. The recommendation model gives absolute freedom to the LORs to show the recommendations to users in any way they want.

Finally, it is possible to use explicit and implicit user feedback in order to enhance future recommendations. A user can provide feedback in several ways: by accepting or rejecting a recommendation (this information can be used to improve the user profile), by evaluating a Learning Object (which enables to calculate new quality scores), by sharing or downloading a Learning Object (which may modify its popularity score), by proposing tags for a published Learning Object (enhancing this way its metadata), by explicitly indicating his/her interests (enriching the user profile), by bookmarking a Learning Object as favorite (which can be interpreted as a explicit declaration of interest), by interacting with a Learning Object (users' preferences can be inferred by interpreting user interactions), etc. With regard to the user interactions, it is worth mentioning that user interaction data can also be used to calculate learning analytics [297], which can be used for several purposes including measuring the effectiveness of Learning Objects [289], [290], obtaining feedback about e-Learning resources, activities and tools used by students [289], [303], and defining learner profiles [305]. More information on learning analytics can be found in section 2.7. Furthermore, chapter 6 of this thesis describes a quality metric based on learning analytics that allows to calculate quality scores for Learning Objects based on the interactions that learners have with them.

7.3.4 Similarity Metrics

This section provides the definitions of all the similarity metrics used in the recommendation process to calculate the scores for the recommendation criteria "similarity with user profile" and "similarity with contextual Learning Object". The parameters of the metrics can be adjusted depending on the environment.

7.3.4.1 Learning Object – Learning Object

This metric calculates the similarity score between two Learning Objects LO_x and LO_y on a 0-1 scale according to the following equation:

$$Sim_{LO-LO}(LO_x, LO_y) = \sum_{i=1}^{N} W_i \times Sim_i(LO_{x_i}, LO_{y_i}) \ , \quad Sim_{LO-LO} \in [0,1]$$

where N is the number of properties of the Learning Objects LO_x and LO_y,
LO_{x_i} and LO_{y_i} are, respectively, the i-th properties of LO_x and LO_y,
$Sim_i(LO_{x_i}, LO_{y_i})$ is the similarity score between LO_{x_i} and LO_{y_i} on a 0-1 scale,
which is 0 if LO_{x_i} or LO_{y_i} has a null value, and otherwise is calculated according to Equation 7.3, 7.6, 7.7 or 7.8 depending on the property type, (7.2)
$W_i \geq 0$ is the weight of the i-th property, and

$$\sum_{i=1}^{N} W_i = 1$$

The function Sim_i to be used to calculate the similarity score between two properties with non-null values depends on the property type. The recommendation model allows to use properties of the following types: *text*, *number*, *date*, *vocabulary*, and *list of items of vocabulary type*. The following sections provide the definitions of the similarity metrics used to calculate the similarity scores between properties of these types.

7.3.4.2 Text

The similarity score between two texts is calculated by using the cosine similarity metric and the TF-IDF (Term Frequency-Inverse Document Frequency) function [389] according to the following equation:

$$Sim_{Text}(T_x, T_y) = \begin{cases} 0, \ \ if\ T_x \text{ and } T_y \text{ do not have words in common} \\ \dfrac{\sum_{i=1}^{N} TF\text{–}IDF(word_i, T_x) \times TF\text{–}IDF(word_i, T_y)}{\sqrt{\sum_{i=1}^{N} TF\text{–}IDF(word_i, T_x)^2} \times \sqrt{\sum_{i=1}^{N} TF\text{–}IDF(word_i, T_y)^2}} \ , \ \text{otherwise} \end{cases}$$

$$Sim_{Text} \in [0,1] \tag{7.3}$$

where N is the number of different words in the texts T_x and T_y,
$word_i$ is the i-th of these words, and
$TF\text{–}IDF$ values are calculated according to Equation 7.4 shown below

$$TF\text{–}IDF(W, T) = TF(W, T) \times IDF(W)$$

where $TF(W, T)$ is the number of occurrences of the word W in the text T, and (7.4)
$IDF(W)$ is calculated according to Equation 7.5 shown next

$$IDF(W) = log\left(\frac{2 + N}{1 + N_W}\right) \tag{7.5}$$

where N_W is the number of Learning Objects in the repository whose textual properties contain the word W, and

$N \geq N_W$ is the total number of Learning Objects in the repository

According to the TF-IDF function, the importance of a word in a document is proportional to the number of times that word appears in the document and inversely proportional to how frequently documents in the corpus contain that word.

7.3.4.3 Number and date

The similarity score between two numerical properties with non-null values N_x and N_y is calculated by using the following equation:

$$Sim_{Numbers}(N_x, N_y) = \left(1 - \frac{|N_x - N_y|}{N_{Max} - N_{Min}}\right)^2, \quad Sim_{Numbers} \in [0,1] \tag{7.6}$$

where N_{Min} and N_{Max} are, respectively, the minimum and maximum values of the considered numerical scale,

$N_x \in [N_{Min}, N_{Max}]$, and $N_y \in [N_{Min}, N_{Max}]$

Given that dates can be easily converted to numbers, this similarity metric can also be used to calculate similarities between dates.

7.3.4.4 Vocabulary

The similarity score between two properties of vocabulary type with non-null values V_x and V_y is calculated as follows:

$$Sim_{Vocabulary}(V_x, V_y) = \begin{cases} 1, & if\ V_x \text{ is equal to } V_y \\ 0, & otherwise \end{cases}, \quad Sim_{Vocabulary} \in [0,1] \tag{7.7}$$

7.3.4.5 List of items of vocabulary type

The similarity score between two lists of items of vocabulary type L_x and L_y is calculated according to the following equation:

$$Sim_{Lists}(L_x, L_y) = \begin{cases} 0, & N_{L_x} + N_{L_y} = 0 \\ \frac{2 \times N_C}{N_{L_x} + N_{L_y}}, & N_{L_x} + N_{L_y} > 0 \end{cases}, \quad Sim_{Lists} \in [0,1] \tag{7.8}$$

where N_{L_x} and N_{L_y} are, respectively, the number of items of the lists L_x and L_y, and

N_C is the number of common items between L_x and L_y

7.3.4.6 User – Learning Object

This metric calculates the similarity score between a user with a user profile U and a Learning Object LO on a 0-1 scale according to the following equation:

$$Sim_{U-LO}(U, LO) = W_1 \times Sim_{LO-LOs}(LO, U_1) + \sum_{i=2}^{N} W_i \times Sim_i(U_i, LO_i) \tag{7.9}$$

$$Sim_{U-LO} \in [0,1]$$

where N is the number of properties of the user profile U,

U_i is the i-th property of U, being U_1 the list of Learning Objects stored in U,

LO_i is the property of LO associated with the property U_i,

$Sim_{LO-LOs}(LO, U_1)$ is the similarty score between LO and the list of Learning Objects U_1 calculated according to Equation 7.10,

$Sim_i(U_i, LO_i)$ is the similarity score between U_i and LO_i on a 0-1 scale, which is 0 if U_i or LO_i has a null value, and otherwise is calculated according to Equation 7.3, 7.6, 7.7 or 7.8 depending on the property type,

$W_i \geq 0$ is the weight of U_i, and

$$\sum_{i=1}^{N} W_i = 1$$

The function Sim_{LO-LOs} calculates the similarity score between a Learning Object LO and a list of Learning Objects LOs stored in a user profile in the following way:

$$Sim_{LO-LOs}(LO, LOs) = \begin{cases} 0, & N = 0 \\ \dfrac{\sum_{i=1}^{N} \alpha_i \times Sim_{LO-LO}(LO, LOs_i)}{\sum_{i=1}^{N} |\alpha_i|}, & N > 0 \end{cases}$$

$$Sim_{LO-LOs} \in [0,1], \text{ if } \alpha_i > 0$$

where N is the number of Learning Objects in the list LOs, (7.10)

LOs_i is the i-th Learning Object of the list LOs,

$Sim_{LO-LO}(LO, LOs_i)$ is the similarity score between LO and LOs_i on a 0-1 scale calculated according to Equation 7.2, and

$\alpha_i \neq 0$ is the weight of LOs_i

The parameter α_i represents how much the user likes the Learning Object LOs_i, or the interest degree of the user for the Learning Object LOs_i. This parameter can have a fixed value, a binary value, or take values within a range depending on how users' preferences are collected in the LOR. For instance, a LOR could store in the user profile only those Learning Objects that the user has bookmarked, and set $\alpha_i = 1$ for all of them. A LOR could also store in the user profile those Learning Objects that the user has evaluated through a rating scale, and set the weight α_i of each Learning Object to the numerical rating given by the user. A LOR could even allow the parameter α_i to take negative values if it wants to penalize Learning Objects similar to those that the user did not like or did not find interesting in the past. However, it should be taking into account that in this case the similarity metric defined in Equation 7.10 would yield scores on the scale [-1,1] instead of on the scale [0,1]. For example, a LOR that provides like and dislike buttons for the published Learning Objects could store in the user profile the liked Learning Objects with a weight of $\alpha_i = 1$, and the disliked Learning Objects with a weight of $\alpha_i = -1$.

If a LOR wants to generate recommendations in real time based on the actions of the user during the browsing session, it would be unfeasible, in many cases, to process all the Learning Objects stored in the user profile. The recommendation model has been designed with this issue in mind, and allows to use a subset of the Learning Objects stored in the user profile instead of the whole list. In this case, the RS would use the metric defined in Equation 7.9, but being U_1 a list composed by M Learning Objects randomly chosen among the last N Learning Objects stored in the user profile. Both M and N are parameters that can be configured in the RS.

According to Equation 7.9, the calculation of the similarity scores between users and Learning Objects requires to associate or match some properties of the Learning Objects with properties of the user profiles, and calculate the similarities between them. The specific association or matching to use should be defined by the LOR based on the modelling of the Learning Objects and the user profiles. Table 7.1 shows some examples of possible associations between properties of Learning Objects considered by the IEEE LOM [119] standard, and properties of user profiles that are often provided by LORs' users or that can be easily obtained. More associations could be established by a LOR by using other LOM metadata fields such as learning resource type, interactivity type, difficulty and typical learning time, and other user information considered by e-Learning standards like IMS LIP [159] and IEEE PAPI Learner [161], such as learning goals, learning related history, competencies and academic achievement. It is worth noting that to calculate the similarity score between a property of a user profile and an associated property of a Learning Object using the metrics defined above, both properties need to be of the same type and, in the case of properties of vocabulary type, they also need to belong to the same vocabulary. Thus, if, for instance, a LOR would associate the typical age range of the Learning Objects with the date of birth of the users, it would need to convert the typical age range into a number (e.g. the middle value of the range) and the date of birth into a number (e.g. the current age of the user) in order to calculate the similarity score between a Learning Object and a user.

Table 7.1: Possible Associations between Properties of Learning Objects and of User Profiles

Learning Object Property	**User Profile Property**
Language	Preferred language Known languages Country
Keywords	Areas of interest Field of expertise
Typical Age Range Educational Context	Date of birth Age
Intended end user role	Occupation

7.4 Implementation

The Learning Object recommendation model proposed in this chapter and described in the above section has been used to implement two RSs for two different LORs: ViSH [56] and Europeana [57]. This section describes the implementations of these RSs as well as the different scenarios.

7.4.1 ViSH

ViSH is a web-based e-Learning platform to create and distribute Learning Objects. At present, the ViSH platform is publicly available at http://vishub.org. It consists of a LOR enriched with features such as authoring tools, a Learning Object evaluation system, a social network, collections, open licensing and learning analytics. ViSH also provides a RS that was implemented based on the Learning Object recommendation model for LORs presented in this chapter. On ViSH, users can upload and publish their e-Learning resources as well as create and publish Learning Objects by using web-based authoring tools available on the platform. The most important resources of the ViSH platform are the Interactive Presentations, a type of Learning Object created by the users of the ViSH community with an authoring tool called ViSH Editor. These Interactive Presentations consists of a series of slides that can integrate different types of resources including text, images, videos, audios, self-graded questions, SCORM [110] and IMS content packages [113], web applications, Flashcards, Virtual Tours and Enriched Videos. On the ViSH web portal, the Interactive Presentations are referred to as "Virtual Excursions". Figure 7.2 shows an example of an Interactive Presentation published on the ViSH platform. Further details about the Interactive Presentations can be found in chapter 4 of this thesis, which presents the ViSH Editor Learning Object authoring tool.

Figure 7.2: Learning Object published on the ViSH platform

On the ViSH platform, users can search, use and download e-Learning resources without registering. Users only need to register to create and publish content, to use the social network features, or to use additional services offered by the platform such as the favorites feature, which allows users to save resources in a personal collection. Both ViSH and its RS, which was developed based on the recommendation model proposed in this chapter, are open source and their source code is available at http://github.com/ging/vish. Further details on ViSH can be found in chapter 3 of this thesis, which provides a detailed description of the ViSH platform.

7.4.1.1 Use cases

In the ViSH scenario there are three situations in which recommendations are shown to users:

1. When registered users enter on their homepage, a section with several resources recommended for them is shown (see Figure 3.8 in chapter 3).
2. When users access the page of a resource, ViSH shows a list of suggested resources in a sidebar on the right side (see Figure 7.2).
3. When users reach the last slide of an Interactive Presentation (like the one of Figure 7.2), they can request recommendations to the ViSH RS by clicking on the "next slide" button. If a user requests recommendations, a new panel is popped up showing six recommended Learning Objects (see Figure 7.3).

The first situation can only occur for registered users while the others may also occur for anonymous users.

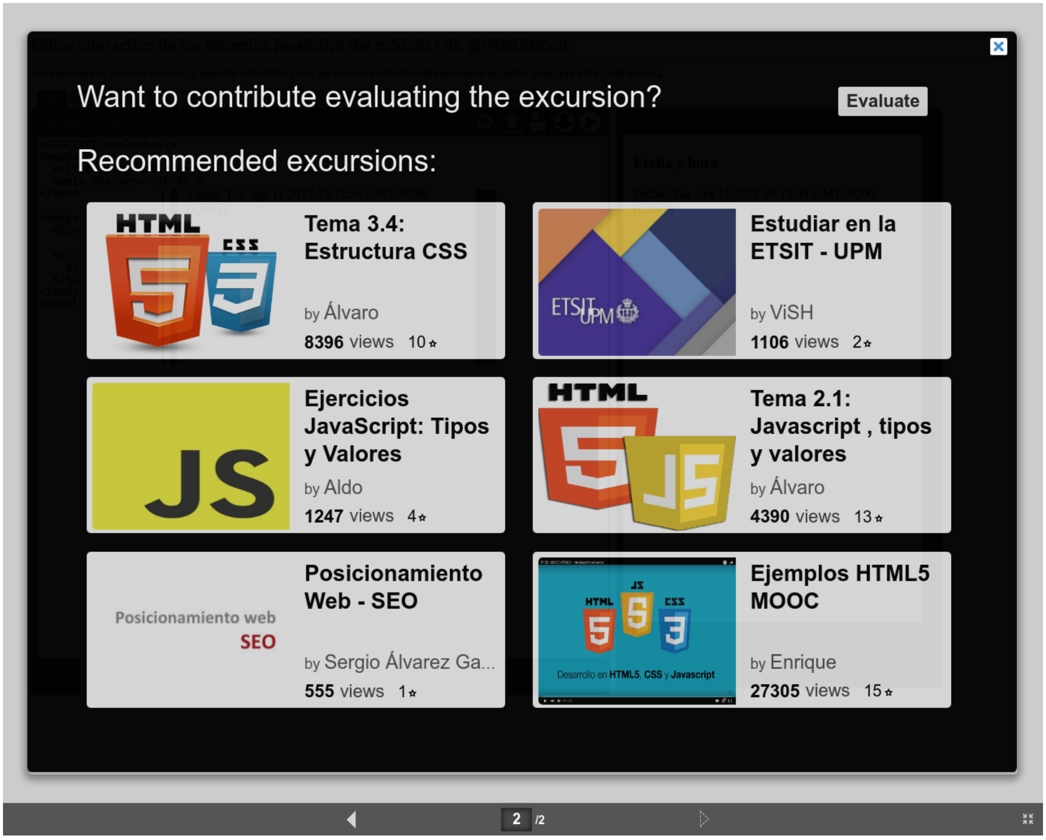

Figure 7.3: Recommendations shown in an Interactive Presentation of the ViSH platform

7.4.1.2 Learning Objects

All the Learning Objects of the ViSH platform are tagged with metadata compliant with the IEEE LOM (Learning Object Metadata) [119] standard. In order to implement the RS of the ViSH platform based on the presented recommendation model, the Learning Objects were modelled by using the following properties: title (type=*text*, weight=0.2), description (*text*, 0.1), language (*vocabulary*, 0.5), and keywords (*list of items of vocabulary type*, 0.2).

7.4.1.3 User profiles

The users were modelled through their language (type=*vocabulary*, weight=0.25), areas of interest (*list of items of vocabulary type*, 0.25), and a list with the Learning Objects that they found interesting in the past (weight=0.5). This list of Learning Objects is automatically updated as the user accesses Learning Objects during the session. More specifically, each time a registered user accesses an Interactive Presentation, that Interactive Presentation is stored in his/her user profile (with a weight of $\alpha = 1$). In order to generate the recommendations, the RS uses 1 random Learning Object of the last 4 Learning Objects stored in the user profile.

7.4.1.4 Quality scores

ViSH has an evaluation system that allows to obtain quality evaluations of the Interactive Presentations from different sources. On the one hand, these Learning Objects can be evaluated by end users with the evaluation models WBLT-S and WBLT-T [9], [281]. WBLT-S is intended to be used by those end users who are learners, and WBLT-T is intended to be used by those end users who are teachers. Besides evaluations from end users, ViSH has a team of reviewers dedicated to evaluating the published Interactive Presentations by using the LORI [273] evaluation model. Based on the evaluations performed according to the different Learning Object evaluation models, ViSH calculates an overall quality score on a 0-1 scale for each evaluated Interactive Presentation. At present, only Interactive Presentations are evaluated by end users and reviewers in the ViSH platform. The other types of resources, as well as the Interactive Presentations that have not been evaluated, receive a default overall quality score of 0.5 out of 1. Thus, all resources of the ViSH platform have an overall quality score. These overall quality scores are the ones used by the ViSH RS to generate the recommendations. Details about the ViSH evaluation system as well as the definition of the metric used to calculate the overall quality scores for the Interactive Presentations are included in chapter 3 of this thesis, which describes the ViSH platform. Furthermore, details about the Learning Object evaluation models used by the ViSH evaluation system can be found in chapter 5 of this thesis, including the definitions of the metrics used to transform the Learning Object evaluations performed according to these models into quality scores.

7.4.1.5 Popularity scores

ViSH calculates popularity scores on a 0-1 scale for all its resources by using popularity metrics. These popularity scores are the ones used by the ViSH RS to generate the recommendations. ViSH uses two different popularity metrics: one for those resources that can be downloaded (e.g. videos, SCORM packages, Interactive Presentations), and another one for those resources that cannot be downloaded (e.g. links). On the one hand, the popularity of downloadable resources is calculated based on the frequencies with which the resources are visited, bookmarked and downloaded. On the other hand, the popularity of non-downloadable resources is calculated based on the frequencies with which the resources are visited and bookmarked. The definitions of the popularity metrics used by ViSH to calculate the popularity scores are included in chapter 3 of this thesis.

7.4.1.6 Recommendation process

In the preselection phase, the ViSH RS applies a quality filter with a threshold value of 0.4, and two preselection filters: language and resource type. The language preselection filter restricts the recommendations to Learning Objects whose content is in a language known to the user or in the same language as the contextual Learning Object. The resource type preselection filter ensures that when the contextual Learning Object is an Interactive Presentation, only other Interactive Presentations are recommended. If the contextual Learning Object is of another type (a PDF document, for example), any resource can be recommended. Thereby, if a Spanish student accesses to an Interactive Presentation in English language, this student will receive recommendations of other Interactive Presentations either in English or Spanish language, whose quality scores are higher or equal than 0.4 out of 1. Another peculiarity of the preselection phase of the ViSH RS, is that when there is a contextual Learning Object, other Learning Objects created by the same author are randomly chosen and added to the preselection. If the amount of candidate Learning Objects is lower than the number of requested recommendations after performing the filtering process in the preselection phase, the ViSH RS adds Learning Objects skipping the language preselection filter (but applying the quality and resource type filters) until the amount of candidate Learning Objects is equal to the number of requested recommendations. Thereby, ViSH aims to provide recommendations whenever possible.

In the phase 2 (i.e. the scoring phase), the ViSH RS uses the weights shown in Table 7.2. As can be seen in the table, these weights will vary depending on whether the recommendations are generated for identified users or for anonymous users, and on the existence of a contextual Learning Object (CLO). In the phase 3 (i.e. the filtering phase), the ViSH RS does not apply additional filters ensuring this way that users will always receive recommendations. Thus, the only filter used in the recommendation process is the quality filter applied in the preselection.

Table 7.2: Weights used by the ViSH Recommender System

Recommendation Criterion	Weights used by the ViSH RS			
	Identified User		Anonymous User	
	With CLO	Without CLO	With CLO	Without CLO
Similarity with user profile	0.2	0.8	-	-
Similarity with CLO	0.6	-	0.8	-
Quality	0.1	0.1	0.1	0.5
Popularity	0.1	0.1	0.1	0.5

CLO (Contextual Learning Object)

In each of the three situations in which recommendations are shown on the ViSH platform, these recommendations are shown in a different way. On the homepage, the recommendations are shown to registered users in a row (see Figure 3.8 in chapter 3). On the resource page, the recommendations are shown in a sidebar (see Figure 7.2). This is the most usual way in which the recommendations are shown. Lastly, when users request recommendations from an Interactive Presentation, these recommendations are shown in a panel (see Figure 7.3).

There are several ways in which explicit and implicit user feedback is used in ViSH in order to enhance the future recommendations. On the one hand, end users can evaluate published Interactive Presentations by using the WBLT-S and WBLT-T [9], [281] Learning Object evaluation models. Based on these evaluations, new quality scores are generated for the evaluated Learning Objects. On the other hand, the popularity scores of the resources depend on the number of times that users visit, download and bookmark as favorite these resources. Therefore, the actions of the users modify the popularity scores of the resources that can be recommended. By default, the user interface of ViSH is displayed in the language identified in the locale settings of the user's web browser, or in English if that language is not supported. End users can change this language at any time, which is used by the ViSH RS to generate the recommendations. Registered users can also explicitly specify their areas of interest (in the form of tags) on their ViSH profile page. Furthermore, when a registered user accesses an Interactive Presentation, this Interactive Presentation is automatically stored in his/her user profile. The ViSH platform is also capable of generating quality scores for the Interactive Presentations based on the interactions that users have with them (see chapter 6 for details). However, these quality scores are currently not used by the ViSH RS.

Finally, it is worth mentioning that the ViSH RS allows ViSH to specify several settings for the recommendation process, including the preselection filters that should be applied, the weights used in the scoring phase, the threshold values of the filters that can be used in the third phase to filter Learning Objects based on their similarity with user profiles, contextual Learning Objects and specific properties (these filters are disabled by default but can be enabled), and the number of Learning Objects stored in the user profile used to generate the recommendations. The settings shown in this section are the ones currently used in the ViSH platform.

7.4.2 Europeana

Europeana is a digital repository that provides access to millions of digitised materials from European museums, libraries, archives and multimedia collections. Its main goal is to provide access to Europe's scientific and cultural heritage through one single access point, its web portal, which is available at http://www.europeana.eu. Currently, Europeana provides access to more than 50 million of resources from across Europe. These resources include books, journals, newspapers, paintings, photographs, music, sounds, videos, TV and radio broadcasts, films, etc. The Europeana foundation aims to increase the use and reuse of these resources in the educational area during the next years [397]. Europeana does not store the resources but it stores their metadata. The web portal provides links to the resources and shows information included in their metadata (e.g. title, description, language, date, license, and provenance). Users can search for resources without registering, but they need to register on the Europeana portal to use the favorites feature or other additional services. Europeana also offers APIs to allow third-party applications to access to its digital resources [398]. More information about the Europeana repository can be found at [399].

In this scenario, the RS was implemented as a standalone application capable of generating recommendations of Learning Objects retrieved from Europeana through its API. This application is called EuropeanaRS and was implemented based on the Learning Object recommendation model for LORs presented in this chapter. Besides the RS itself, EuropeanaRS provides a web portal. Figure 7.4 shows the frontpage of this web portal.

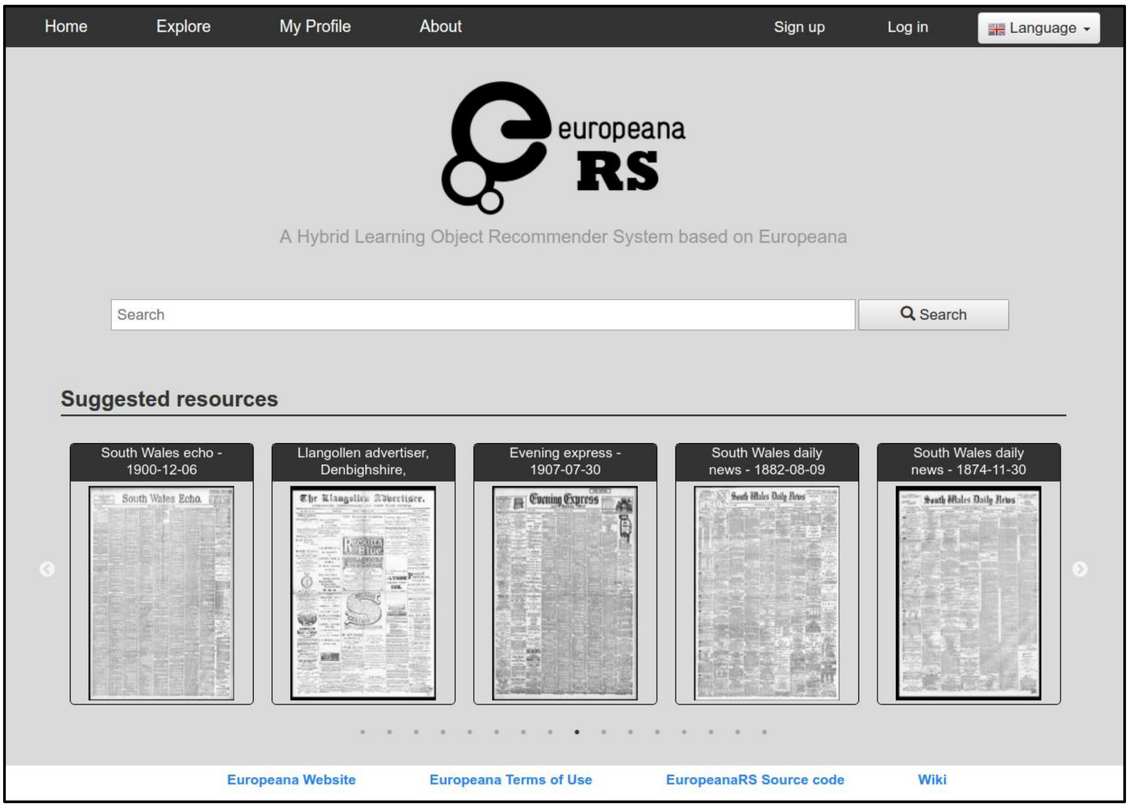

Figure 7.4: Frontpage of the EuropeanaRS portal

The EuropeanaRS portal provides several services to users, including a Learning Object search tool, viewing of Learning Objects, a favorites feature, and user profile edition. Figure 7.5 illustrates how a Learning Object of Europeana and their corresponding recommendations are displayed in the EuropeanaRS portal. Users can access the EuropeanaRS portal and search and view Learning Objects without registering, as well as receive recommendations. However, to use the favorites feature and edit their profile they need to register. Users can also login to EuropeanaRS using their Europeana credentials. In this case, the user profile is imported from Europeana including the list of favorite Learning Objects. EuropeanaRS is open source and its source code is available at http://github.com/agordillo/EuropeanaRS. Besides, a wiki of EuropeanaRS is available at http://github.com/agordillo/EuropeanaRS/wiki, which includes various documentation such as installation and deployment instructions, configuration guides, and API specifications. An instance of EuropeanaRS was deployed on the Web and populated with 12,380 digitised issues of historical newspapers from different countries and years, which were retrieved from Europeana by using EuropeanaRS. Figure 7.5 shows one of these resources. This instance was used to evaluate EuropeanaRS in this scenario.

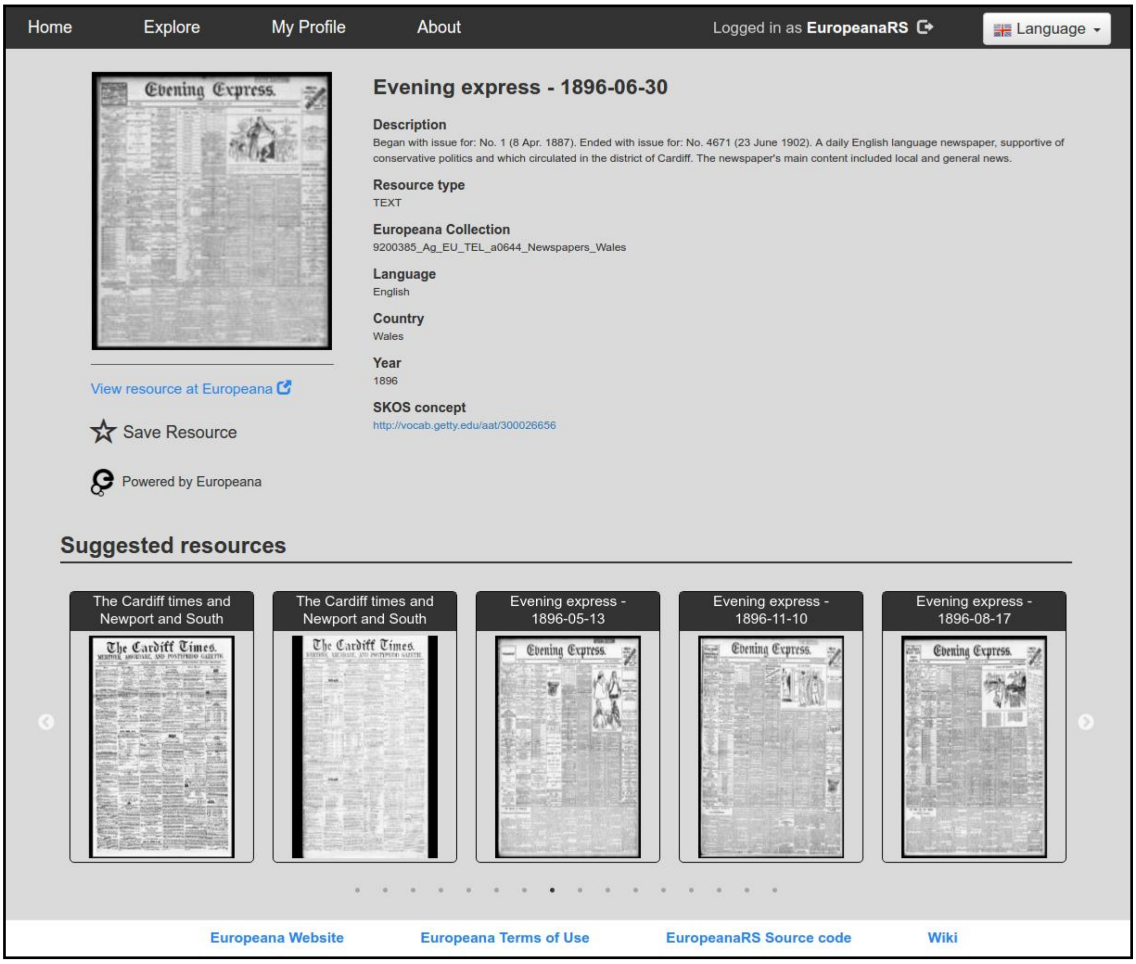

Figure 7.5: Learning Object of Europeana in the EuropeanaRS portal

7.4.2.1 Use cases

In this second scenario there are two situations in which Learning Objects are recommended:

1. When users enter on the frontpage of the EuropeanaRS portal, several newspaper issues recommended for them are shown in a carousel (see Figure 7.4).
2. When users access the page of a newspaper issue, EuropeanaRS shows a list of suggested newspaper issues in a carousel (see Figure 7.5).

Both situations can occur for registered and anonymous users.

7.4.2.2 Learning Objects

The Learning Objects of Europeana have metadata compliant with the EDM data model [400]. For the implementation of the RS in this scenario based on the presented recommendation model, a set of Learning Objects composed by 12,380 digitised issues of historical newspapers from different countries and years retrieved from Europeana were used. These Learning Objects were modelled by using the following properties: title (type=*text*, weight=0.2), description (*text*, 0.15), language (*vocabulary*, 0.5), and year of publication (*date*, 0.15).

7.4.2.3 User profiles

The users were modelled through their language (type=*vocabulary*, weight=0.2) and a list with the Learning Objects that they found interesting in the past (weight=0.8). In this scenario, for registered users, this list is composed by the Learning Objects added to favorites. For anonymous users, a virtual user profile is created and the last accessed Learning Objects are stored in it. A weight of $\alpha = 1$ is set for all Learning Objects stored in the user profiles. In order to generate the recommendations in this scenario, EuropeanaRS uses 2 random Learning Objects of the last 5 Learning Objects stored in the user profile.

7.4.2.4 Quality and popularity scores

At the time this work was undertaken, Europeana did not provide measurements of pedagogical quality for the Learning Objects, nor did provide popularity indicators or usage statistics for the Learning Objects. Therefore, quality and popularity scores were not used in this scenario.

7.4.2.5 Recommendation process

In this scenario, EuropeanaRS applies a language preselection filter in the preselection phase, which restricts the recommendations to Learning Objects whose content is in a language known to the user, in the same language as the contextual Learning Object, or in the language of any of the Learning Objects saved in the user's list of favorites. EuropeanaRS also supports other preselection filters (quality, popularity and resource type), but they were not used in this scenario. EuropeanaRS allows to use two different data sources to generate recommendations. On the one hand, EuropeanaRS can recommend Learning Objects from Europeana by using the Europeana API. On the other hand, it can recommend Learning Objects from the EuropeanaRS database. In this regard, EuropeanaRS provides features to populate its database by retrieving Learning Objects from Europeana. A hybrid approach where Learning Objects both from Europeana and the EuropeanaRS database are recommended can also be used. In this scenario, recommendations were generated using only the EuropeanaRS database, which was populated with 12,380 digitised newspaper issues retrieved from Europeana. If the amount of candidate Learning Objects is lower than the number of requested recommendations after performing the filtering process in the preselection phase, EuropeanaRS does not take any additional action.

Unlike the ViSH RS, EuropeanaRS allows users to modify some settings of the RS from the web portal. Concretely, users can modify the weights used in the scoring phase and the threshold values of all filters used in the recommendation process. The weights used by default in this scenario are shown in Table 7.3. As in the ViSH RS, these weights will vary depending on the existence of a contextual Learning Object. However, since in this scenario a virtual user profile is automatically build for anonymous users, the same weights will be used regardless of whether the recommendations are generated for identified users or for anonymous users. The weights used to calculate similarities between Learning Objects and between user profiles and Learning Objects can also be customized by the users. The default values of these weights are those indicated in the above sections. In the filtering phase, EuropeanaRS allows to filter Learning Objects by their similarity with the user profile, by their similarity with the contextual Learning Object, by the similarity of their properties (title, description, language and year) with those of the contextual Learning Object, and by the similarity with the properties of the user profiles (language and list of Learning Objects). The default threshold values of all these filters are 0, but they can be customized by the users.

On the EuropeanaRS portal, recommendations are always shown in a carousel (as shown in Figures 7.4 and 7.5). EuropeanaRS also provides an API that allows external applications to request recommendations of Europeana Learning Objects. In this case, the way in which the recommendations are displayed would depend on the application that requested them. In this scenario users receive recommendations exclusively through the web portal of the deployed EuropeanaRS instance. Thus, they are always shown in a carousel.

Table 7.3: Default Weights used by the Recommender System for Europeana

Recommendation Criterion	**Default Weights used by EuropeanaRS**			
	Identified User		**Anonymous User (with Virtual User Profile)**	
	With CLO	**Without CLO**	**With CLO**	**Without CLO**
Similarity with user profile	0.5	1	0.5	1
Similarity with CLO	0.5	-	0.5	-
Quality	0	0	0	0
Popularity	0	0	0	0

CLO (Contextual Learning Object)

There are some ways in this scenario in which user feedback is used by EuropeanaRS in order to generate personalized recommendations. On the one hand, EuropeanaRS uses the language and Learning Objects stored in the user profiles. Registered users can set the language of its profile through the web portal (on the registration form and on the user profile page). For anonymous users, the language of the user interface, which they can change at any time, is used by EuropeanaRS to generate the recommendations. Initially, this language is set to the language identified in the locale settings of the user's web browser (or to English if the identified language is not supported). Regarding the Learning Objects stored in the user profiles, EuropeanaRS uses the lists of Learning Objects bookmarked as favorites by the registered users to generate recommendations for them. These favorites lists can be built within EuropeanaRS or they can be imported from the Europeana repository. In the case of anonymous users, a virtual user profile is generated. The language of a virtual user profile is the one that the user has set for the user interface, and the list of Learning Objects is automatically generated by adding the last Learning Objects the user has visited in EuropeanaRS. On the other hand, registered users can explicitly define in the EuropeanaRS portal the weights and the threshold values of the filters that EuropeanaRS should use to generate their recommendations.

Finally, it is worth pointing out that several settings of the recommendation process can be specified in a EuropeanaRS instance, including the preselection filters that should be applied, the data source used to generate Learning Object recommendations (Europeana, EuropeanaRS or both), the default weights used in the scoring phase, the default threshold values of the filters that can be used in the filtering phase, and the number of Learning Objects stored in the user profile considered to generate the recommendations. The settings shown in this section are the ones of the EuropeanaRS instance used in this scenario.

7.5 Evaluation and Results

7.5.1 Evaluation Study

An evaluation study was conducted to evaluate the RSs for ViSH and Europeana implemented based on the Learning Object recommendation model for LORs presented in this chapter. In this evaluation study, 20 people were recruited to evaluate each RS. Thereby, the ViSH RS was evaluated by 20 users, 14 males and 6 females, 22 to 60 years of age (M=37.5, SD=13.3), and EuropeanaRS was evaluated by other 20 users, 16 males and 4 females, 22 to 60 years of age (M=31.6, SD=10.0). The evaluations were performed in the scenarios described in the above section, that is, in the ViSH platform available at http://vishub.org, and in the EuropeanaRS instance deployed on the Web and populated with 12,380 digitised newspaper issues. Participants performed the evaluation on their own computers through a web browser and following a guide. This guide asked participants to complete the following steps:

1. Register in the corresponding web platform: ViSH or EuropeanaRS.
2. Follow a guided tour to learn how to use the main services offered by the web platform: search and viewing of Learning Objects, favorites feature, user profile edition, recommendations, etc.
3. Carry out four tasks related to the Learning Object search service of the web platform. Users were also encouraged to explore and freely use the system.
4. Find at least five Learning Objects relevant or interesting to the user and add them to the favorites list. In the case of ViSH, participants were asked to find Interactive Presentations while in EuropeanaRS participants were asked to find newspaper issues.
5. Complete an evaluation questionnaire. This questionnaire included 14 questions of the ResQue (Recommender systems' Quality of user experience) model [333], the System Usability Scale (SUS) [279], and a question asking for an overall opinion of the RS.
6. In this step, a list of recommendations with 12 randomly sorted Learning Objects is presented to the user. The user is required to rate the relevance of each of the 12 Learning Objects of the list on a 5-point scale ranging from 1 (not at all relevant to me) to 5 (very relevant to me).
7. Finally, a Learning Object of the repository is shown to the user together with a new list of recommendations with 12 randomly sorted Learning Objects. In this new situation, the user is required to rate the relevance of each of the 12 recommended Learning Objects using the same scale as in the previous step.

7.5.2 Accuracy

The accuracy of the RSs was evaluated in an offline experiment through the leave-one-out cross-validation method. The Learning Objects stored in the users' favorites lists were used to perform the leave-one-out analyses. For each user, it was measured how often the left-out Learning Object appeared in the top N recommended Learning Objects, for N equals 1, 5, 10 and 20. Therefore, this experiment measured, for each user, how often a Learning Object from his/her favorites list was recommended by the RS based on his/her profile and favorites list but without using such a Learning Object. Figure 7.6 shows the results of the experiment.

For the accuracy evaluation of the ViSH RS, all information available in the ViSH database at the time of the experiment was used. In total, the data of 950 users whose lists of favorites had on average 3.8 Learning Objects were used. The remaining users, whose lists of favorites were empty, were not taken into account. Besides, only Interactive Presentations were considered for the evaluation because they are the only Learning Objects for which ViSH calculates quality scores based on human evaluations. At the time of this experiment, there were approximately 1,150 Interactive Presentations published on the ViSH platform, of which around 25% had been evaluated by reviewers or end users.

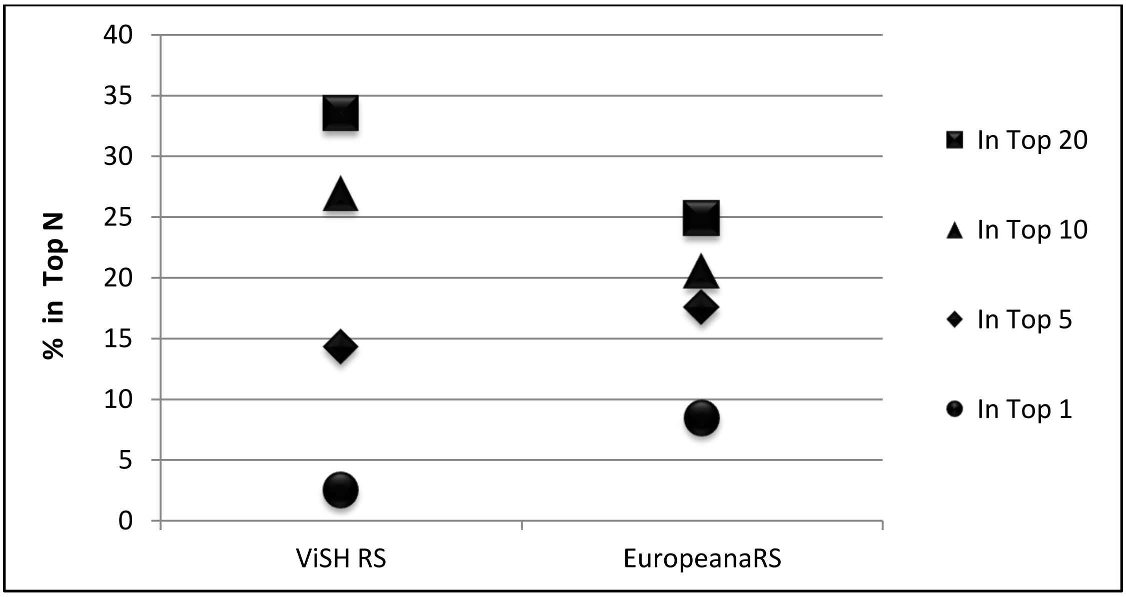

Figure 7.6: Accuracy of the Recommender Systems for ViSH and Europeana. Results of the leave-one-out analyses

For the accuracy evaluation of EuropeanaRS, the data of the 20 users who participated in the EuropeanaRS evaluation study were used. These users stored, on average, 5.25 Learning Objects in their lists of favorites. A total of 12,380 Learning Objects were available in the EuropeanaRS instance used in this evaluation.

At the time of this experiment, the accuracy of a system that randomly recommends published Interactive Presentations in the ViSH platform would be lower than 1.8% in the best case (N=20). In the EuropeanaRS instance used in this evaluation, the accuracy of a system that randomly recommends newspaper issues would be lower than 0.17% for N=20. The results of the leave-one-out analyses show that the accuracies of the ViSH RS and EuropeanaRS were, respectively, 33.5% and 24.9% for N=20. These accuracies are immensely higher than the one that can be obtained by a system that generates random recommendations.

7.5.3 Utility of the Recommendations

In the evaluation study, lists with Learning Object recommendations were presented to the participants in two different situations. In the first situation, the recommended Learning Objects were presented to the participants as specific recommendations for their users. In the second situation, a Learning Object of the repository was shown to the users together with the list of recommendations. The Learning Object showed in this situation was automatically selected for each user by taking into account his/her profile and list of favorites. In the case of ViSH, the showed Learning Objects were Interactive Presentations, and in the case of EuropeanaRS these Learning Objects were newspaper issues. Each of these two situations corresponds to one of the main use cases of the recommendation model presented in this chapter: “recommend a list of Learning Objects to a particular user” and “recommend to a user Learning Objects similar to other one”. The lists of recommendations were built by concatenating a list of 6 Learning Objects generated by the RS and another list of 6 Learning Objects randomly chosen from the same set of Learning Objects used by the RS. Then, the lists were shuffled. Thereby, each of the lists had 12 randomly sorted Learning Objects, of which 6 were real recommendations generated by the RS, and the other 6 were Learning Objects chosen at random. In the first situation, the RSs generated the recommendations based on the user profiles and, in the case of ViSH, quality and popularity scores of the Learning Objects. In the second situation, recommendations were generated also based on the similarity with the contextual Learning Object (i.e. the Learning Object shown together with the list of recommendations). Users rated the relevance of each of the Learning Object recommendations on a 5-point scale ranging from 1 (not at all relevant to me) to 5 (very relevant to me).

In order to measure the utility of the recommendations generated by the RSs and of the random recommendations, a variation of the R-Score metric [311], [401] was used. The R-Score metric assumes that the utility of a list of recommendations is additive, given by the sum of the utilities of the individual recommendations. It also assumes that the utility of the recommendations decreases exponentially as their position in the ranked list decreases. According to the R-Score metric, the utility score of a list of recommendations L for a user is calculated as follows:

$$R_U = \sum_{j=1}^{N_L} \frac{MAX(S_j - d, 0)}{2^{\frac{j-1}{\alpha-1}}} \tag{7.11}$$

where N_L is the number of items of the list L,
S_j is the rating given by the user to the item in the j-th position of the list L,
d is an adjustable threshold value that determines the minimum rating than the user should give to an item in order to consider that item useful, and
$\alpha > 1$ is a half-life parameter that controls the exponential decrease of the utility of the recommendations based on their position in the list L

In order to measure the utility of the recommendations presented to a set of users, the R-Score metric can be used to calculate an overall score according to the following equation:

$$R = 100 \times \frac{\sum_{i=1}^{N_U} R_i}{\sum_{i=1}^{N_U} R_{i_{MAX}}} \tag{7.12}$$

where N_U is the number of users that have rated a list of recommendations,
R_i is the utility score for the i-th user calculated using the R-Score metric (Equation 7.11), and
$R_{i_{MAX}}$ is the utility score of the best possible ranking for the i-th user also calculated using the R-Score metric

In this evaluation, a new metric termed "normalized R-Score" was used to measure the utility of the recommendations generated by the RSs and of the random recommendations. This metric was defined by modifying the original R-Score metric to yield values on a 0-1 scale. The normalized R-Score metric calculates the utility score of a set of lists of N_L recommendations presented to a set of N_U users on a 0-1 scale according to the following equation:

$$R = \frac{1}{N_U} \times \sum_{i=1}^{N_U} \frac{\sum_{j=1}^{N_L} \frac{MAX(S_{ij} - d, 0)}{2^{\frac{j-1}{\alpha-1}}}}{\sum_{j=1}^{N_L} \frac{S_{MAX} - d}{2^{\frac{j-1}{\alpha-1}}}}, \quad R \in [0,1]$$

where N_U is the number of users that have rated a list of N_L recommendations,
S_{ij} is the rating given by the i-th user to the item in the j-th position of the list,
$S_{MAX} \geq S_{ij}$ is the maximum rating that a user can give to an item, (7.13)
$d < S_{MAX}$ is an adjustable threshold value that determines the minimum rating than an user should give to an item in order to consider that item useful, and
$\alpha > 1$ is a half-life parameter that controls the exponential decrease of the utility of the recommendations based on their position in the list

According to the normalized R-Score metric, the maximum utility of a set of recommendations is 1, and is achieved when all users give the maximum rating S_{MAX} to all the recommended items. Conversely, the minimum utility of a set of recommendations is 0, and is obtained when all users give ratings lower or equal than the threshold value d to all the recommended items. In this evaluation, S_{MAX} was 5 since users rated Learning Objects on a 1-5 scale, the threshold value d was set to 2, and the α parameter was set to 3.5.

Table 7.4 shows, for each of the two scenarios (ViSH and EuropeanaRS) and for each of the two use cases, the utility score calculated with the normalized R-Score metric for the lists of Learning Object recommendations generated by the RS (column *RS*), and for the lists of Learning Objects randomly chosen from the same set of Learning Objects used by the RS (column *Random*). The utility scores of the recommendations generated by the RSs were equal or higher than 0.72 out of 1 in all scenarios and use cases. These utility scores were notably higher than those achieved by the random recommendations.

Table 7.4: Utility of the Recommendations calculated with the Normalized R-Score Metric

ViSH				**EuropeanaRS**			
Use Case 1		**Use Case 2**		**Use Case 1**		**Use Case 2**	
RS	**Random**	**RS**	**Random**	**RS**	**Random**	**RS**	**Random**
0.84	0.22	0.90	0.09	0.79	0.20	0.72	0.14

7.5.4 User Satisfaction and Usability

The user satisfaction and usability were evaluated through a questionnaire that included 14 questions of the ResQue (Recommender systems' Quality of user experience) model [333], the System Usability Scale (SUS) [279], and a question asking for an overall opinion of the RS.

ResQue is a model that aims to assess the perceived qualities of RSs such as their usability, usefulness, interface and interaction qualities, and user satisfaction. The model also aims to assess the influence of these qualities on users' behavioral intentions. ResQue consists of 13 constructs and a total of 60 question items. A simplified version of ResQue has been also defined, which consists of 15 questions. This simplified version can be used to perform a quick and easy usability and adoption evaluation of a RS. Users should indicate their answers to each of the questions of the ResQue model using a 1-5 Likert scale, where 1 indicates "strongly disagree" and 5 indicates "strongly agree". In the questionnaire used in this evaluation, a total of 14 questions from the ResQue model were incorporated (see Table 7.5).

SUS is a simple 10-item scale giving a global view of subjective evaluations of systems usability. Each of the 10 items should be answered by users on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Half of the items are positively worded and half are negatively worded. SUS defines a metric that yields a score on a 0-100 scale representing a composite measure of the overall usability of the system being evaluated. See section 2.6 for further details on SUS.

Lastly, the questionnaire included a question asking for an overall opinion of the RS. Users answered this question using a 5-point scale ranging from 1 (awful) to 5 (excellent).

The questionnaire was completed by all the participants of the evaluation study. In the case of ViSH, the questionnaire was also completed by 30 regular users of the platform. Thereby, a total of 50 questionnaires were collected for the ViSH RS, and a total of 20 questionnaires were collected for EuropeanaRS. Of the 50 users who completed the questionnaire for the ViSH RS, 34 were males and 16 were females. These users were aged between 22 and 60 years (M=35.7, SD=11.5). Table 7.5 presents the results of the questionnaire, including for each question the mean value (M) and the standard deviation (SD).

The results of this evaluation show that users had a good overall opinion of the RSs implemented for ViSH (M=4.4, SD=0.6) and Europeana (M=4.1, SD=0.8). Users rated the RSs positively in terms of quality of the recommendations, interface adequacy, perceived ease of use, perceived usefulness, transparency, trust and overall satisfaction. All included questions of the ResQue model received ratings higher than 3.8 (on a 1-5 scale) for the ViSH RS, and higher than 3.1 for EuropeanaRS. The average of the ratings given to the ResQue questions was 4.3 for the ViSH RS and 3.8 for EuropeanaRS. Both RSs obtained an overall SUS score of 84 out of 100, which indicates that they have a high usability. All positively worded SUS items were rated above 3.6, while all negatively worded SUS items were rated below 1.8.

Table 7.5: Results of the User Satisfaction and Usability Evaluation of the Recommender Systems for ViSH and Europeana

	ViSH RS (N=50)		**EuropeanaRS (N=20)**	
	M	**SD**	**M**	**SD**
What is your overall opinion of the recommender system? 1 (awful) – 5 (excellent)	4.4	0.6	4.1	0.8
ResQue items 1 (strongly disagree) - 5 (strongly agree)				
1. The resources recommended to me matched my interests	4.4	0.8	4.1	0.8
2. Some of the recommended resources are familiar to me	4.2	0.7	3.8	1.2
3. The resources recommended to me are attractive	4.2	0.7	3.9	0.9
4. The resources recommended to me are novel and interesting	3.9	0.9	3.6	0.9
5. The resources recommended to me are diverse	3.9	1.0	3.2	1.4
6. I understood why the resources were recommended to me	4.1	1.0	3.9	1.3
7. The layout of the recommender interface is attractive and adequate	4.6	0.6	3.9	1.4
8. I easily found the recommended resources	4.7	0.6	4.5	1.1
9. I was able to take advantage of the recommender very quickly	4.4	0.9	4.1	1.1
10. The recommended resources effectively helped me find the ideal Learning Object	4.1	0.8	3.7	1.4
11. I feel supported to find what I like with the help of the recommender	4.2	0.8	3.8	1.1
12. Overall, I am satisfied with the recommender	4.5	0.7	3.8	1.2
13. I am confident I will like the resources recommended to me	4.1	0.9	3.5	1.1
14. I will use this type of recommender frequently	4.2	1.0	3.8	1.1
SUS Score 0 – 100	84	12.2	84	17.3
SUS items 1 (strongly disagree) - 5 (strongly agree)				
1. I think that I would like to use this system frequently	4.3	0.8	3.7	1.3
2. I found the system unnecessarily complex	1.6	1.0	1.7	0.9
3. I thought the system was easy to use	4.1	1.2	4.2	1.2
4. I think that I would need the support of a technical person to be able to use this system	1.5	1.0	1.3	0.7
5. I found the various functions in this system were well integrated	4.3	0.9	4.1	1.1
6. I thought there was too much inconsistency in this system	1.4	0.9	1.5	0.8
7. I would imagine that most people would learn to use this system very quickly	4.2	1.0	4.6	0.7
8. I found the system very cumbersome to use	1.4	0.9	1.6	1.1
9. I felt very confident using the system	4.3	0.7	4.4	0.8
10. I needed to learn a lot of things before I could get going with this system	1.5	1.0	1.3	0.6

7.5.5 A/B Test

An A/B test was conducted on the ViSH platform in order to evaluate the implemented RS in the context of a real-world application. The A/B test was run for a period of six months. In this A/B test, the recommendations generated by the ViSH RS implemented based on the recommendation model for LORs presented in this chapter were compared with random recommendations (i.e. recommendations of Learning Objects randomly chosen from the same set of Learning Objects used by the ViSH RS).

As was indicated in section 7.4.1.1, when users reach the last slide of an Interactive Presentation (like the one of Figure 7.2), they can request recommendations to the ViSH RS by clicking on the “next slide” button. If a user requests recommendations, a new panel is popped up showing six recommended Interactive Presentations (see Figure 7.3). Then, the user can access any of the Interactive Presentations or close the panel, thus rejecting the recommendations. This situation was chosen for the A/B test because it was the only one where an explicit acceptance or rejection of the recommendations is produced. Only Interactive Presentations are recommended in this situation because, as was explained in section 7.4.1.6, the ViSH RS applies a resource type preselection filter that ensures that when the contextual Learning Object is an Interactive Presentation, only other Interactive Presentations are recommended. A total of 8,979 recommendations generated in the indicated situation during the six months of the test were analyzed. Each recommendation consisted of a ranked list of six Interactive Presentations provided by ViSH. Of the 8,979 recommendations, around 50% were generated by the ViSH RS, and around 50% were generated by a system that randomly chose Interactive Presentations from the same set of Learning Objects used by the ViSH RS. Recommendations were compared in terms of acceptance rate, quality of the Learning Objects accessed through the recommendations, and time spent by the users on these Learning Objects. Table 7.6 exposes the results of the A/B test.

Table 7.6: Results of the A/B Test on the ViSH Platform

	Recommendations generated by the ViSH RS		**Random Recommendations**		**Chi-square test of independence**	
Number of recommendations					X^2	**p-value**
Total	4,591		4,388			
Accepted	1,258 (27.4%)		567 (12.9%)		856	< 0.001
	M	**SD**	**M**	**SD**	**Independent samples t-test p-value (2-tailed)**	
Accepted Learning Objects						
Quality score (0-10)	7.0	1.5	5.5	1.4	< 0.001	
Time spent (s)	162	232	63	163	< 0.001	

The acceptance rate obtained by the recommendations generated by the ViSH RS (27.4%) was significantly higher than the one obtained by the random recommendations (12.9%). A chi-square test of independence using an alpha level set at 0.05 was performed to determine if the acceptance rate of the recommendations was independent of the use of the RS. The result of the chi-square test of independence was $X^2=856$ with $p<0.001$. Since X^2 is higher than the critical value of 3.8, the independence hypothesis is rejected. Thus, it can be stated that there is a statistically significant relationship between the acceptance rate of the recommendations and the use of the RS. The recommendations generated by the ViSH RS also outperformed the random recommendations in terms of the quality of the Learning Objects whose recommendations were accepted, and in terms of the time spent by the users on these Learning Objects. Both differences were found to be statistically significant ($p<0.001$). These results show that the recommendations generated by the ViSH RS made possible for users to discover better and more interesting Learning Objects.

7.6 Conclusions

This chapter presents a hybrid Learning Object recommendation model for Learning Object Repositories (LORs) that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. The model supports three main use cases: recommend a list of Learning Objects to a particular user, recommend to a user Learning Objects similar to other one, and perform a personalized search of Learning Objects. In order to generate the recommendations, four knowledge sources are considered: Learning Object metadata, user profiles, quality scores, and popularity scores. The recommendation process defined by the model is comprised of six steps that are carried out sequentially: recommendation request, preselection phase, scoring phase, filtering phase, ranking phase, and visualization of the recommendation. The chapter also describes how two recommender systems (RSs) have been implemented based on the presented model for two different LORs: ViSH [56] and Europeana [57]. For each these two implementations, the chapter describes the covered use cases, the used knowledge sources, and how the recommendation process was applied. The ViSH RS was implemented as part of the ViSH platform while the RS for Europeana was implemented as a standalone application called EuropeanaRS, which is capable of generating recommendations of Learning Objects retrieved from Europeana through its API. Finally, the chapter reports the results of the evaluations of the implemented RSs. Each RS was evaluated in a different scenario. For each RS, the accuracy, utility, user satisfaction and usability were evaluated. The accuracy was evaluated in an offline experiment through the leave-one-out cross-validation method. The utility of the recommendations was evaluated through a user study in which participants were asked to rate the relevance of several recommendations in different situations. Lastly, the user satisfaction and usability of the RSs were evaluated through a questionnaire that included 14 questions of the ResQue (Recommender systems' Quality of user experience) model [333], the System Usability Scale (SUS) [279], and a question asking for an overall opinion of the RS. Moreover, the chapter reports the results of an A/B test that was conducted on ViSH in order to compare, in the context of a real-world application, the recommendations generated by the RS with random recommendations in terms of acceptance rate, quality of the Learning Objects accessed through the recommendations, and time spent by the users on these Learning Objects.

The results of the leave-one-out analyses indicate that the implemented RSs had a satisfactory accuracy, and that this accuracy was immensely higher than the one that can be obtained by a system that generates random recommendations. In the utility evaluation, the recommendations generated by the RSs in two different situations obtained high utility scores from users, these scores being notably higher than those achieved by random recommendations. The results of the user satisfaction and usability evaluation show that users had a good overall opinion of the implemented RSs, and that they rated the RSs positively in terms of quality of the recommendations, interface adequacy, perceived usefulness, transparency, trust, overall satisfaction and usability. Lastly, the results of the A/B test show that the recommendations generated by the ViSH RS statistically significantly outperformed random recommendations in terms of acceptance rate, quality of the Learning Objects whose recommendations were accepted, and time spent by the end users on these Learning Objects. In summary, the two RSs implemented based on the Learning Object recommendation model for LORs presented in this chapter had a satisfactory accuracy, were perceived as useful, achieved high user satisfaction, were easy to use, and were able to generate recommendations that significantly outperformed random recommendations. There are other works in the literature that have compared recommendations generated by RSs with random recommendations. For instance, [332] found that personalized recommendations of video clips generated by a content-based RS had higher perceived quality as compared to random recommendations, and that this higher perceived quality lead to a higher choice satisfaction and perceived system effectiveness, which in turn leads to a higher intention to provide feedback.

The research question of the thesis covered in this chapter was the following: What kind of recommendation model is suitable for implementing Learning Object recommender systems? Which factors need to be contemplated in their implementation? To address this question, this chapter first describes the main recommendation techniques that are used to implement RSs (content-based, collaborative filtering, demographic, knowledge-based, community-based, context-aware, and hybrid) and provides references to several works in which a wide variety of recommendation models to implement Learning Object RSs have been described and referenced [42], [315]–[317], [320]–[330] (further details are included in section 2.8 of this thesis, including a brief description of these works).

Then, the chapter proposes a hybrid Learning Object recommendation model for LORs that combines content-based, demographic and context-aware techniques, and that uses as knowledge sources Learning Object metadata, user profiles, and Learning Object quality and popularity scores. This recommendation model was designed to support a wide variety of use cases by taking into account the most common activities and features of LORs. The chapter also describes the implementation of two RSs based on the proposed recommendation model, and reports the results of the evaluations of such RSs in two different scenarios. Based on these results, it can be suggested that the proposed recommendation model is suitable for implementing Learning Object RSs for LORs. Other suitable Learning Object recommendation models can be found in the literature, but most of them have not been evaluated in the context of a real-world application, or have been evaluated using a prototype implementation of the RS, or have been evaluated only in one environment [330], [334]. Future studies could investigate which Learning Object recommendation models are most suitable depending on the use cases and the characteristics of the environment.

Regarding the factors that need to be taken into account to implement Learning Object RSs, several issues should be considered including: the use cases of the RS, the knowledge sources to use, the modelling of the Learning Objects, the generation of the user profiles, the recommendation techniques to use, the way of showing the recommendations to end users, and how these users can interact and give feedback to the RS. To a large extent, the choices that should be made in the implementation of a Learning Object RS to address these issues are influenced and constrained by the scenario or environment in which the RS will operate. This influence and constraint is especially important when a RS is implemented in the context of a real-world application. In this regard, [395] proposes to systematically study the environment based on three dimensions: the users (who are they, what are their goals), the data used to generate the recommendations (i.e. the knowledge sources), and the overall application into which the RS is going to be integrated.

After study the environment, the use cases that the RS aims to support need to be defined. This includes defining the purpose of the RS, the role of the RS within the overall application, and how the RS is going to be integrated with the features of this application.

An important factor when implementing a Learning Object RS is the characteristics of the Learning Objects the system will recommend. These characteristics include, among others, the quantity, diversity, distribution, stability and reusability of the Learning Objects. A key factor is the quality and quantity of the metadata of the Learning Objects, especially when using content-based techniques. These metadata should be stored, whenever possible, in a structured way according to metadata standards such as IEEE LOM [119] or Dublin Core [120]. In this regard, it should be considered that some standards are able to represent richer metadata than others. For instance, Simple Dublin Core defines a vocabulary of just 15 terms, while LOM defines a total of 45 different main metadata fields grouped into 9 categories. This chapter indicates some LOM metadata fields that could be useful to recommend Learning Objects such as title, description, keywords, language, learning resource type, typical age range, educational context, intended end user role, difficulty and typical learning time. Besides, this chapter provides metrics that show how to calculate similarity scores between Learning Objects and between Learning Objects and user profiles using some of such fields. Within this context, a Learning Object metadata instance is considered of high quality to the extent that it allows the described Learning Object to be distinguished from others that could be recommended. The quality of a Learning Object metadata instance can be automatically measured by using metadata quality metrics (see chapter 5 of this thesis for further details).

In order to provide more data about the Learning Objects to the RS, the overall application can implement new features. For instance, a LOR could implement a Learning Object evaluation system to allow reviewers and/or end users to rate the published Learning Objects, generating this way quality scores for them. In TEL environments, quality scores are very important because the recommended Learning Objects not only have to be relevant, but also have to be effective in terms of learning. Besides, quality scores have proved to be able to enhance Learning Object recommendations. The results of an A/B test reported in chapter 5 of this thesis show that the recommendations generated by the ViSH RS using quality scores statistically significantly outperformed those generated by the ViSH RS without using quality scores in terms of acceptance rate, quality of the Learning Objects accessed through the recommendations, and time spent by the end users on these Learning Objects. There are many Learning Object evaluation models and quality metrics that an e-Learning system can use to calculate Learning Object quality scores. The decision of which models and metrics to use is important because the validity of these quality scores strongly depends on them. A review of the most relevant Learning Object evaluation models and quality metrics can be found in section 2.6 of this thesis. Finally, it is worth mentioning that quality scores could also be obtained based on the interactions that end users have with the Learning Objects (see chapter 6 for further details).

A LOR could also provide to the RS popularity scores for the Learning Objects by using metrics that calculate these scores based on the number of visits, downloads and/or likes of the Learning Objects. Popularity scores can be easily and automatically calculated for all the published Learning Objects. If a RS uses popularity scores, it can still recommend the most popular resources when there is no other information available to generate recommendations. There are other measures that can be adopted by a LOR in order to enhance the information about the Learning Objects provided to the RS, such as requiring contributors to tag the submitted Learning Objects with some mandatory metadata (e.g. a minimum number of keywords) or providing a social tagging feature.

Another important factor when implementing a Learning Object RS is how to model and generate the user profiles. The Learning Objects that the users liked or found interesting in the past are highly valuable information, which can be used to generate recommendations using, among others, content-based, collaborative filtering and community-based techniques. This information can be collected in several ways including lists of favorites, bookmarks, like and dislike buttons, and user ratings. A system could also infer this information by interpreting user interactions. For instance, the access to a page that shows details of a Learning Object may be considered as an implicit interest for that Learning Object. User ratings of Learning Objects (expressed explicitly or implicitly) are especially important for collaborative filtering techniques, which generate recommendations using only information about these ratings. Moreover, Learning Object evaluations from users can be used to generate quality scores.

For a Learning Object RS, it could be highly useful to use demographic information of the users such as their language and age. This is especially useful in scenarios where there are Learning Objects available in multiple languages or targeted for specific age groups. In these scenarios, by using a demographic technique, a RS could filter those Learning Objects in a language not known to the user or suggest those that best match with the educational level of the user. Demographic information also allows to define user group clusters, which can be used to generate recommendations based on stereotype profiles.

Other valuable information to create user profiles is the one that users can explicitly provide about their tastes, needs or areas of interest. For example, a LOR could require users to enter areas of interest in the form of tags at registration time. This work describes examples of how to model user profiles in two different scenarios by using lists of Learning Objects, demographic information, and areas of interest. Data about the learning goals, learning related history, competencies and academic achievement of the users could also be useful to generate Learning Object recommendations. These data could be explicitly expressed or might need to be inferred from the user’s interactions. Furthermore, information about the user’s social relationships can be used by community-based techniques to generate recommendations based on the preferences of the user's friends and contacts.

Another issue that needs to be considered in the implementation of a Learning Object RS is how to generate recommendations for anonymous users (i.e. users that have not registered or logged in) who do not have a user profile. This issue is very important because a significant percentage of the visits can be from anonymous users. For instance, on the ViSH platform around 80% of the accesses are performed by non-logged users. In those situations where there is contextual information available (e.g. the Learning Object the user is viewing), it is possible to generate recommendations based only on this information by using, for instance, content-based techniques, or collaborative filtering techniques if there is a large dataset of user ratings. If recommendations cannot be generated using the available contextual information, a

RS can recommend Learning Objects to anonymous users based on quality and/or popularity scores. These recommendations will be not personalized, but a reasonable hypothesis is that they will be better than random recommendations. Lastly, another option is to generate virtual user profiles for the anonymous users throughout the browsing session. The user language can be easily obtained by using the locale settings of the user's web browser or the language explicitly specified for the user interface. The recommendations could be generated taking into account the Learning Objects the user previously accessed during the session. In this regard, an analysis of the data about the user's interactions could be performed in order to infer which Learning Objects the user found interesting and which ones the user did not find interesting.

In many scenarios, a typical use case is recommending Learning Objects similar to the one the user is viewing. Both when accessing the page of the Learning Object as well as after finishing the viewing of the Learning Object are appropriate moments to show the recommendations [321]. In order to support this use case, the RS needs to be context-aware because it needs to know the activity performed by the user (view a Learning Object) as well as the Learning Object the user is viewing. The work presented in this chapter suggests that the combination of content-based and context-aware techniques can produce satisfactory results in this situation.

The different recommendation techniques used to implement the RS can be chosen based on the use cases and the available knowledge sources. The main recommendation techniques are introduced in this chapter (further details can be found in section 2.8 of this thesis). The results of this work suggests that a hybrid recommendation model that combines multiple techniques is a suitable option, but models based on one single technique could also be suitable in certain scenarios. In order to generate personalized recommendations, the profile of the users should be taken into account in the recommendation process. However, if there is no user profile (or the profile provides poor information), it is still possible for a RS to generate recommendations based on other knowledge sources such as contextual information, quality scores, and popularity scores.

A Learning Object RS can use filters to prevent users to receive recommendations whose suitability is not high enough. Regarding this, the use of quality and popularity filters allows to discard those Learning Objects with poor quality or barely used. In the model presented in this chapter, Learning Objects can be filtered by overall score, similarity with the user profile, similarity with the contextual Learning Object, similarity with specific properties, quality and popularity. In those situations where recommendations are always expected to be shown, the use of filters may have little utility. However, in other situations where recommendations can be shown or not depending on their suitability, filters play an essential role. For example, filters are crucial in proactive context-aware Learning Object RSs that push recommendations to the users when the current situation seems appropriate.

Regarding the recommendation process, several factors need to be taken into account in the development of a Learning Object RS including the accuracy, utility, acceptance, diversity, coverage and serendipity of the Learning Object recommendations, as well as the system scalability. In this regard, [311] described different methods and metrics to evaluate these properties. Besides general properties of RSs as the ones listed above, Learning Object RSs should also consider educational aspects, both in their design and implementation as well as in their evaluation. For instance, the recommendation model presented in this chapter was designed to use Learning Object quality scores, which can be generated based on evaluations performed by reviewers and/or end users. In the A/B test conducted on the ViSH platform, the ViSH RS was evaluated in terms of two educational aspects: the pedagogical quality of the Learning Objects accessed through the recommendations, and the time spent by the users on these Learning Objects.

Besides the recommender algorithm, other factors influence the user experience of a RS. This fact has been evidenced in some studies which have shown that user satisfaction and perceived usefulness do not always correlate with high recommender accuracy [331], [332]. Therefore, Learning Object RSs should be developed by considering aspects such as usability, interaction adequacy, interface adequacy, trust, perceived usefulness, and user satisfaction. Other two important aspects are transparency and control. With regard to transparency, RSs should also be concerned with helping users to understand why the Learning Objects are recommended to them. Regarding control, one option that should be considered is to allow users to configure some aspects of the recommendation process. In the case of hybrid RSs, a reasonable option would be to allow users to customize the weights used to calculate the overall scores. Another option, especially interesting for proactive context-aware Learning Object RSs, would be to allow users to customize the threshold values of the filters employed in the recommendation process.

Finally, it should be decided which explicit and implicit user feedback is going to be used to feed the RS and how to collect such feedback. This decision will depend, among other factors, on the knowledge sources used by the RS. There are several ways in which a user can provide feedback: by explicitly giving information (about his/her interests, goals, skills, learning related history, ...), by accepting or rejecting a recommendation, by rating a Learning Object, by leaving a comment, by bookmarking a Learning Object as favorite, by clicking on a “Like” or “Dislike” button, by sharing or downloading a Learning Object, etc. Furthermore, users’ preferences can be inferred from their interactions. For instance, if a user spends a lot of time interacting with a Learning Object, it could be concluded that such a user is interested in that Learning Object. With regard to the user interactions, it is worth mentioning that in certain scenarios it is possible to estimate the quality scores of Learning Objects based on the interactions that end users have with them (see chapter 6 of this thesis for details).

This chapter makes three main contributions. The first contribution is the proposal of a hybrid Learning Object recommendation model for LORs that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. As part of this contribution, metrics have been proposed to calculate similarity scores between Learning Objects, and between user profiles and Learning Objects. The results reported in this chapter indicate that the proposed recommendation model can be used to implement effective Learning Object RSs. Thus, this model contributes to addressing the difficulty that users have in finding suitable Learning Objects in the different LORs available on the Web, which is one of the main barriers to the use and adoption of Learning Objects. The second contribution is the open source Learning Object RSs that were implemented based on the proposed model for the LORs ViSH and Europeana. These RSs have proved to be effective in recommending Learning Objects, and therefore they can be helpful in the distribution stage of the Learning Object life cycle. Furthermore, the design of the proposed recommendation model and the implementation of the two RSs based on it allowed to identify several factors that should be considered in the implementation of Learning Object RSs. Therefore, the results presented in this chapter can drive future development of better Learning Object RSs. The third contribution is the evaluation of the proposed Learning Object recommendation model. On the one hand, the model was evaluated in two different scenarios. On the other hand, the model was evaluated in the context of a real-world application. Many Learning Object recommendation models have been proposed in the literature, but most of them were not evaluated in the context of a real-world application, or were evaluated only in one environment, or were evaluated using a prototype [330], [334]. In fact, many Learning Object recommendation models reported in the literature have not been evaluated through trials that involved human users, or have not been evaluated at all.

Chapter 8
Integration Models for Learning Objects

Learning Objects need to be integrated into a software system before they can be used. Thus, integration plays a key role in the use and adoption of Learning Objects. Although various e-Learning standards have been developed to facilitate the integration of Learning Objects, these standards are not enough to enable a successful integration of Learning Objects into all the different systems and contexts in which they can be used. Despite this fact, scarce work has been done in developing tools, approaches or methodologies to facilitate the integration of Learning Objects. This chapter presents three integration models for Learning Objects: a model to allow e-Learning authoring tools to assemble Learning Objects by integrating and combining other ones compliant with multiple e-Learning standards, a model to enable the integration of Learning Objects provided by Learning Object Repositories into web videoconferencing services, and a model to integrate Learning Objects packaged according to the SCORM standard into web games in order to create educational web games. The chapter also shows the results of the implementations made to validate the three Learning Object integration models.

8.1 Introduction

The fundamental idea behind Learning Objects is that educational content can be broken down into small chunks that can be independently created and reused in different contexts and e-Learning systems [1]. The key difference between Learning Objects and other types of e-Learning resources is that Learning Objects are designed to have high reusability, this reusability being understood as the capacity of Learning Objects to be used or exploited repeatedly in different e-Learning systems and instructional contexts. There are four different ways in which a Learning Object can be reused [184]: by reusing the Learning Object as is without modification, by creating a new Learning Object by altering or adapting the original one, by combining the Learning Object (original or adapted) with others to create a new one, and by sharing the Learning Object with others.

In order for a Learning Object to be used by learners or to be reused in any other way, such a Learning Object first needs to be integrated into a software system such as a Virtual Learning Environment (VLE), a Learning Object Repository (LOR) or an e-Learning authoring tool. For instance, a VLE such as a traditional Learning Management System (LMS) needs to integrate a Learning Object before deliver it to learners, a LOR must integrate the submitted Learning Objects to allow users to interact with them from its web portal, an authoring tool should be able to integrate Learning Objects to allow their adaptation and the creation of new Learning Objects by aggregation, and an interactive digital television system needs to integrate the Learning Objects before using them in that context. Taken all these into account, it becomes clear that integration plays an essential role in the use and adoption of Learning Objects.

For this reason, various e-Learning standards have been developed to integrate Learning Objects into LMSs and other e-Learning systems. Some of them such as IMS CP [113], SCORM [110] and IMS CC [116] enable the integration by packaging the Learning Objects in a standardized way. Others like IMS QTI [115] represent the Learning Objects in files (typically in XML format) using a standardized data model. Lastly, standards such as IMS LTI [114] and xAPI [111] achieve integration by defining standard ways of communicating with Learning Objects, which can be hosted remotely and provided through third-party services. It is worth pointing out that not all integrations are equally strong. For example, IMS CP does not allow communication between the Learning Objects and the system in which they are integrated while SCORM does. Besides content integration standards, several metadata standards for Learning Objects have been also defined. The most widely used is IEEE LOM [119], but there are others such as Dublin Core [120], ISO/IEC MLR [142] and LRMI [144], [145]. Finally, it is also worth mentioning that there are standards such as OAI-PMH [166], [167], which have been produced to facilitate the integration of Learning Objects (and their metadata) from LORs into other LORs or software systems interested in providing value-added services. Section 2.2 of this thesis includes a review of the most relevant e-Learning standards used in the field of educational technology, including descriptions of all standards referenced in this chapter. The e-Learning standards, especially SCORM, IMS CP and IEEE LOM, have allowed the development of many software systems (mainly LMSs and e-Learning authoring tools) that have facilitated the integration of Learning Objects and hence have contributed to their adoption.

Although e-Learning standards play a crucial role in facilitating the integration of Learning Objects, they are not enough by themselves to enable a successful integration of Learning Objects into all the different systems and contexts in which they can be used. On the one hand, it is necessary to develop tools, technologies and methodologies that fully exploit the affordances of the e-Learning standards [335]. On the other hand, the integration of Learning Objects into novel contexts or into contexts in which educational technology is not typically present requires analyzing the particular characteristics and constraints of those contexts and developing suitable integration approaches. Nevertheless, scarce work has been done in developing tools, models, approaches or methodologies to facilitate the integration of Learning Objects into the different systems and contexts in which they can be used. In this regard, section 2.9 of this thesis provides a review on integration of e-Learning applications and Learning Objects into various systems and contexts, including descriptions of works about extensions of e-Learning standards and integration of Learning Objects into different contexts such as interactive digital television, videoconferencing and video games.

This chapter presents three different integration models for Learning Objects. The first model allows e-Learning authoring tools to assemble Learning Objects by integrating and combining other ones compliant with multiple e-Learning standards [402]. The second model enables LORs to integrate Learning Objects into web videoconferencing services [403]. Finally, the third model defines how to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games in order to create educational web games [404]. The three Learning Object integration models were validated through implementations. This chapter also shows the results of these implementations.

The chapter is structured as follows. Next section shows all the objectives and research questions of this thesis covered by the chapter. Sections 8.3, 8.4 and 8.5 present, respectively, the first, second and third Learning Object integration model. Each of these sections has three subsections: introduction, model, and validation and results. The first subsection explains the motivations for developing the model, the second subsection describes the model in detail, and the last subsection shows the results of its implementation. Finally, section 8.6 closes the chapter summarizing the main conclusions.

8.2 Objectives

This chapter tackles the following three objectives of the thesis:

- *Propose and validate a model to allow e-Learning authoring tools to assemble Learning Objects by integrating and combining other ones.*
- *Propose and validate a model to enable Learning Object Repositories to integrate Learning Objects into web videoconferencing services.*
- *Propose and validate a model to integrate Learning Objects into web games.*

The accomplishment of these three objectives requires proposing and validating a total of three different Learning Object integration models. These models are presented, respectively, in sections 8.3, 8.4 and 8.5 of this chapter. These sections also show the results of the implementations that were made in order to validate the Learning Object integration models.

This chapter also addresses the two last research questions of the thesis:

- *How can Learning Objects be assembled by integrating and combining other ones?*
- *How can Learning Objects be integrated into contexts in which educational technology is not typically present such as web videoconferencing or web games?*

These research questions are answered based on the lessons learned from the design and implementation of the Learning Object integration models presented in this chapter.

8.3 A Model to Integrate, Combine and Assemble Learning Objects

8.3.1 Introduction

Learning Objects were envisioned as building blocks which could be easily combined among them in order to build more complex ones forming a hierarchy. The idea was that if Learning Objects have this ability, they would achieve high reusability. The process where a Learning Object is assembled by integrating and combining other ones is referred to as authoring by aggregation [187]. This process is still a challenge mainly due to three reasons. The first one is that authoring tools are usually limited to create monolithic Learning Objects, which sometimes are not built conforming to any e-Learning standard. The second reason is that, although the created Learning Objects adhere to an e-Learning standard, these standards are generally designed to integrate Learning Objects into VLEs as standalone e-Learning resources, and they are not designed to allow authoring by aggregation in such a way that different aggregated resources behave as one single resource in the eyes of the VLEs into which they are integrated. Lastly, the third reason is that, since there are several e-Learning standards for packaging, representing and integrating e-Learning content, the integration and combination of Learning Objects compliant with different specifications needs to be addressed too. Other factor that hampers this authoring process is the so called cross-domain issue [346], [405], which is suffered by some e-Learning content packaging standards like SCORM, and that should be considered when content is delivered from a different web domain. Taking all this into account, it can be stated that there is a need of authoring tools which effectively support Learning Object authoring by aggregation.

This section 8.3 presents a model for e-Learning authoring tools to facilitate the creation of Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards. Authoring tools that implement this model will be able to use Learning Objects built conforming to different e-Learning standards as building blocks to create new ones, which, at the same time, will also adhere to an e-Learning standard. The model allows to integrate and combine Learning Objects created with different authoring systems or according to distinct e-Learning standards as well as generic web applications which do not follow any e-Learning specification. The Learning Objects created according to the presented model, regardless of the number of Learning Objects used to assemble them, will behave as one single Learning Object or activity in the eyes of the VLEs into which they are integrated. The model was implemented and validated in a Learning Object authoring tool called ViSH Editor available on the ViSH e-Learning platform [56]. A detailed description and evaluation of the ViSH Editor authoring tool is included in chapter 4 of this thesis.

8.3.2 Model

8.3.2.1 Authoring by aggregation process

The authoring by aggregation process proposed by the model is conceptually represented in Figure 8.1. This process involves the following steps:

1. The user (i.e. the author) accesses an e-Learning authoring tool that has implemented the model and creates a new Learning Object (or edits an existing one). Hereafter, this Learning Object will be referred to as "Assembled Learning Object".
2. The author can add content and resources to the Assembled Learning Object using the authoring tool as usual. Resources that do not adhere to any e-Learning standard such as a picture or a video file do not need any additional action to be integrated.
3. Authors can also specify the metadata of the Assembled Learning Object according to some metadata standard like IEEE LOM [119] through the user interface. Metadata are not built as a composition of the metadata of the resources and Learning Objects that compose the Assembled Learning Object. Although this metadata aggregation is technically feasible, enabling authors to define the metadata is a better approach since it gives them full freedom.
4. The author integrates other existing Learning Objects which have been packaged or created according to some e-Learning standard. The following e-Learning standards are considered by the current version of the model: SCORM [110], IMS CP [113], IMS QTI [115] and Moodle XML [153]. A description of all these standards can be found in section 2.2.3 of this thesis. Thereby, SCORM and IMS content packages (in the form of ZIP files) as well as tests and questions defined in XML files according to IMS QTI or Moodle XML can be integrated into the Assembled Learning Object. Furthermore, the author can also integrate Learning Objects created with the same authoring tool and generic web applications packaged in a ZIP file.

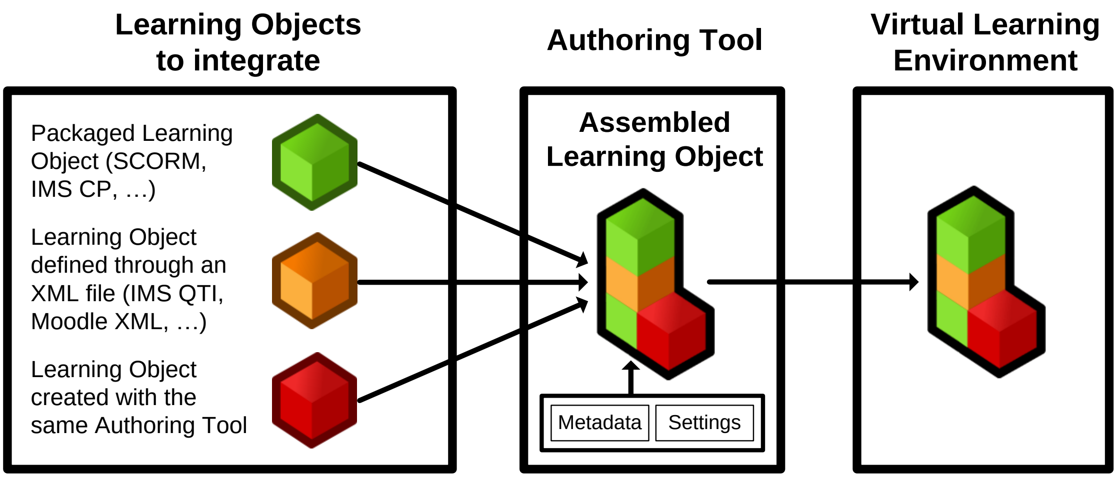

Figure 8.1: Learning Object authoring by aggregation process proposed by the model

Although the model has been designed taking into account a finite set of content integration e-Learning standards, more of these standards can be considered following the same concepts as long as they do not have substantial differences with the aforementioned ones.

5. Once a Learning Object has been integrated, the author can specify different types of settings for it. Some settings are related to the presentation of the content and the navigation options while others are related to the behaviour of the content. For instance, the author can set settings for the questions in order to specify a maximum number of attempts or a time limit, or to specify that the different choices should be shuffled. Furthermore, for the Learning Objects that report a score or a success or completion status, the author can specify the weight or level of importance of the Learning Object in the Assembled Learning Object. The option of ignoring the scores and statuses sent by a certain Learning Object (or assigning a weight of 0) is also considered. For example, if an author integrates a SCORM package containing a resource (e.g. an interactive questionnaire) which reports a score, and specifies in the settings of the resource a weight of 10%, the score reported by this resource would contribute a maximum of 1 point over 10 to the overall score reported by the Assembled Learning Object (and/or to the score used to calculate the success status). Similarly, the completion of the above resource would represent the completion of 10% of the Assembled Learning Object in order to determine its completion status.
6. When the authoring process is completed, the author can package the whole Assembled Learning Object according to different e-Learning standards. The current version of the model considers SCORM [110] and xAPI [111]. Nevertheless, more content integration e-Learning standards similar to the previous ones can be included following the same concept. It should be clarified that although the xAPI specification does not define how to package and launch the content, an additional specification was developed for defining how to package and launch xAPI content [151] (see section 2.2.3.4 for further details). Thus, it is possible to package Learning Objects compliant with the xAPI standard. Once the Assembled Learning Object is packaged according to one of the offered e-Learning standards, it can be integrated into VLEs (or other software systems) that support the standard. This Assembled Learning Object, regardless of the number of Learning Objects that were integrated and combined to create it, will behave as one single Learning Object in the eyes of the VLE into which it is integrated.

8.3.2.2 Integration of content and communications

At this point, the question is how can an authoring tool technically integrate and combine different Learning Objects to create a new one in such a way that this new Learning Object behaves as a single resource or activity when it is integrated into a VLE. Overcoming this challenge requires solving three issues: the integration of metadata, the integration of content, and the integration of the communications between the Learning Objects and the VLEs. The first issue, as explained above, is solved by giving the author the freedom of defining the metadata of the Assembled Learning Object through the authoring tool. The integration of the content and the communications is solved according to the scheme represented in Figure 8.2. Three different cases are considered depending on the type of Learning Object to be integrated into the Assembled Learning Object: Learning Objects created with the same authoring tool, Learning Objects defined through XML files, and Learning Objects packaged in ZIP files. Next sections describe each of these cases.

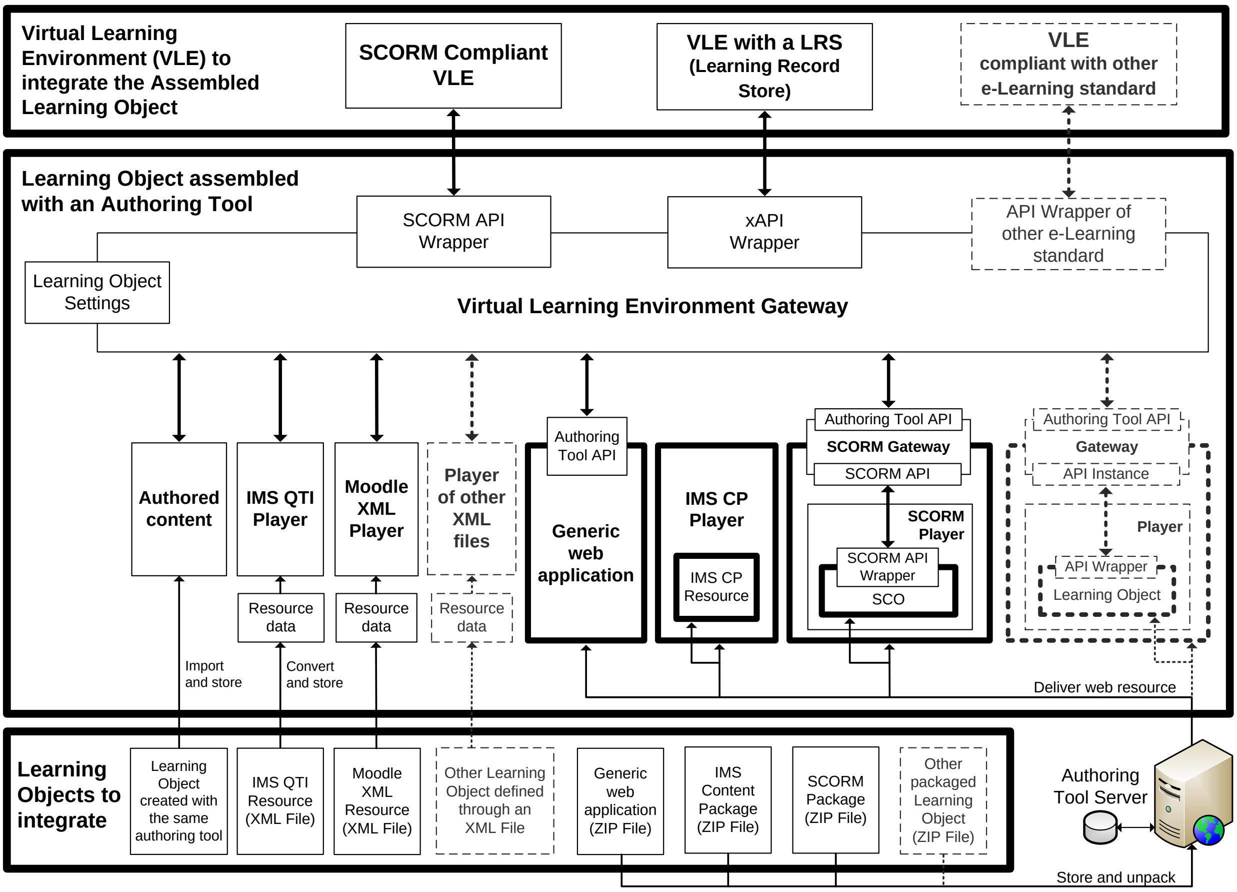

Figure 8.2: Integration of content and communications of Learning Objects

8.3.2.2.1 Learning Objects created with the same authoring tool

When a Learning Object is created using an authoring tool, it can be saved to a file or a web server in different formats such as XML or JSON using a custom data model only understandable by the tool. This file or record stored on a web server can be loaded later by the authoring tool in order to edit the saved Learning Object and not just to display it as with typical e-Learning packages. The Learning Objects created with the same authoring tool are the easiest to integrate because they follow the Learning Object model chosen by the tool, and they have been saved using the format and data model handled by the tool. In these cases, the authoring tool can allow the author to select a Learning Object to import, decompose this Learning Object into smaller resources (according to the Learning Object model), and merge these resources with the Learning Object the author is creating (i.e. with the Assembled Learning Object). Since each authoring tool uses its own Learning Object model and its own data model, this process will be different for each one. In these cases, the tracking of the progress and success of the learners with the integrated resources will be performed in the same way as with other content created through the authoring tool.

8.3.2.2.2 Learning Objects defined through XML files

Learning Objects defined through XML files according to some e-Learning standard can be integrated using players. These players are web-based applications which read data from a resource, load and display that resource in a web browser, and take charge of handling the interactions of the learners with the resource and of the tracking of the progress and success of the learners with such a resource. To integrate a Learning Object defined through an XML file, the author first needs to import the XML file (this can be done on the client side or using a web server). After that, the authoring tool will read the data from the XML file, and then it will internally store these data, either as XML or by converting the data to its own data model. The authoring tool can store the Learning Object as one single resource or decompose it into smaller resources (e.g. an IMS QTI test can be decomposed into IMS QTI questions). In order to display a resource (or resources) in a web browser, a player will read the data stored by the authoring tool. When some relevant tracking data are captured by a player (e.g. when a learner successfully answers a question), it notifies these data to the Assembled Learning Object. More specifically, this notification is sent to a component inserted in the Assembled Learning Object by the authoring tool called “VLE Gateway”.

The VLE Gateway is responsible for gathering all relevant tracking data of the different Learning Objects that are integrated into the Assembled Learning Object, combine these data, and notify them in a unified way to the VLE into which the Assembled Learning Object is integrated using the API of an e-Learning standard such as SCORM or xAPI. All integrated Learning Objects, regardless of whether they were authored from scratch or imported, will communicate with the VLE Gateway instead of communicating directly with the VLE. The VLE Gateway calculates the overall progress, the overall score, and the completion and success statuses reported by the Assembled Learning Object to the VLE based on the gathered tracking data and the settings specified by the author.

8.3.2.2.3 Learning Objects packaged in ZIP files

Content packaging e-Learning standards like SCORM and IMS CP are designed to package web-based content generally into ZIP files. In these cases, the packaged content always consists of web applications. To integrate these web applications into the Assembled Learning Object the author needs to upload the content packages to a web server (this server has been termed “Authoring Tool Server” in Figure 8.2). Once a content package has been uploaded and stored on the web server, this server will unpack the package extracting all resources inside it. For SCORM packages, each of these resources can be a SCO (Shareable Content Object) or an asset. A SCO is a resource that will use the SCORM API to interact with the SCORM Run-Time Environment when it is launched and while it is running, and an asset is a resource that is used in a learning activity but does not use the SCORM API (see section 2.2.3.3 for further details). After unpacking a Learning Object packaged in a ZIP file according to some content packaging e-Learning standard, all the extracted resources will be web applications hosted on the Authoring Tool Server and that can be delivered by it. There are two ways in which these Learning Objects can be integrated into the Assembled Learning Object. On the one hand, each extracted resource of the Learning Object can be integrated into the Assembled Learning Object as an independent Learning Object. On the other hand, the Learning Object can be integrated as a single Learning Object which provides access to all its resources (e.g. using a navigation bar). The authoring tool can use any of these approaches, or can allow the author to choose which one to use for each Learning Object. Regardless of the integration approach used, a player will be used to integrate and appropriately display the packaged Learning Objects in a web browser. This player is a web application in charge of displaying the web resources as well as providing additional features such as navigation through the content. The player will display the resources by using the iframe HTML element, which allows the embedding of HTML documents.

In order to integrate the Learning Objects packaged in ZIP files according to some content packaging e-Learning standard, each Learning Object to be integrated should be delivered by the Authoring Tool Server through an HTML document that contains the player corresponding to the e-Learning standard used to package the Learning Object together with the URLs of its resources. The authoring tool should integrate each of these Learning Objects by embedding the HTML document delivered by the web server using an iframe. Both the players and the resources are hosted by the Authoring Tool Server and therefore, given that they are delivered from the same web domain, the cross-domain issue is solved. For e-Learning standards such as IMS CP which does not contemplate communication between resources and VLEs this integration should be enough. However, for e-Learning standards such as SCORM which allow this communication additional actions are needed.

In order to integrate SCORM packages, the HTML document delivered by the web server with the SCORM player needs to include an additional component called “SCORM Gateway”. On the one hand, this component has an instance of the SCORM API which communicates with the SCORM API Wrapper used by the SCOs of the SCORM packages, and that mimics the behaviour of the instances of the SCORM API provided by the LMSs when a SCORM package is played. On the other hand, the SCORM Gateway has a custom JavaScript API defined by the authoring tool (termed “Authoring Tool API” in Figure 8.2), which allows to enable a cross-origin communication between the HTML document in which the SCORM player is contained and the VLE Gateway through the iframe by using the HTML5 Cross-Document Messaging API [406]. Therefore, the SCORM Gateway just has to adapt the tracking data received through the SCORM API and send them to the VLE Gateway using the Authoring Tool API. Although this strategy has been designed with SCORM in mind, it is valid for any e-Learning standard that uses JavaScript APIs for the communication between the Learning Objects and the VLEs. The Authoring Tool API should be able to send all the tracking data that can be sent through the APIs of the different supported e-Learning standards. It is worth pointing out that this strategy is transparent both to the author (i.e. the user of the authoring tool) and the e-Learning content packages. The Authoring Tool API, which should be implemented by the developers of the authoring tool, is automatically inserted by the server. Moreover, the use of the gateway provides an extra layer of security without suffering the cross-domain issue.

Finally, web application developers can also build generic web applications that can be integrated into the Assembled Learning Object in the same way that e-Learning content packages do. They can use the Authoring Tool API in their web applications to send the same tracking data as if they use an API of one of the supported e-Learning standards. Extra features can also be provided to the developers in the Authoring Tool API. When a generic web application packaged in a ZIP file is uploaded to the Authoring Tool Server, the ZIP file is stored and unpacked, but after that the web application is delivered directly in an HTML document since it does not require any player.

8.3.2.3 Limitations

The model to create Learning Objects by integrating and combining other Learning Objects described in the above sections presents some limitations that should be taken into account by developers who want to implement it in an authoring tool:

- The Learning Objects packaged in ZIP files cannot be edited by the author from the tool.
- The integration of Learning Objects packaged in ZIP files requires them to be delivered from a web server and hence internet connection is required to load them. Nevertheless, it would be possible to package the Assembled Learning Object so that it could be used offline.

- For each e-Learning standard the authoring tool wants to support, it should provide a new player or convert the Learning Objects created according to that standard in such a way that they can be loaded using an existing player. Besides, if an e-Learning standard defines how communication between Learning Objects and VLEs should be done, a new gateway that connects the API of the standard with the Authoring Tool API needs to be implemented.
- The captured tracking data are limited by the e-Learning standards. For instance, if a Learning Object created by aggregating an IMS content package and a SCORM package is packaged according to SCORM and integrated into a VLE, the progress, score and statuses reported by such a Learning Object to the VLE will be calculated based only on the tracking data received from the SCOs of the integrated SCORM package.
- Not all e-Learning standards are covered by the current version of the model and therefore not all Learning Objects built conforming to an e-Learning standard can be integrated. However, the model can be extended to support new specifications.

8.3.3 Validation and Results

The model has been implemented and validated in a web-based Learning Object authoring tool called ViSH Editor available on the ViSH e-Learning platform [56]. ViSH Editor allows authors to create Interactive Presentations in the form of Learning Objects, in which they can integrate several types of resources including: text, images, videos, audios, PDF files, self-graded questions (created from scratch or imported from IMS QTI or Moodle XML files), SCORM and IMS content packages, web applications, Flashcards, Virtual Tours and Enriched Videos. The tool also allows authors to fill the metadata of the Interactive Presentations through the user interface. Almost all these metadata can be represented using the IEEE LOM standard. ViSH Editor is open source and the code is available at http://github.com/ging/vish_editor (client side) and http://github.com/ging/vish (server side). More information about the ViSH Editor authoring tool is available in chapter 4 of this thesis.

The current version of the authoring tool (ViSH Editor 0.9.4) allows to integrate Learning Objects that adhere to the following e-Learning standards: IMS QTI 2.1, Moodle XML 2.8, IMS CP 1.1.4, SCORM 1.2 and SCORM 2004 4th Edition. ViSH Editor also allows to integrate generic web applications which do not follow any e-Learning specification. The only condition that these web applications must meet is to be packaged in a ZIP file with an index.html file inside it. Lastly, ViSH Editor also allows to integrate other Learning Objects created with it. Authors can retrieve Interactive Presentations from JSON files or web repositories, and add any of their slides to the Interactive Presentation they are creating. These slides can contain resources of any type supported by the tool. Thereby, ViSH Editor allows authors to integrate into the Interactive Presentations the following types of resources: questions defined in XML files according to IMS QTI 2.1 or Moodle XML 2.8, IMS content packages compliant with IMS CP 1.1.4 provided as ZIP files, SCORM packages compliant with SCORM 1.2 or SCORM 2004 4th Edition, generic web applications provided as ZIP files with an index.html file inside, and slides from other Interactive Presentations retrieved from JSON files or web repositories. SCORM and IMS content packages are integrated as single Learning Objects.

ViSH Editor provides a common player for questions, a player for IMS CP, and a player for SCORM. Besides, it provides an Authoring Tool API and gateways for all supported SCORM versions. This API can be used by web content developers to build web applications for being used in Interactive Presentations. The specification of the API is published on the ViSH Editor wiki available at http://github.com/ging/vish_editor/wiki. Figure 8.3 illustrates how a self-graded multiple choice question imported from an XML file (compliant with IMS QTI or Moodle XML) is visualized in the ViSH Editor authoring tool and how the author can edit its content. Figure 8.4 shows the above question (on the left side) and a SCORM package created with the Articulate Quizmaker authoring tool (on the right side) integrated into two different slides of an Interactive Presentation created with ViSH Editor.

For questions, ViSH Editor allows authors to specify several settings including the maximum number of attempts, the choices shuffling, and the score (see Figure 8.5). This score specified by the author determines the weight of the question in the Interactive Presentation. For SCORM and IMS content packages as well as for web applications, the author can specify if the resource should be unloaded when its slide disappears, if the Authoring Tool API should be enabled for the resource, if the resource reports scores, and if so, the score assigned to the resource (which determines its weight in the Interactive Presentation).

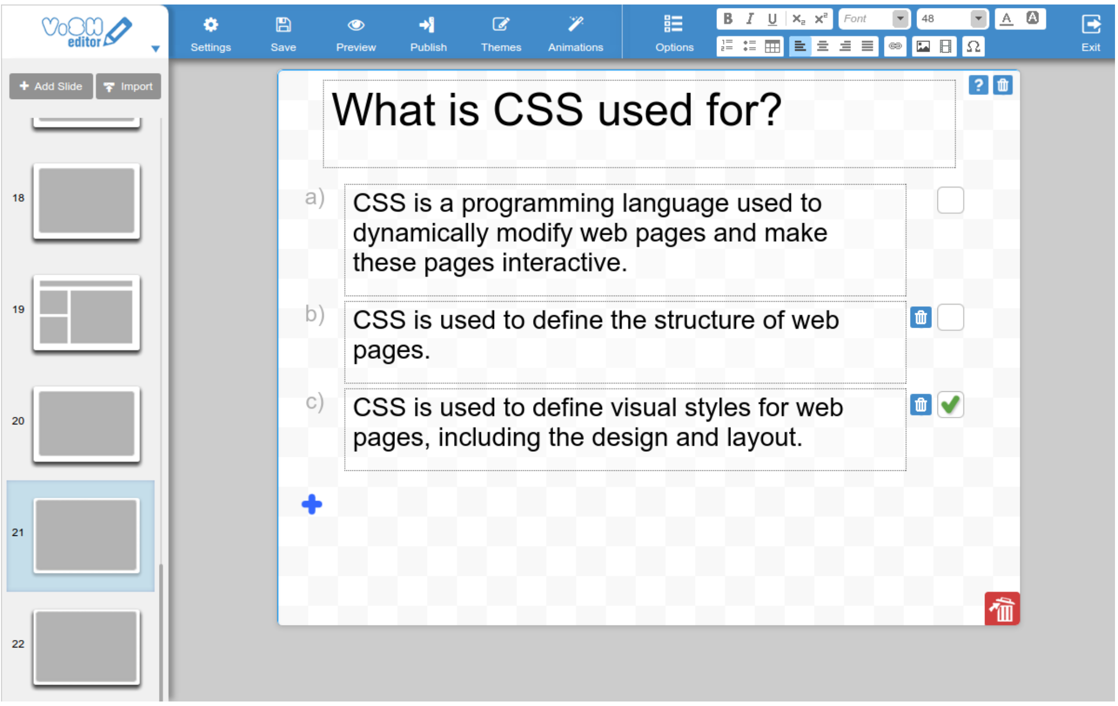

Figure 8.3: Question defined in an XML file integrated through ViSH Editor

In ViSH Editor, the authors can export the assembled Learning Objects (i.e. the Interactive Presentations) to SCORM 1.2 and SCORM 2004 4th Edition. Thereby, these assembled Learning Objects can be integrated into any SCORM compliant VLE. Metadata are included in the SCORM packages according to the IEEE LOM standard. The conformance of the SCORM packages was validated using the latest versions of the ADL SCORM Test Suite (see section 2.2.3.3.5 for details). Future plans for the ViSH Editor authoring tool include adding support for the xAPI e-Learning standard.

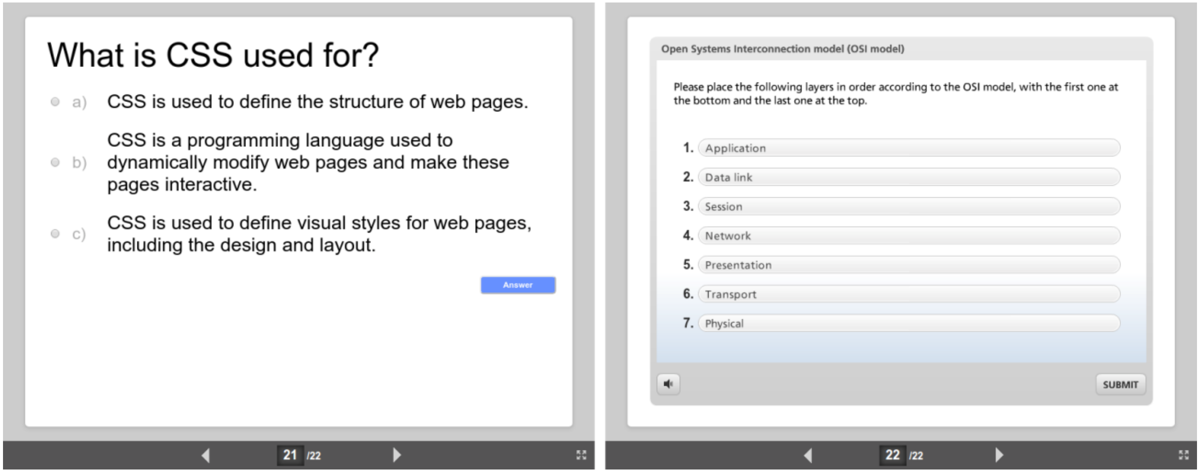

Figure 8.4: Question defined through an XML file and SCORM package integrated into a Learning Object created with ViSH Editor

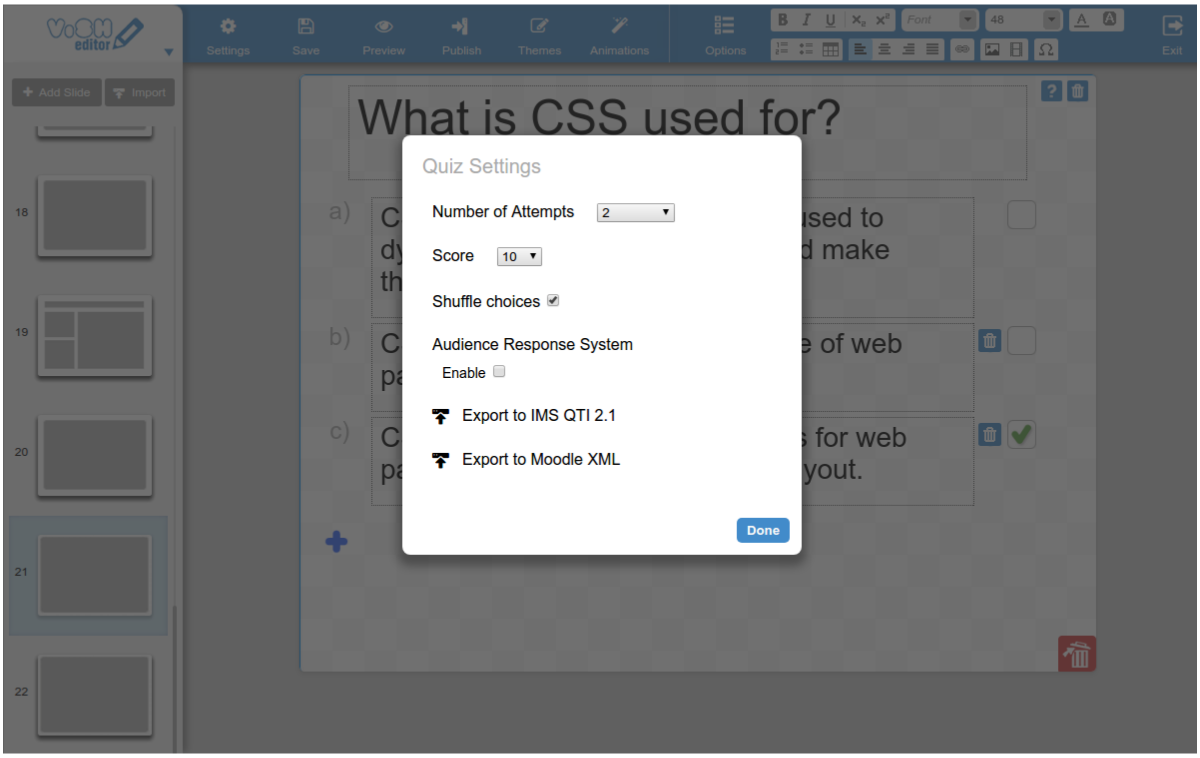

Figure 8.5: Settings of a question in the ViSH Editor authoring tool

8.4 A Model to Integrate Learning Objects into Web Videoconferencing Services

8.4.1 Introduction

The use of videoconferencing in the field of education is becoming increasingly popular due to the range of benefits it can offer [352]. Furthermore, the successful adoption of HTML5 technologies such as WebRTC (Web Real-Time Communication) has enabled the implementation of new web videoconferencing services which allow users to have real-time video and audio communications directly in the web browser without plugins or extensions. Nowadays, there are many videoconferencing systems that can be used for synchronous e-Learning [353], [354]. These systems can bring many benefits for education such as the sharing, co-viewing and co-browsing of Learning Objects at the same time that real-time communication is provided. However, to take advantage of this benefit, the Learning Objects need to be integrated into the videoconferencing systems. In this regard, it should be taken into account that not all integrations are equally strong. In the context of videoconferencing, depending on the degree of integration, the Learning Objects will be able to be shared (each participant will see his/her own isolated instance of the Learning Object), co-viewed (all participants will see the same instance of the Learning Object), and/or co-browsed (all participants will also be able to perform actions over the co-viewed Learning Object). For instance, in those videoconferencing systems that support screen sharing, Learning Objects can be co-viewed but they cannot be co-browsed using that feature because only the participant who is sharing the screen can interact with them. Thus, when screen sharing is used, it is not possible to take advantage of the benefits that the co-browsing of Learning Objects can offer. Although several e-Learning interoperability standards have been developed, none of them have addressed the videoconferencing context. Moreover, no integration approach has been proposed to facilitate the integration of Learning Objects into videoconferencing systems. As a consequence, these systems have been forced to develop ad-hoc solutions to achieve this integration. Examples of videoconferencing systems that have implemented features to integrate Learning Objects are Isabel [355], [356] and Bridgit [357].

This section 8.4 presents a model to integrate Learning Objects provided by Learning Object Repositories (LORs) into web videoconferencing services. By applying this model to a LOR, the sharing, co-viewing and co-browsing of their Learning Objects through the use of web videoconferencing services can be enabled. In order to validate the model, it was implemented in two different repositories to enable the Learning Objects created with an authoring tool to be integrated into three different web videoconferencing services. One of these implementations of the model was used in real-world learning experiences.

8.4.2 Model

The main aim of the model is to enable the sharing, co-viewing and co-browsing of Learning Objects delivered by LORs through the use of web videoconferencing services. Next sections explain step by step the integration approach proposed by the model.

8.4.2.1 Delivering of Learning Objects

In order to deliver Learning Objects, the LOR should provide a request/deliver Learning Object function. This is the one of the most basic features provided by LORs, and its implementation is recommended by the IMS DRI (Digital Repositories Interoperability) specification [168]. Figure 8.6 illustrates how the request/deliver Learning Object function considered by the model should work. This function should allow any system to request access to a Learning Object through an HTTP GET request. Upon receiving a Learning Object request, the LOR should perform the following steps to respond:

1. The Learning Object to be delivered should be in a web-ready format. Otherwise, it should be adapted. This adaptation can be performed when the Learning Object is stored in the LOR, or in some cases it could be performed on the fly for each request. The LOR will respond with an HTML page containing the requested Learning Object (termed LO in Figure 8.6). For instance, if a video is requested, this video could be delivered embedded in an HTML page through an HTML5 video tag. If the source video file is not in an HTML5 compliant format, this file needs to be converted before the video can be delivered.
2. Besides the requested Learning Object in a web-ready format, a lightweight JavaScript API (hereafter termed LO API) will be included in the delivered HTML page in order to capture the events triggered as a response to the user's actions with the Learning Object. This API should also provide functions capable of replicating these actions using the captured data. For example, if a video is requested, the included API should be able to detect when a user plays or stops the video as well as to replicate any of these actions. This step makes no sense for non-interactive Learning Objects (e.g. an image), and hence in those cases it can be skipped.
3. Finally, the HTML page will be delivered to the application that requested the Learning Object. This application is expected to integrate the Learning Object using an iframe HTML element. The iframe HTML element allows to embed HTML documents, and also allows to enable bidirectional cross-origin communication between the embedded HTML document and its parent document (i.e. the page that contains the iframe) by using the HTML5 Cross-Document Messaging API [406].

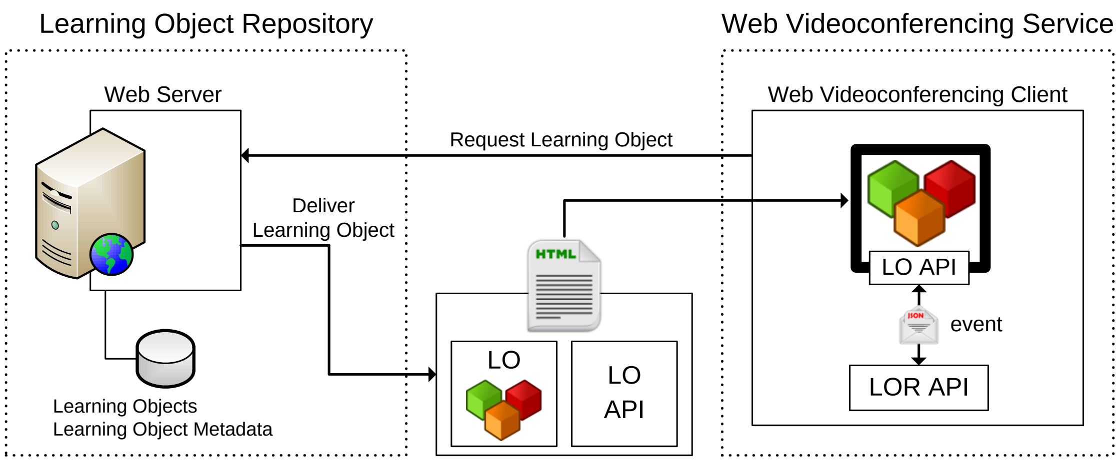

Figure 8.6: Delivering of Learning Objects to web videoconferencing services

8.4.2.2 Delivering of particular Learning Objects

As indicated in the above section, the LOR should include a LO API together with the requested Learning Object in the delivered HTML page in order to capture the events triggered by user's actions and replicate such actions using captured data. For those Learning Objects such as audios and videos which can be represented by using a standard HTML5 element, it is possible to use a common LO API to automatically capture and replicate the user’s actions. However, this approach is not valid for particular Learning Objects, which have their own specific actions. For example, the actions that users can perform in a slide presentation (e.g. advancing to the next slide) are quite different from the ones they can perform in a quiz (e.g. answering a question), or in an educational video game (e.g. shooting). Therefore, each type of Learning Object needs to provide its own LO API. As an example, SlideShare (http://slideshare.net) provides an API to interact with its slide presentations which specifies a total of six functions: *jumpTo*, *next*, *previous*, *first*, *last* and *getCurrentSlide*.

Taking into account that Learning Objects are usually created through authoring tools, this model proposes that the LO API of each type of particular Learning Object should be provided by the authoring tool that allows to create that type of Learning Object. Thereby, authoring tools will be in charge of providing the LO APIs for the particular Learning Objects (i.e. for those Learning Objects which cannot be represented using a standard HTML5 element).

The model specifies the requirements that must be met by the LO APIs provided for the Learning Objects. First, in order to implement a LO API, it is necessary to define the different actions that can be performed in the Learning Object and for which the state of each of the participants’ instances of the Learning Object should be updated. The LO API must be able to replicate these actions and capture the events triggered by them. The events must be captured in such a way that the captured data allow to replicate the actions that triggered them. There are two main approaches that can be used to meet this requirement. The first approach consists of implementing in the LO API two functions for each defined action: one to replicate the action, and another one to capture the event triggered by that action. The second approach consists of implementing in the LO API only two functions: one to update the state of the whole Learning Object, and another one to be notified when the state of the Learning Object changes. The model just specifies the requirements that LO APIs must meet, the way in which these APIs are implemented is outside of its scope.

For example, if an authoring tool that allows to create slide presentations wants to integrate their presentations into a web videoconferencing service following this model, that authoring tool could provide a LO API with two functions: *jumpTo* that allows to go to a specific slide, and *onSlideEnter* that allows to be notified when a new slide is displayed. This way, if a user goes to the slide 5 the *onSlideEnter* function will be triggered with the parameter 5, and if the *jumpTo* function is invoked with this parameter the presentation will go to the slide 5. The key idea relies on the fact that in both cases the final state of the presentation is the same. Another option that the authoring tool could consider is providing a LO API with functions to update the state of the whole presentation and to be notified when this state changes.

8.4.2.3 Delivering of Learning Object events

Previous sections have explained how the events triggered by the user's actions with the Learning Object are captured and how such actions are replicated based on the event data. This section explains how events are delivered in a web videoconferencing session to all participants in order to update the state of their instances of the Learning Object.

First off, the web videoconferencing client needs to include a JavaScript API provided by the LOR (hereafter termed LOR API) to integrate the Learning Objects, in the same way as it needs to include APIs from third-party content providers such as SlideShare or YouTube to integrate and interact with their resources (i.e. their slide presentations and videos respectively).

The LOR API should include two functions: *onMessage* to receive the events sent by the LO API, and *sendMessage* to send these events to the LO API. Each time an event is captured, the LO API must generate a message containing the event data and send this message to the LOR API. Each time the LO API receives one of these messages with data of a captured event, it must replicate the action that triggered the captured event. Messages should be generated in JSON format. A different data model can be used for each LO API, so that authoring tools can freely choose which data model to use. Since the LO API is included together with the Learning Object in an HTML page delivered by the LOR which is expected to be embedded in an iframe by the web videoconferencing client (see Figure 8.6), the communication between the LOR API and the LO API should be enabled by using the HTML5 Cross-Document Messaging API [406]. Thereby, a bidirectional cross-origin communication between the web videoconferencing client and the LO API is enabled by using the LOR API.

Figure 8.7 shows by means of an example how Learning Object events are delivered in a web videoconferencing session. In this example, Alice and Bob are participating in a web videoconferencing session. They are co-browsing a presentation and talking about its content. Concretely, they are seeing the slide 6. In a certain moment, Alice clicks on the "next slide" button to go to the slide 7. Then, the following steps take place:

1. The Alice's instance of the presentation (i.e. the instance that Alice is seeing) advances to slide 7. As a consequence, an event is triggered which is captured by the LO API of this presentation instance. Then, the LO API generates a message containing the event data. As explained above, these data should include enough information to allow other instance of the presentation to replicate the action that triggered the event. For example, in this case the message could include the event type and slide number or the state of the whole presentation. Lastly, the LO API sends this message to the Alice's web videoconferencing client through the LOR API in order to deliver the event.
2. When the Alice's web videoconferencing client receives the message, it sends this message to the videoconferencing server through a data channel.
3. The videoconferencing server does not have to read or understand the messages generated by the APIs of the Learning Objects, it just has to broadcast these messages to the participants of the videoconferencing session through its usual data channel.
4. After the broadcast, Bob's web videoconferencing client receives the message and sends it to the LO API using the LOR API.
5. When the message is received by the LO API of the Bob's instance of the presentation, this LO API replicates the action that triggered the delivered event by using the data contained in the message. As a consequence, the state of the Bob's instance of the presentation is updated and this presentation instance also advances to slide 7. Thus, the final state of Alice's and Bob's instances of the presentation is the same.

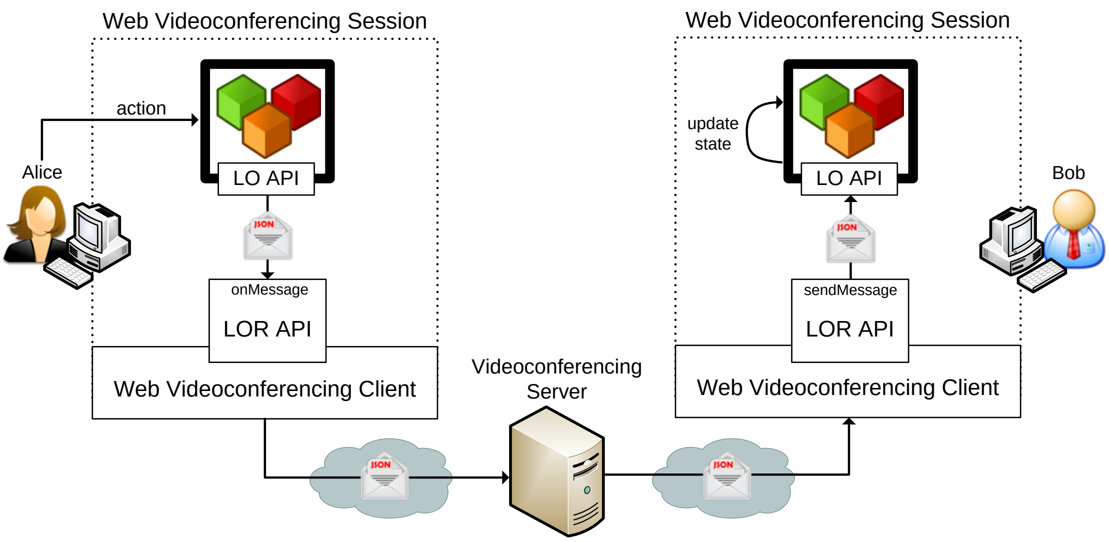

Figure 8.7: Delivering of Learning Object events in web videoconferencing sessions

Taking into account that Bob can also perform actions in the co-viewed presentation in the same way as Alice does, this example shows how the co-viewing and co-browsing of Learning Objects through the use of a web videoconferencing service is achieved.

8.4.2.4 Achieve synchronized co-browsing

The previous section shows an example of co-browsing, but such co-browsing is not synchronized. Considering again the previous example where Alice and Bob are seeing the slide 6 of a presentation during a videoconferencing session, if Alice clicks on the next slide button at the same time Bob clicks on the previous slide button, the Alice's instance will send an event indicating that the presentation is on the slide 7 while the Bob's instance will send other event indicating that the presentation is on the slide 5. As a consequence, the final state of the instances will be different: the Alice's instance will be in the slide 5 since it receives the event from the Bob's instance, and the Bob's instance will be in the slide 7 due to the event of the Alice's instance.

In order to achieve synchronized co-browsing of Learning Objects, the problem of maintaining the same state on each of the participants' instances of the Learning Object and update the state of the Learning Object according to the actions of the participants should be solved. There are different mechanisms that can be used to solve this state synchronization problem. For example, mechanisms such as Lamport timestamps and vector clocks can be used to determine the order of events in distributed systems. The implementation of the synchronization mechanisms is outside the scope of this model. Any mechanism that solves the state synchronization problem stated above can be used to achieve synchronized co-browsing of Learning Objects. Nevertheless, it should be taken into account that some synchronization mechanisms require the implementation of logic in the videoconferencing server, and therefore these mechanisms could not be implemented in those scenarios where modifying this server is not possible. A simple option that a web videoconferencing service might consider in order to address the state synchronization problem, is to provide an interaction mode in which the co-browsed Learning Object can only be controlled by one user at a time. The control of the Learning Object could be transferred to different users throughout the videoconferencing session. For example, a teacher could start controlling a presentation to explain some topic to their students and then transfer its control to a certain student in order to allow him/her to answer a questionnaire embedded in the presentation.

Next, an example of a straightforward solution to achieve synchronized co-browsing of Learning Objects is presented. In this solution the LO API enables a new operation mode of the Learning Object. When this operation mode is enabled, each time a user tries to perform an action, instead of allowing the user to perform the action and then notify the event through the LO API, the action is prevented but the event is sent. Thereby, the action will only be performed if the event is forwarded by the videoconferencing server. This solution to achieve synchronized co-browsing also uses a simple implementation of an event-locking mechanism. When using this mechanism, the server delivers the events periodically. Therefore, the state of the Learning Object can be updated every period. During each time slot (i.e. each period) the clients can send their events to the server to be broadcasted, but those that arrive too late are discarded. Consequently, the server just has to deal with the event collisions that occur when two or more inconsistent events are received in a same time slot. The solution considered in this example allows just one event per time slot and in case of collision chooses one event at random and discards the rest.

Coming back to the example where Alice clicks on the next slide button at the same time Bob clicks on the previous slide button, if the above solution to achieve synchronized co-browsing were applied, the process would occur as follows:

1. After Alice clicks on the button, her instance of the presentation will remain in the same state but the event will be sent to the web videoconferencing client. The same will happen with Bob.
2. Alice's and Bob's web videoconferencing clients send their corresponding received events to the videoconferencing server.
3. If the two events arrive in the same time slot, the videoconferencing server will choose one at random and will broadcast it to all participants. The other event will be discarded. If the two events arrived in different time slots due to high network latency, the event that arrived later would be discarded and the other one would be broadcasted. Suppose in this example that the two events arrive in the same time slot and the server broadcasts the Alice's event and discards the Bob's event.
4. When the Alice's event arrives to each of the participants' web videoconferencing clients, each of these clients sends the event to the LO API of its corresponding instance of the presentation using the LOR API.
5. The action indicated by the Alice's event is performed in all instances of the presentation (i.e. in the Alice's instance and in the Bob's instance). As a consequence, the final state of Alice's and Bob's instances of the presentation is the same.

Other issue that should be taken into account is how to set the initial state of the instance of the Learning Object for new participants who join the videoconferencing session after several actions have been performed in the Learning Object. A possible option is to send to these new participants the current state of the whole Learning Object. For instance, in the above example, the messages generated by the LO APIs could include the state of the whole presentation, and the videoconferencing server could store the last broadcasted message and deliver it to each new participant that joins the videoconferencing session.

8.4.2.5 Achieve integration without modifying web videoconferencing services

A web videoconferencing service can offer its own API to provide third-party web applications with features such as messaging or data channels (which allows communication between application instances), access to users' information, user interface customization, and control of microphones, cameras, speakers and volume levels. An example of a well-known web videoconferencing service that offers this kind of API is Google Hangouts [407].

Previous sections have explained how to deliver Learning Objects to web videoconferencing services and how to deliver the events in web videoconferencing sessions in order to enable the co-viewing and co-browsing of Learning Objects. However, the solution proposed so far has the drawback that it requires web videoconferencing services to be modified in order to include and use the LOR API. Taking into account that web videoconferencing services can provide their own API, this section explains how to achieve the integration of Learning Objects into these services without modifying them, and the requirements that they should meet to do so.

The presented model allows a LOR to enable the sharing, co-viewing and co-browsing of their Learning Objects through the use of a web videoconferencing service without modifying that service as long as this service meets two requirements. First, the web videoconferencing service should provide a JavaScript API (hereafter termed WVS API) that offers a messaging feature or a data channel that allows the communication between the different application instances that run in the participants' videoconferencing clients. Furthermore, if the WVS API allowed application instances to use some synchronization mechanism, the synchronized co-browsing of Learning Objects would be easier to achieve. For example, the Google Hangouts API provides two main features for sharing data between instances: messaging and shared state. On the one hand, the Google Hangouts API allows application instances to send messages to other instances. On the other hand, it provides the application instances with a shared state JavaScript object that contains data that are kept up-to-date in every instance.

The second requirement that a web videoconferencing service should meet is to allow the initial loading of the Learning Objects. In order to start the co-viewing or co-browsing of a Learning Object in a videoconferencing session according to this model, the participants' web videoconferencing clients should embed this Learning Object in an iframe. The only information needed by the clients to do that is the URL of the Learning Object. There are two main ways in which a web videoconferencing service can allow the initial loading of Learning Objects: by providing an own feature to share URLs, and by allowing the integration of third-party web applications (such as Google Hangouts does). In the latter case, the LOR should develop and provide the web application in charge of loading the Learning Objects. Other desirable feature that web videoconferencing services might offer is the generation of links to share videoconferencing sessions specifying a URL to be automatically shared.

The solution proposed by this model to allow a LOR to integrate Learning Objects into a web videoconferencing service that meets the requirements stated above without requiring that service to include the LOR API, consists of introducing an additional step in the request/deliver Learning Object function (described in section 8.4.2.1). When a Learning Object is requested, instead of delivering the HTML page that contains the requested Learning Object together with its LO API, the LOR will deliver a new HTML page that contains an iframe embedding the previous HTML page (which includes the requested Learning Objects and the LO API), and a new component called "LOR Gateway" (see Figure 8.8). On the one hand, the LOR Gateway has the LOR JavaScript API to communicate with the LO API of the Learning Object. On the other hand, the LOR Gateway has the JavaScript API of the web videoconferencing service (i.e. the WVS API) to use the messaging features or data channels offered by that service. The LOR Gateway will use the WVS API to deliver to the web videoconferencing client those messages generated by the LO API and received through the LOR API, and also will use the LOR API to send to the LO API those messages received by the web videoconferencing client and notified through the WVS API. Thereby, the LOR Gateway enables a bidirectional communication between the LO API and the web videoconferencing client. It is worth pointing out that this strategy is transparent both to the LOR and the web videoconferencing service. If Learning Objects are integrated by using web applications, the LOR Gateway can be provided by such applications instead of being provided by the request/deliver Learning Object function.

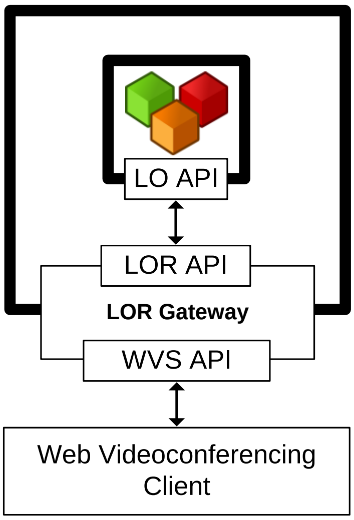

Figure 8.8: Gateway to integrate Learning Objects into web videoconferencing services

8.4.2.6 Limitations

This section summarizes the main limitations of the model described in the above sections to integrate Learning Objects delivered by LORs into web videoconferencing services. Developers interested in implementing this model should consider these limitations.

- Only those Learning Objects that can be represented using a standard HTML5 element and those that can be created with authoring tools can be automatically integrated.

- To integrate Learning Objects created with an authoring tool, that tool needs to provide a JavaScript API capable of capturing the events triggered by user's actions with the Learning Objects, replicating these actions using the captured data, and sending and processing the messages notifying the captured events.
- A synchronization mechanism or an interaction mode in which the co-browsed Learning Object can only be controlled by one user at a time should be used in order to achieve synchronized co-browsing.
- To implement the model without modifying the web videoconferencing services, these services should allow the initial loading of the Learning Objects (e.g. by providing a URL sharing feature or by allowing the integration of third-party web applications), and should also provide a JavaScript API that enables the communication between the different instances.

8.4.3 Validation and Results

The model was implemented in two different repositories to enable the integration of Learning Objects created with an authoring tool into three web videoconferencing services: MashMeTV [408], Google Hangouts [407], and a web videoconferencing service developed based on the Licode platform [409]. The following sections describe the implementations that were made to validate the model in these three web videoconferencing services.

8.4.3.1 MashMeTV

In this validation, the model was implemented in the ViSH platform [56] in order to enable the integration of the Learning Objects created with the ViSH Editor authoring tool into the MashMeTV web videoconferencing service. The ViSH platform consists of a LOR enriched with features such as authoring tools, an evaluation system, a recommender system, collections and a social network. A detailed description of ViSH is given in chapter 3 of this thesis. On the ViSH platform, registered users can use the ViSH Editor authoring tool to create and publish Learning Objects. These Learning Objects are Interactive Presentations in which users can integrate several types of resources including text, images, videos, self-graded questions and web applications, as well as other Learning Objects created with the tool such as Flashcards, Virtual Tours and Enriched Videos. ViSH Editor also allows users to convert PDF slideshows into Interactive Presentations, which can be later enriched with more content and resources. This tool has already been introduced in section 8.3 of this chapter. More information about it can be found in chapter 4 of this thesis.

MashMeTV [408] is an online meeting platform that allows video calls while sharing synchronized experiences and multimedia content using only the web browser. On MashMeTV, users can create virtual meeting rooms in which web videoconferencing sessions can be established. These rooms aim to emulate real meeting rooms. On a virtual meeting room, the user can perform several actions such as inviting other users to join the room (i.e. to join the web videoconferencing session), chatting with other participants, synchronously sharing YouTube videos and SlideShare presentations, sharing URLs through a co-browsing tool, sharing Google Drive documents and Flickr images, drawing on a collaborative blackboard, making polls, and enabling different interaction modes. MashMeTV provides a feature called "MashMeTV Buttons" that allows the integration of virtual meeting rooms into third-party websites. Besides, MashMeTV provides a JavaScript API that enables the communication between the different instances of the websites shared through its co-browsing tool.

The first step carried out in this implementation was to modify the ViSH Editor authoring tool to provide a LO API for their Learning Objects that meets the requirements defined by the presented integration model. As a result, ViSH Editor provides a JavaScript API that allows to capture the events triggered by the user's main actions with the Learning Objects (e.g. going to a slide, opening a slide in a Flashcard, or playing a video), replicate these actions using the captured data, and send and process the messages notifying the captured events. Moreover, in order to facilitate the achievement of synchronized co-browsing, the LO API allows to enable an operation mode of the Learning Object in which each time a user tries to perform one of the considered actions, instead of allowing the user to perform the action and then notify the event through the LO API, the action is prevented but the event is sent. Thereby, the action will only be performed if the event is forwarded by the videoconferencing server.

The second step consisted of implementing the request/deliver Learning Object function specified by the model in the ViSH platform in order to allow the delivering of Learning Objects created with the ViSH Editor authoring tool. In this regard, the LOR API and LOR Gateway components defined by the model were developed for ViSH to enable the bidirectional communication between the LO API of the Learning Objects created with ViSH Editor and the web videoconferencing client of MashMeTV. The JavaScript API provided by MashMeTV was used in the gateway to enable this communication.

Finally, a MashMeTV button was added to all pages of the ViSH platform that displayed a Learning Object created with ViSH Editor. This button allowed users to automatically share and co-browse these Learning Objects in MashMeTV rooms integrated into the ViSH platform. Figure 8.9 shows a Learning Object created with ViSH Editor integrated into a MashMeTV room by using a MashMeTV button available on the ViSH platform. Furthermore, users could also share and co-browse the Learning Objects created with ViSH Editor and published on the ViSH platform in any MashMeTV room by entering their URL in the co-browsing tool. The synchronized co-browsing could be achieved by using an interaction mode in which the co-browsed Learning Object was only controlled by one user at a time.

This implementation of the model was used in real-world learning experiences. More specifically, MashMeTV was used in the GLOBAL excursion project [54] to hold meetings with students, teachers and scientists, in which Learning Objects available on the ViSH platform were shared, co-viewed and co-browsed. Thereby, the implementation described in this section helped to achieve one of the goals of the GLOBAL excursion project: connect classrooms and scientists. More information about this project is included in chapter 9 of this thesis.

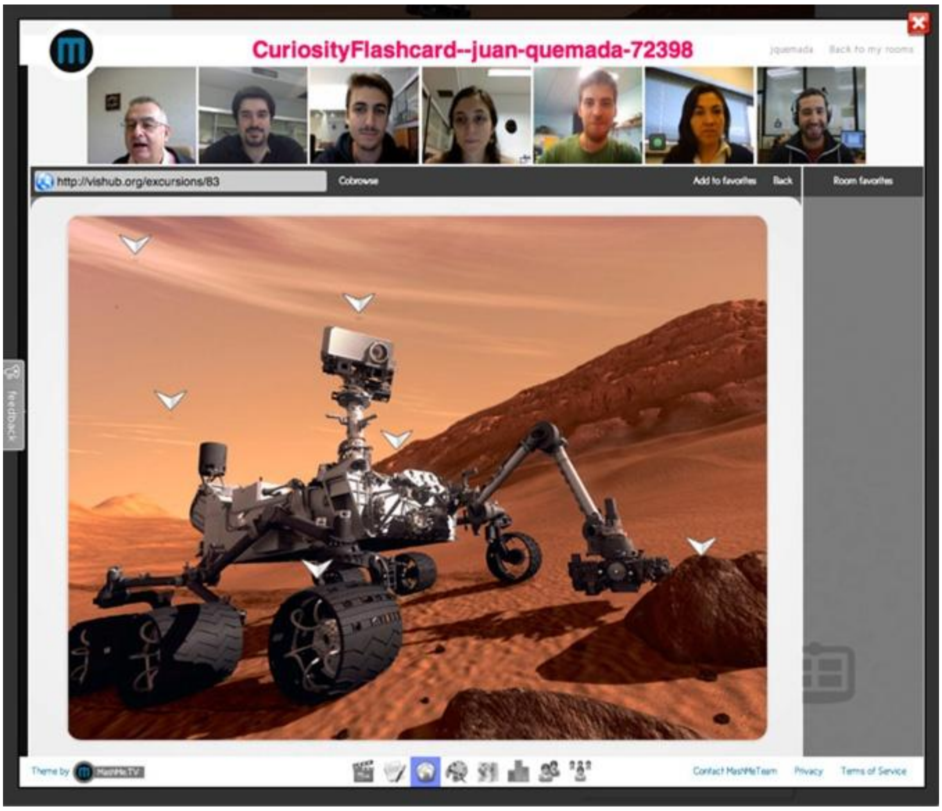

Figure 8.9: Learning Object published on the ViSH platform integrated into MashMeTV

8.4.3.2 Google Hangouts

In this second validation, a proof-of-concept implementation of the model was made in order to enable the integration of the Learning Objects created with the ViSH Editor authoring tool and published on the ViSH platform into Google Hangouts.

Google Hangouts [407] is a free communications service developed by Google which allows users to initiate and participate in text, voice and video chats, either one-on-one or in group. It can be accessed online through a web browser (using a plugin) or through Android and iOS mobile applications. Google Hangouts allows to establish web videoconferencing sessions which can include up to 10 people. In these sessions users can perform several actions including inviting others users to join the session, chatting with other participants, sharing photos, sharing their screen, and running Google Hangout applications. These applications are web applications that can run inside of a Google Hangouts videoconferencing session and that can use the Google Hangouts API. They are represented through XML files that contain their HTML, JavaScript and CSS code. These XML files should be hosted on a server in such a way that they are publicly available and do not require authentication. The Google Hangouts API enables Google Hangout applications to perform various actions such as sharing data between instances, listing the participants of the videoconferencing session, controlling some aspects of the user interface, and controlling the microphone, camera and speaker settings. As mentioned before, two main features are provided by the Google Hangouts API to share data between instances: messaging and shared state. The messaging feature allows application instances to send messages to other instances. The shared state feature provides the application instances with a shared state JavaScript object that contains data that are kept up-to-date in every instance. Google Hangouts also provides the "Google Hangout button", which allows launching Google Hangouts videoconferencing sessions directly from third-party websites. When using this button, a variety of configurations can be specified for the videoconferencing session (e.g. a Google Hangout application that launches along with the session).

The ViSH Editor authoring tool, the LO API and the LOR API used in the validation of the model described in the above section were reused in this new validation. The request/deliver Learning Object function provided by the ViSH platform used in this validation did not include the additional step to provide the LOR Gateway component. This function operated as specified in section 8.4.2.1. Therefore, the ViSH platform responded to the Learning Object requests made to this function by delivering an HTML page containing the requested Learning Object in a web-ready format together with the LO API.

In order to integrate the Learning Objects created with the ViSH Editor authoring tool and published on the ViSH platform into Google Hangouts according to the proposed model, a proof-of-concept Google Hangout application was developed. Figure 8.10 shows a Learning Object integrated into Google Hangouts through this application.

The developed Google Hangout application was comprised of an iframe embedding the HTML page delivered by the ViSH platform with the requested Learning Object and the LO API, and a new LOR Gateway component, which included on the one hand the LOR API provided by the ViSH platform and on the other hand the Google Hangouts API. The application got the URL of the Learning Objects to be integrated and co-browsed from a parameter. In this case, the synchronized co-browsing of Learning Objects could be achieved by using the shared state feature provided by the Google Hangouts API.

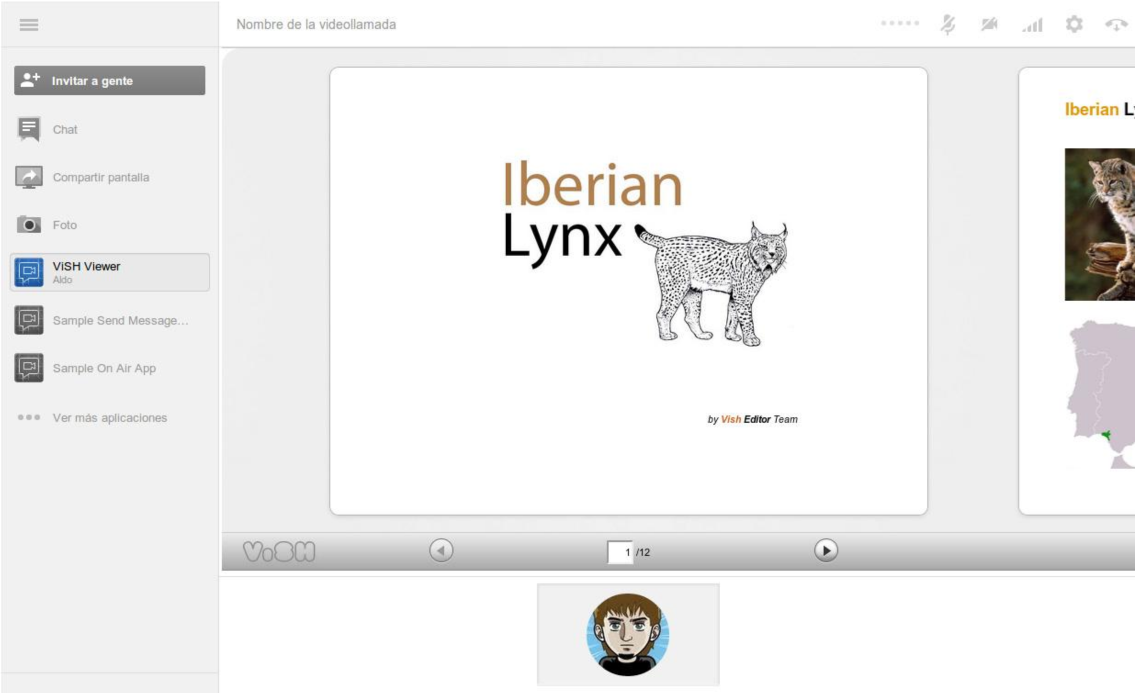

Figure 8.10: Learning Object published on the ViSH platform integrated into Google Hangouts

8.4.3.3 Web videoconferencing service developed based on Licode

In this validation, the model was implemented in a web-based platform called IDeM (Innovation, Dissemination et Multimedia) in order to enable the integration of the Learning Objects created with the ViSH Editor authoring tool into a web videoconferencing service developed based on the Licode platform that was integrated into IDeM.

IDeM is an open source web-based platform for researchers to share research papers, create slide presentations about these works, and schedule and record webinars to disseminate research findings and activities. Figure 8.11 shows the frontpage of the IDeM platform. Users need a Loop account to log in to IDeM. Loop [410] is a social network for researchers that aims to enhance academic reputation and impact for researchers within their communities as well as to the public. Loop provides a wide range of features including typical social networking features (personal accounts, user profile pages, following/follower relationships, activity panels, notifications and private messaging), sharing of publications, searching for articles and researchers, statistics, and user recommendations.

When users log in to IDeM using their Loop credentials, all their publications shared in Loop are included in their IDeM profile. After that, users can create slide presentations for their publications by using the ViSH Editor authoring tool, which was integrated into the IDeM platform. For example, users can use ViSH Editor to create web-based slide presentations for their conference papers by converting the PDF slideshows used to present such papers in the conferences. Users can also schedule webinars about their publications in order to disseminate their work. A webinar is a presentation, lecture or workshop that is transmitted over the Web using a videoconferencing system and that allows real-time interaction between the speakers and the audience. On a webinar conducted through the IDeM platform, the owner can invite users to join the webinar by sharing its URL, broadcast audio and video to all attendees, and synchronously share slide presentations created with the ViSH Editor authoring tool. Figure 8.12 shows a slide presentation created with ViSH Editor integrated into a webinar conducted through IDeM. A chat is provided to enable the communication between the speaker (i.e. the owner) and the audience as well as among the attendees. Furthermore, the owner can record the webinar so that it can be downloaded and used in the future. The recordings of the webinars can be published on the IDeM platform. Lastly, another relevant feature provided by IDeM is recommendations of research papers and ViSH Editor presentations. Papers are retrieved from Loop using its API while ViSH Editor presentations are retrieved from the IDeM database. The IDeM recommender system was implemented based on the recommendation model presented in chapter 7 of this thesis. IDeM was developed as a prototype for a competition for innovation in research social networks organized by Frontiers and UPM (Universidad Politécnica de Madrid). It is open source and the code is publicly available at http://github.com/ging/IDeM.

On the IDeM platform, webinars are conducted by using a web videoconferencing service integrated into the platform that was developed based on Licode. Licode [409] is an open source WebRTC communications platform developed by Lynckia that allows the creation of scalable web videoconferencing services based on WebRTC technologies, which can provide web videoconference rooms, streaming and recording among other real-time multimedia features. Licode also provides web applications with a client JavaScript API that offers several features including data sharing between web videoconferencing clients.

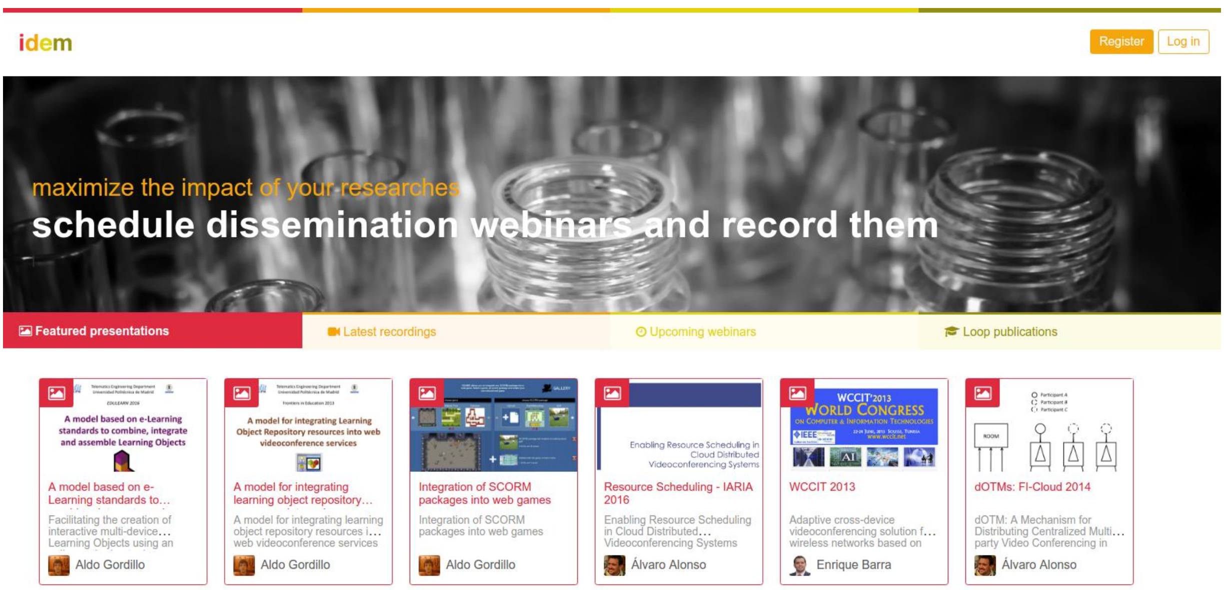

Figure 8.11: Frontpage of the IDeM platform

In this implementation, the ViSH Editor authoring tool, the LO API and the LOR API used in the previous validations of the model were reused. The request/deliver Learning Object function provided by the IDeM platform did not include the additional step to provide the LOR Gateway component (thus this function operates as specified in section 8.4.2.1). In order to integrate the Learning Objects created with the ViSH Editor authoring tool and published on the IDeM platform into the webinars conducted by using an integrated web videoconferencing service developed based on Licode according to the proposed model, a new LOR Gateway component was developed and included in the page of the webinars. This gateway includes on the one hand the LOR API and on the other hand the Licode client API. Thereby, the page of the webinars includes a web videoconferencing client developed based on Licode and the LOR Gateway component. The loading of the slide presentations created with ViSH Editor in the webinars is handled by the web videoconferencing client. To synchronously share a slide presentation, the web videoconferencing client requests IDeM the HTML page with that slide presentation and the LO API, and then embeds this page in an iframe. In this case, the Learning Objects (i.e. the slide presentations created with the ViSH Editor authoring tool) are co-viewed since all participants see the same instance but only the speaker can interact with them. Future versions of the IDeM platform could allow to conduct webinars with multiple speakers where all speakers were able to control the slide presentations.

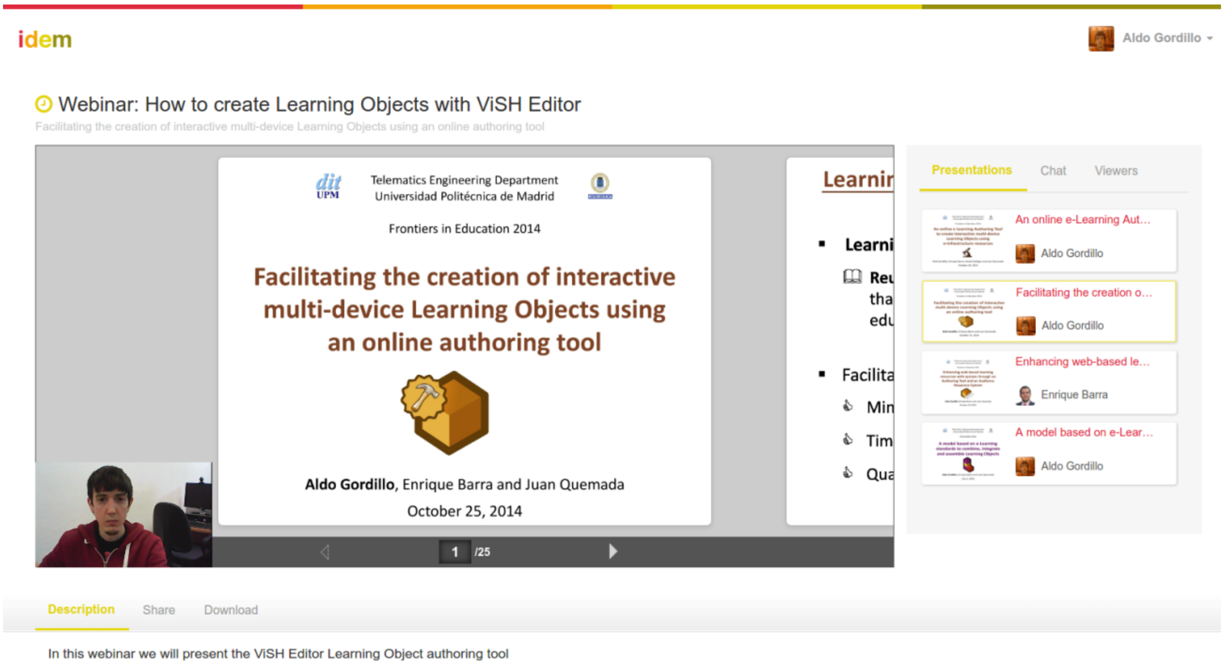

Figure 8.12: Learning Object integrated into a webinar conducted through the IDeM platform by using a web videoconferencing service developed based on Licode

8.5 A Model to Integrate SCORM Packaged Learning Objects into Web Games

8.5.1 Introduction

Game-Based Learning (GBL) is a learning approach in which learning is delivered through educational games. Several studies have provided empirical evidence that playing with educational video games can lead to positive impacts in terms of motivation and learning outcomes [358], [359]. Learners seem to like the game-based approach to learning and find it motivating and enjoyable. Besides, some studies (e.g. [359]) have also shown that, in some cases, GBL can not only motivate learners but also enhance learning effectiveness. All this evidence suggests that GBL can be an effective approach for teaching and learning. Taking this into account, it is not surprising that GBL has been pointed out as an emerging and promising research field [71]–[73].

One of the main barriers hampering the introduction, use and adoption of educational video games in educational contexts is their huge development cost [360], [361]. Learners expect to find in the educational video games the elements that they encounter in the entertainment games (i.e. non-educational games) that they play outside learning environments [359]. Therefore, educational video games should bear the features of entertainment games in order to meet learners' expectations and retain their interest. Moreover, since one of the main challenges of developing an educational video game is the achievement of an adequate balance between entertainment and educational value, this development adds, to the difficult and costly task of designing and implementing game elements that are fun and engaging, the challenge of achieving educational value [361]. Educational institutions and educators usually cannot afford to develop custom educational video games that meet the aforementioned requirements, and hence they have to resort to existing games. The main problem of using existing educational video games is that there are many topics and levels of difficulty which are not covered by them, and that these games cannot be customized in order to be used in different subjects and contexts. Another drawback of using existing educational video games is that these games usually do not provide teachers an easy and effective way of tracking and assessing the progress and learning outcomes of the learners. This fact also hinders the use and adoption of educational video games in educational contexts.

A possible solution for the limited availability of educational video games and the need to customize these games to adapt them to specific contexts is to use authoring tools. However, the number of authoring tools to create educational video games available to educators is still very low. Some examples of these tools are <e-Adventure> [361], e-Training DS [362], Game·Tel [363] and StoryTec [364], [365]. The variety of educational video games that can be created with existing authoring tools is very small. Currently, most of these tools are aimed to create educational video games of the story-driven genre. Some of them use an approach based on game templates, in which authors can create the educational video games through the configuration and customization of provided pre-made games. This approach often involves the integration of content and e-Learning resources into the game templates. Other common limitation of existing authoring tools to create educational video games is that the games they allow to create are much simpler and limited compared to most entertainment games. This is an important limitation because, as indicated before, educational video games should bear the features of entertainment games in order to meet learners' expectations and retain their interest.

One way to create educational video games is by integrating Learning Objects into existing video games. On the one hand, this approach allows to reuse existing video games for learning. Thereby, there is no need to develop games from scratch which has a huge cost, and the games used for learning will have similar features as the games used for entertainment. On the other hand, this approach allows to customize the educational video games by integrating different Learning Objects allowing their use in different subjects and contexts. The Learning Objects integrated into the games can be existing Learning Objects or can be created from scratch. Despite the clear advantages of this approach to create educational video games by integrating Learning Objects into existing video games, not much work has been done to put it into practice or to develop authoring tools based on it. One work that addresses this approach is that of Minović, Milovanović and Starčević [366], who proposed a solution to integrate Learning Objects into various multimedia platforms, and validated that solution in the context of video games (see section 2.9 for details). However, in practice, this solution is ineffective to create educational video games by integrating Learning Objects into existing video games because it does not rely on e-Learning standards, requires transforming Learning Objects to XML files using custom data models, and does not allow educators to easily create the educational video games by using authoring tools.

This section 8.5 presents a model to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games in order to create educational web games. Authoring tools that employ this model will be able to allow educators to create educational web games by integrating SCORM packaged Learning Objects into existing web games. Educators will also be able to customize the educational content inside the games allowing their use in different subjects and contexts. The integrated Learning Objects will be shown to the players when they perform specific actions or when certain conditions are met, and the games will be able to reward the players based on their interactions with the Learning Objects. In order to validate the presented model, a web-based platform was developed which provides an authoring tool that allows educators to create educational web games by integrating SCORM packaged Learning Objects into web games that act as game templates.

8.5.2 Model

8.5.2.1 Overview

The model designed to integrate Learning Objects packaged according to SCORM into web games in order to create educational web games presented in this chapter was named SGAME. This name is a blend of the words "SCORM" and "GAME". In the educational web games created using SGAME, the integrated Learning Objects will be shown to the players when certain events are triggered. These events may be triggered when the players perform specific actions or when certain conditions are met. After a player finishes interacting with a Learning Object, the game will be able to reward that player depending on whether or not he/she has successfully completed the Learning Object. For example, in a game created using SGAME, if players found a new weapon they would have to answer correctly to a self-graded question to acquire it. The use of rewards in this context seems to be a suitable approach because Learning Objects designed as games with clear rewards have been found capable of maintaining high levels of interest, and also there is evidence that suggests that these educational resources should be designed so that students can succeed in games only by demonstrating and applying the intended learning [15]. A Learning Object integrated into the game will communicate with the game in the same way as it would have communicated with an LMS if the SCORM package that contained it had been integrated into such an LMS. Thereby, the game can obtain and process the tracking data sent by the Learning Objects to determine if a player has successfully completed them. SCORM packages were designed to be integrated into LMSs. SGAME is based on the fact that these packages can be integrated into web games in a similar way.

SGAME aims to build a bridge between the educational community and the game developers' community. On the one hand, it enables the development of authoring tools that allow educators to use already developed web games to create educational web games whose learning content can be customized, either by integrating existing Learning Objects or Learning Objects created from scratch using Learning Object authoring tools. On the other hand, it allows game developers to create educational web games reusing existing Learning Objects, as well as to easily convert their web games into game templates that can be used to create customizable educational web games through authoring tools.

8.5.2.2 SCORM and Games

Today, SCORM is the most used e-Learning standard for packaging Learning Objects [148], and it is supported in most of the major LMSs. Section 2.2.3.3 of this thesis provides the reader with a detailed description of SCORM. Although the present section summarizes the key aspects of SCORM necessary to understand how SGAME works, the reader is encouraged to read section 2.2.3.3 to obtain more detailed knowledge. The present section also provides an analysis of the possibilities that SCORM offers to integrate Learning Objects into games.

8.5.2.2.1 Overview of SCORM

The latest and recommended version of SCORM is SCORM 2004 4th Edition [110]. This overview provides a brief summary of this version. In SCORM, web-based resources are packaged through SCORM Content Packaging, an extension of the IMS CP 1.1.4 specification [113]. Only web-based resources are allowed to be packaged. A SCORM package consists of a ZIP file that contains a manifest file in XML format that strictly adheres to IMS CP 1.1.4 and all the local resources. Remote resources, if any, are referenced in the manifest file. Each resource contained in a SCORM package can be a SCO (Shareable Content Object) or an asset. A SCO is a resource that will use the SCORM API to interact with the SCORM Run-Time Environment when it is launched and while it is running, and an asset is a resource that is used in a learning activity but does not use the SCORM API. SCORM also specifies how to use IEEE LOM metadata to describe the different packaged resources and how to include those metadata in XML format in a SCORM package. Although other metadata standards can be used, SCORM strongly recommends the use of IEEE LOM 1.0 [119].

SCORM defines how the web-based resources have to be launched in LMSs and the way of doing the communication between SCOs and LMSs using the SCORM API. LMSs must launch the SCOs in web browser windows that provide an instance of the SCORM API as a DOM [150] object accessible via JavaScript. This API instance must be provided by the LMSs and must implement and expose the functions of the SCORM API. It is the responsibility of the SCOs to recursively search the parent and/or opener window hierarchy until the API instance is found, as well as to initialize and terminate the communication. A SCO can report various information to the LMS using the SCORM API including:

- *Success status*. Indicates whether the learner has mastered or passed the SCO.
- *Completion status*. Indicates whether the learner has completed the SCO.
- *Score*. The learner score or grade for the SCO.
- *Progress Measure*. A measure of the progress the learner has made towards completing the SCO.

SCORM packages can define threshold values in their manifest file to allow LMSs to determine the success status and the completion status for the SCOs based on, respectively, the score and progress measure reported by them. Although SCORM specifications are focused on LMSs, SCORM can be implemented and used in other software systems. SGAME is based on the fact that SCORM packages can be integrated into web games in a similar way as they are integrated into LMSs.

Lastly, SCORM also describes how to build sequencing information according to the IMS SS 1.0 specification [117] and how to place that information in the manifest file. Thereby, a SCORM package can specify the order in which resources will be presented to the learners. Moreover, a SCORM package can also include information related to navigation options.

8.5.2.2.2 Possibilities to integrate SCORM packaged Learning Objects into games

SCORM only allows to package resources of type "webcontent". That means that, in practice, all SCORM packaged Learning Objects are web applications. Therefore, from a technical point of view, these Learning Objects can be easily integrated into web games by using the iframe HTML element. The communication between the integrated Learning Objects and a web game can be achieved if the game launches the Learning Objects in an iframe and provides an instance of the SCORM API accessible via JavaScript. In this regard, a technological issue that should be taken into account is the so called cross-domain issue [346], [405], which should be solved in order to enable this communication when the Learning Objects are delivered from a different web domain than the one from which the web game is delivered. Thus, one way to enable the communication between the Learning Objects and the web games into which they are integrated is to store and deliver the games and the Learning Objects from the same web server. Other possible way is to overcome the cross-domain issue, for instance, by using the solution proposed by the model to integrate, combine and assemble Learning Objects presented in section 8.3 of this chapter.

Although there are no insurmountable technical constraints to integrate SCORM packaged Learning Objects into web games, not all educational resources are suitable to be used in games. For example, although a one-hour video can be a very good educational resource to be used in a traditional course, it is not suitable to be used in a game. Educational video games should have an adequate balance between entertainment and educational value. Players should not be interrupted for a long time while they are playing with educational video games because otherwise they will find the game boring, lose interest and leave the game before acquiring any knowledge. Thus, only those Learning Objects which are very small in terms of learning time needed to complete them should be integrated into games. Furthermore, as in any other learning context, Learning Objects should be aligned with learner characteristics. Mainly, they should be in a language known to the players and have an appropriate level of difficulty for the intended players. Besides, it would be convenient that all Learning Objects were aligned with the same learning goals. Another issue to consider is the alignment between the Learning Objects and the games into which they can be integrated. It is reasonable to think that the integration will be better if the topic of the Learning Objects is related to the game and their look and feel is in line with the game.

IEEE LOM, the most widely used metadata standard in the field of educational technology and the one recommended by SCORM to describe the packaged Learning Objects, defines several metadata fields that can include very valuable information to determine the suitability of a Learning Object to be integrated into a game. The "typical learning time" LOM metadata field indicates the approximate or typical time it takes to work with or through the Learning Object for the typical intended target audience. The "duration" field includes the time a continuous Learning Object (e.g. a video or a sound) takes when played at intended speed. These LOM metadata fields can be used to determine if a Learning Object is small enough in terms of learning time needed to complete it to be integrated into a game. LOM defines other metadata fields useful to determine if a Learning Object is aligned with learner characteristics. The "language" field of the general category indicates the language of the Learning Object while the "language" field of the educational category indicates the language used by the typical intended learner. The "typical age range" field provides the age of the typical intended learner while "context" provides the principal environment (school, higher education, training or other) within which the use of the Learning Object is intended to take place. Lastly, the "difficulty" field indicates how hard it is to work with or through the Learning Object for the typical intended learner on a qualitative scale with five values: very easy, easy, medium, difficult, and very difficult. Other LOM metadata fields that could be useful to determine the suitability of a Learning Object to be integrated into a game are "keyword" and "learning resource type".

Although LOM defines various metadata fields useful for integration purposes, in practice, many of them are not often used to describe Learning Objects. For instance, [217] analyzed more than 600,000 LOM metadata instances provided by 7 LORs and found that language was defined in around 90% of the instances, learning resource type and keywords were defined in around 60% of the instances, typical age range and context were defined in less than 50% of the instances, duration and learner language were defined in less than 20% of the instances, and difficulty and typical learning time were defined in less than 10% of the instances. A similar study analyzed more than 300,000 Learning Objects from 8 LORs that used LOM metadata and found that, aside learning resource type (31%) and context (20%), no other LOM educational fields were defined in more than 15% of the Learning Objects [211]. If a Learning Object is not tagged with appropriate metadata, it would be not possible to automatically decide whether it is suitable or not to be integrated into a game. If the integration is performed through an authoring tool, users can be in charge of deciding which Learning Objects should be integrated. In this case, available metadata can be used to help users to make these decisions.

A key issue in integrating SCORM packaged Learning Objects into games is how to track the progress of the players towards completing the integrated Learning Objects and how to determine whether they successfully complete these Learning Objects. As explained before, a web game can enable the integrated Learning Objects to communicate with it by providing an instance of the SCORM API accessible via JavaScript. Thereby, a web game will be able to collect the same tracking data of the Learning Objects as an LMS. Nevertheless, it should be taken into account that the SCORM API will only be used by those Learning Objects that are SCOs and not by those that are assets.

Assets do not use the SCORM API and therefore they do not report any tracking data. Thus, assets can be displayed in the games but when a player leaves an asset the only information that a game can obtain is the time during which the asset was displayed. As a consequence, games need to determine whether a player has successfully consumed an asset based exclusively on the time spent. In this regard, one option that a game could take would be to determine the player's success by comparing the time spent on the asset with the typical learning time defined in its metadata.

For SCOs, a game can determine the success and progress of the players by using the success status, completion status, score and progress measure reported by them. For instance, if a game integrates a SCO consisting of one multiple choice question that reports a "passed" success status through the SCORM API when a player answers it correctly, that game could determine that a player has successfully completed the SCO based on the reported success status. Besides the above tracking data, games can obtain additional data about the interactions the players have with the SCOs through the SCORM API. It must be taken into account that SCORM that does not require SCOs to report any tracking data. Therefore, in those cases where a SCO does not report enough tracking data, games will need to determine whether a player has successfully consumed the SCO based exclusively on the time spent by the player on the SCO in the same way as with assets.

Finally, although the sequencing information included in SCORM packages can be very useful for the integration of Learning Objects into e-Learning systems such as LMSs, this information could be less useful for their integration into games. Games present Learning Objects to the players when certain conditions are met (e.g. when players perform a certain action or when a game event happens). Generally, the games will decide which Learning Object will be shown on each occasion based on the game state. Nevertheless, games could decide the order in which Learning Objects are presented to the players based also on the provided sequencing information. For instance, a game could show a whole SCORM package to the players by using a SCORM viewer, and allow the players to navigate through all the Learning Objects of the package according to the included sequencing information. However, this option is not adequate because, as explained above, games should not be interrupted for a long time. On each interruption, a game should present only one small and self-contained Learning Object instead of presenting a set of resources. Thus, the navigation options that can be included in SCORM packages are not very useful for the integration of Learning Objects into games. A more interesting option for games is to use the sequencing information defined in the SCORM packages to present the Learning Objects of a same SCORM package one by one, but according to the sequencing information included in the package. Thereby, games will not be interrupted for long periods of time but Learning Objects related among them will be able to be suitably integrated. For example, a slideshow with 10 slides about a certain topic could be integrated into a game in such a way that the slides were presented in order but that only one was displayed each time a player is interrupted while playing.

8.5.2.3 SGAME Architecture

Figure 8.13 shows the architecture defined by the SGAME model, including the different components involved in the integration of SCORM packaged Learning Objects into web games in order to create educational web games and the interactions among these components. Next, a brief description of each of the components is provided:

- *Game Instances*. Game instances are educational web games created by integrating Learning Objects into a game template according to the SGAME model. These games are presented to the users as traditional entertainment games, but they are interrupted to show Learning Objects to the players when certain events are triggered. Thereby, at a given instant, game instances can show to a player the game or a Learning Object to be completed. Game instances are games which are expected to reward the players when they successfully complete a Learning Object. To show the Learning Objects and communicate with them, game instances use the SGAME API. Thus, game instances are composed of a game template, a set of Learning Objects and the SGAME API.
- *Game Templates*. A game template is an entertainment web game that has included the SGAME API in order to request Learning Objects to be shown to the players when certain events are triggered. Game templates should define the specific events whose triggering will cause a Learning Object to be shown, as well as the rewards that players will receive when they successfully complete one of these Learning Objects.

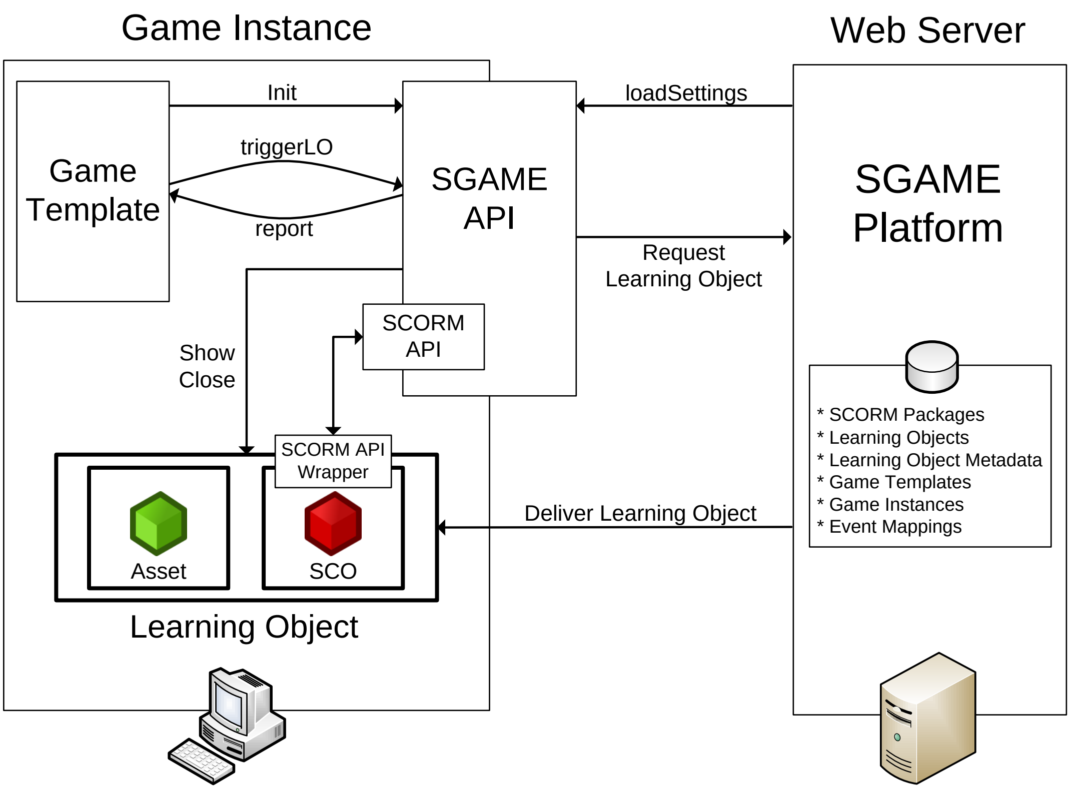

Figure 8.13: Architecture defined by the SGAME model to integrate SCORM packaged Learning Objects into web games

- *Learning Objects*. SGAME assumes that all Learning Objects have been extracted from a SCORM package. Thus, these Learning Objects can be assets or SCOs.
- *SGAME API*. It is a JavaScript API that allows any web game to request Learning Objects and show them to the players inside the game, as well as to obtain tracking data about the success and progress of the players with the showed Learning Objects. These tracking data are provided with the intention of allowing the game to reward the players when they successfully complete Learning Objects. By including and using the SGAME API, any web game can be used as a game template to create game instances by integrating Learning Objects. The SGAME API requests the Learning Objects to a web server termed SGAME platform, and launches them in iframes. Furthermore, in order to obtain the tracking data reported by SCOs, it includes an instance of the SCORM API accessible via JavaScript. Further details about the SGAME API are provided in the next section.
- *SGAME Platform*. This platform is a web server that stores the SCORM packages, the Learning Objects and their metadata, the game templates, and the game instances. The SGAME platform must provide five main features. First, it must allow to upload SCORM packages as well as to extract and store all the Learning Objects (i.e. all the assets and SCOs) contained in these packages and their metadata. Second, it must allow to upload and store game templates. Third, it must provide an authoring tool to create game instances (i.e. educational web games) by mapping the events defined by a game template with Learning Objects. The event mapping of each created game should be stored in the database together with the game. Fourth, the SGAME platform must deliver the created game instances to web browsers with their corresponding settings. Lastly, the SGAME platform must communicate with the SGAME API of the game instances to deliver the requested Learning Objects. Since both game instances and Learning Objects are hosted by the SGAME platform, the cross-domain issue is avoided. Interesting optional features that an implementation of the SGAME platform might offer are, among others, edition of Learning Object metadata, Learning Object authoring tools, exportation of game instances to SCORM (see section 8.5.2.6), quality metrics, learning analytics, and recommendations of Learning Objects, game templates and game instances.

8.5.2.4 SGAME API

The SGAME API is the most important component of the SGAME model. It is a JavaScript API that allows game developers to easily convert web games into game templates that can be later used by authoring tools to create educational web games by integrating Learning Objects, as well as to develop educational games using web technologies and relying on the SCORM e-Learning standard to integrate Learning Objects.

The SGAME API is simple to integrate and use. It provides game templates with only two functions: *Init* and *triggerLO*.

The *Init* function can be called by the game templates when the game is initialized in order to set some settings. The SGAME API must allow game templates to specify a *togglePause* function that allows to pause the game when a Learning Object is popped up as well as to resume the game when the Learning Object is closed. This setting is the only one that the SGAME API is required to support. However, implementations of the SGAME API are free to support more settings such as user interface options (e.g. a background image to be added to the windows in which the Learning Objects are shown, or a CSS file to fully customize the look and feel of these windows), parameters or custom functions to determine whether the showed Learning Objects are successfully completed by the players, and criteria (e.g. time, difficulty and learning resource type) to select the most appropriate Learning Object to be shown when an event is triggered and there are multiple options available. Game templates are not required to call the *Init* function if they pause and resume the game when necessary. However, in that case, the SGAME API will work with its default settings.

The *triggerLO* function is the function that game templates should call to interrupt the game and show a Learning Object to a player when a certain event is triggered. The only parameters that game templates should pass to this function are the identifier of the event and a callback function. When the *triggerLO* function is called, the SGAME API must determine the Learning Object that will be shown to the player based on the event identifier passed as a parameter and the event mapping of the game instance. This event mapping can map the event to a specific Learning Object or to a specific list of Learning Objects. If the event is mapped to a single Learning Object, that Learning Object will be selected. If the event is mapped to a list of Learning Objects, the SGAME API must decide which one will be shown. To take this decision, the SGAME API can use metadata of the events, metadata of the Learning Objects, sequencing information, and settings provided by the game template using the *Init* function. SGAME does not specify how the SGAME API must decide which Learning Object should be shown when there are multiple options available, and hence implementations of the SGAME API are free to use their own decision-making algorithms. When the SGAME API decides which Learning Object is going to be shown, it will request this Learning Object to the SGAME platform. The SGAME API will launch the Learning Object in an iframe and, for SCOs, it will provide an instance of the SCORM API accessible via JavaScript. If a *togglePause* function has been set by the game template, the SGAME API will use it to pause the game before popping up the Learning Object as well as to resume the game after this Learning Object is closed.

Whenever the player leaves the launched Learning Object by closing the window in which it is shown, the SGAME API must invoke the callback function specified by the game template with two parameters: a Boolean value named *success* indicating whether the player has successfully completed the Learning Object, and a JavaScript object named *report* containing tracking data of the Learning Object. The SGAME API must include in the *report* the metadata of the displayed Learning Object and the time during which this Learning Object was displayed (i.e. the time the player spent on it). Besides, for SCOs, the SGAME API must include in the report the following information if it is reported by them: success status, completion status, score and progress measure. The SGAME API should calculate the *success* parameter that indicates if the player successfully consumed the Learning Object in a different manner depending on whether the Learning Object was an asset or a SCO.

Since assets do not use the SCORM API and hence they do not report any tracking data, the only information that can be obtained is the time the player spent on the asset. Thus, for assets the *success* parameter can be calculated based on this time according to the following algorithm:

$$success(t_{spent}) = \begin{cases} true, & if\ t_{spent} \geq t_{required} \\ false, & otherwise \end{cases}$$

where

$$t_{required} = \begin{cases} MIN(\alpha \times t_{TLT}, t_{MAX}), & if\ t_{TLT}\ exists \\ t_{default}, & otherwise \end{cases}$$

where t_{spent} is the time during which the Learning Object was shown to the player,
$t_{required}$ is the time during which the Learning Object should have been shown to the player to consider that this player successfully completed it,
t_{TLT} is the typical learning time defined in the metadata of the Learning Object,
α is a parameter that can be adjusted to calculate $t_{required}$ as a percentage of t_{TLT},
$t_{MAX} \geq t_{default}$ is the maximum value that $t_{required}$ can take, and
$t_{default}$ is a fixed value that $t_{required}$ takes when t_{TLT} has not been defined
(8.1)

For SCOs, besides the time during which they were shown to the player, the SGAME API can obtain different tracking data reported by them using the SCORM API. Therefore, the SGAME API can calculate the *success* parameter for SCOs using also these data.

For SCOs compliant with SCORM 2004 4th Edition, the SGAME API can calculate the *success* parameter using the following elements of the SCORM data model: *cmi.success_status*, *cmi.score.scaled* and *cmi.scaled_passing_score*. The *cmi.success_status* element indicates whether the learner has mastered or passed the SCO. This element has a default value of "unknown" but the SCO can set it to "passed" or "failed". The *cmi.score.scaled* is a real number on a scale from -1 to 1 that the SCO can set to reflect the performance of the learner. Lastly, the *cmi.scaled_passing_score* element is the score on a scale from -1 to 1 required to master or pass the SCO. This element cannot be set by the SCO using the SCORM API. Instead, it is defined in the manifest file of the SCORM package containing the SCO. If *cmi.scaled_passing_score* is defined, *cmi.success_status* can be determined based on the *cmi.score.scaled* reported by the SCO.

Taking all these into account, the SGAME API can calculate the *success* parameter for SCOs compliant with SCORM 2004 4th Edition as follows. If the value of *cmi.success_status* is different than "unknown", *success* will be true if the value of *cmi.success_status* is "passed" and false otherwise. If the value of *cmi.success_status* is "unknown" but *cmi.score.scaled* exists (i.e. if a score has been reported by the SCO), the *success* parameter is calculated as follows:

$$success(cmi.score.scaled) = \begin{cases} true\,, & if\ cmi.score.scaled \geq s_{required} \\ false\,, & otherwise \end{cases}$$

where

$$s_{required} = \begin{cases} cmi.scaled\_passing\_score, & if\ cmi.scaled\_passing\_score\ is\ \ defined \\ s_{default}\,, & otherwise \end{cases} \tag{8.2}$$

where $s_{required}$ is the score the player must achieve to master or pass the Learning Object, and

$s_{default}$ is a fixed value that $s_{required}$ takes when $cmi.scaled\_passing\_score$ has not been defined

Finally, if at the time the player leaves the launched SCO by closing the window in which it is shown this SCO has not reported a *cmi.success_status* or a *cmi.score.scaled*, the *success* parameter will be set to false.

This algorithm to determine the *success* parameter for SCOs assumes that if a player successfully completes a SCO, this SCO will report a *cmi.success_status* or a *cmi.score.scaled* through the SCORM API. However, since SCORM does not require SCOs to report any tracking data, there may be cases in which this assumption is not satisfied. Unfortunately, there is no way to automatically identify which SCOs will report enough tracking data to calculate the *success* parameter and which ones will not. Thus, SGAME proposes that the users that upload SCORM packages and create game instances should be in charge of providing this information, and that the SGAME platform should store such information in the metadata of the SCOs that are provided to the SGAME API. Thereby, the SGAME API can use the algorithm for SCOs described above to calculate the *success* parameter for those SCOs that report a *cmi.success_status* and/or a *cmi.score.scaled,* and the algorithm for assets to calculate the *success* parameter for the other SCOs based exclusively on the time players spend on them.

For SCOs compliant with SCORM 1.2, the SGAME API can calculate the *success* parameter in a similar way as it does for SCORM 2004 4th Edition using the following elements of the SCORM data model: *cmi.core.lesson_status* (instead of *cmi.success_status*), *cmi.core.score.raw* (instead of *cmi.score.scaled*), and *cmi.student_data.mastery_score* (instead of *cmi.scaled_passing_score*). Therefore, the SGAME API allows to integrate Learning Objects compliant with any of the two main SCORM versions: SCORM 1.2 and SCORM 2004 4th Edition.

The algorithms defined so far to calculate the *success* parameter for assets and SCOs are recommendations proposed by the SGAME model. The parameters of these algorithms can be freely selected. In the SGAME API developed to validate the SGAME model, α was set to 0.5, t_{MAX} was set to 60 seconds, $t_{default}$ was set to 15 seconds, and $s_{default}$ was set to 0.8 out of 1. Implementations of the SGAME API are also free to modify the recommended algorithms as well as to provide new algorithms. Nonetheless, any implementation of the SGAME API must calculate the *success* parameter and send it to the game template each time a player leaves a Learning Object in order to indicate whether this player has successfully completed the Learning Object. Furthermore, an implementation of the SGAME API can also allow game templates to provide their own parameters or functions to calculate the *success* parameter by using the *Init* function. This could be especially useful for game developers who want to develop full educational web games using the SGAME API.

In conclusion, when a player closes a window in which a Learning Object is shown in a game instance as a result of the game template calling the *triggerLO* function, this game template will receive from the SGAME API a Boolean value indicating whether the player successfully completed the Learning Object, and a JavaScript object containing tracking data as well as the metadata of the showed Learning Object. The game template can use this information to decide if the player should be rewarded and, if so, to decide which reward should be given. For example, a game template could call the *triggerLO* function when the player opens a chest to show a quiz with 5 equally-weighted questions, and give the player 20 coins for each correct answer (i.e. a number of coins equal to 100 multiplied by the *cmi.score.scaled* included in the report). The game template could also give different rewards depending on the difficulty of the Learning Object defined in its metadata. For instance, in the previous example, for “difficult” quizzes players could receive 30 coins for each correct answer while for “easy” quizzes they could receive only 10 coins.

Game templates can trigger Learning Objects for very different events and purposes. For instance, an RPG (Role-Playing Game) could trigger a Learning Object when players try to enter in a village, and do not allow them to enter until they successfully complete it. Instead, a platform game could give players the chance of consuming a Learning Object each time their characters die in order to obtain an extra life. In summary, there is plenty of ways in which Learning Objects can be integrated into games so that players can be motivated to successfully complete them. According to the SGAME model, game templates are responsible of defining the specific events whose triggering will cause Learning Objects to be shown, as well as of determining the rewards that players will receive when they successfully consume these Learning Objects based on the metadata of the Learning Objects and the reported tracking data. The mapping between the events defined by the game templates and the Learning Objects is performed on the SGAME platform through an authoring tool to create game instances.

Lastly, the SGAME API provides a *loadSettings* function that must be called to initialize the game instance to which the API belongs. This function is not intended to be used by game templates. Instead, it should be invoked by JavaScript code provided by the SGAME platform or by the game instances. When a game instance is delivered by the SGAME platform, the platform will be responsible of calling the *loadSettings* function. Thus, when the SGAME platform delivers an HTML page containing a game instance, it must include JavaScript code in that page to call the *loadSettings* function of the SGAME API. There are cases in which game instances are not delivered by the SGAME platform. For instance, when they are exported as SCORM packages to be integrated into VLEs, or when game developers implement their own game instances using the SGAME API. In these cases, the *loadSettings* function should be called by the game instances (i.e. by the educational web games).

The *loadSettings* function must receive only one parameter: a JavaScript object containing, at least, the metadata of the Learning Objects integrated into the game instance and the mapping between the events defined by the game template and these Learning Objects. The metadata of each Learning Object must include, in addition to the metadata defined in the SCORM package from which it was unpacked, its SCORM version, type (asset or SCO), unique identifier within the game instance, and URL. For SCOs, these metadata could also include a field indicating if they report enough tracking data (e.g. a success status or a score) to calculate the *success* parameter. The event mapping must include, for each event defined by the game template, its identifier as defined by the game template and the Learning Object or set of Learning Objects mapped to it. These Learning Objects should be referenced using their unique identifiers within the game instance. If the SGAME API uses event metadata or sequencing information, these data should be also provided through the *loadSettings* function. Moreover, implementations of the SGAME API are free to support more settings.

When game instances are delivered by the SGAME platform, the settings passed to the *loadSettings* function must be retrieved from the database of this platform. In this case, the identifiers and URLs of the Learning Objects in the SGAME platform will be used. When game instances are not delivered by the SGAME platform, they must have all data required to initialize the game (i.e. the metadata of the Learning Objects and the event mapping) and call the *loadSettings* function. If game instances are exported as SCORM packages through the SGAME platform, their settings can be easily retrieved from the database of the platform and included in the SCORM packages (see 8.5.2.6 for details). When game developers use the SGAME API to implement game instances (i.e. educational web games compliant with the SGAME model) without using the SGAME platform, they need to call *loadSettings* from the game instance passing the required initialization data (i.e. the metadata of the Learning Objects and the event mapping). In this case, the Learning Objects must be stored together with the game instance, and the game developers must specify their identifiers and URLs.

8.5.2.5 Creation of SGAME compliant game templates and full games

This section lists the requirements that game developers should take into account to convert web games into game templates compliant with SGAME that can be later used to create educational web games through authoring tools, as well as to develop full educational web games using the SGAME API to integrate SCORM compliant Learning Objects.

Game developers who want to convert web games into game templates should consider that a web game must meet the following requirements to be a SGAME compliant game template:

- Include the SGAME API, use this API to show Learning Objects when certain events are triggered, and reward the players when they successfully complete these Learning Objects.
- The game should be paused when a Learning Object is popped up, and should be resumed when that Learning Object is closed. This will be automatically handled by the SGAME API if the game provides it with a function to toggle the pause status.
- Include an HTML file called “index.html” that launches the game.
- Include a JSON file called “sgame_events.json” describing the events of the game whose triggering can cause Learning Objects to be shown. This file should contain an array of objects, each object representing an event. Each event must have the following mandatory fields: “id” (event identifier within the game), “name” and “description”. Implementations of the SGAME model can use data models for the events that define more fields such as “type” (e.g. extra life, new item, blocking), “importance” (e.g. low, medium, high) or “frequency” (e.g. one shot, rare, recurrent).

In order to upload a game template to the SGAME platform, this game template should be packaged in a ZIP file with the “index.html” and “sgame_events.json” files at the root. The sgame_events.json file will be used by the SGAME platform to store the events defined by the game template in the database.

Game developers who want to create full educational web games using the SGAME API instead of game templates should consider that these full games must meet, in addition to the first two requirements of the game templates, the following requirements:

- The Learning Objects must be unpacked and stored together with the game.
- The game must call the *loadSettings* function of the SGAME API passing the required initialization data: the metadata of the Learning Objects and the event mapping. Thus, game developers should define the identifiers and URLs of the Learning Objects as well as the identifiers of the events.

The way in which these full educational web games are delivered to the learners after their creation is outside the scope of SGAME. Next section presents one possible way of delivering these games by integrating them into SCORM compliant VLEs.

8.5.2.6 Integration of game instances into SCORM compliant Virtual Learning Environments

This section explains how educational web games created according to the SGAME model (i.e. game instances) can be exported as SCORM packages enabling their integration into SCORM compliant VLEs. The solution proposed by SGAME to achieve this integration consists of using the model to integrate, combine and assemble Learning Objects presented in section 8.3 of this chapter. Since this assembly model was designed for e-Learning authoring tools, it can be implemented in the authoring tool provided by the SGAME platform to create educational web games by integrating SCORM packaged Learning Objects. Thereby, the created educational web games (i.e. the game instances) will behave as one single resource or activity in the eyes of the VLEs into which they are integrated independently of the number of Learning Objects used to create them.

The VLE Gateway component defined by the assembly model should be included in the SGAME API. This component should gather all relevant tracking data of the different Learning Objects integrated into the game, combine these data, and notify them in a unified way to the SCORM compliant VLE into which the game is integrated using the SCORM API (see Figure 8.2). The settings used by the VLE Gateway to calculate the success status, score, completion status and progress reported by the game to the VLE can be provided through the *loadSettings* function of the SGAME API. In order to solve the cross-domain issue, both the Learning Objects and the SCORM player should be delivered by the SGAME platform. Besides, the SCORM player must include the SCORM Gateway component.

In order to package a game instance in a SCORM package, the SGAME platform should include in this SCORM package the game template of the game instance, including the SGAME API with the VLE Gateway. Furthermore, the SGAME platform should include in the SCORM package an HTML page containing the game template (together with the SGAME API) and JavaScript code to call the *loadSettings* function of the SGAME API passing the required initialization data: the metadata of the Learning Objects and the event mapping. This HTML page, which will be used to launch the game instance in the VLE, should be included in the manifest file of the SCORM package as a resource of type SCO. The initialization data passed to the *loadSettings* function can be obtained from the database of the SGAME platform.

When game developers use the SGAME API to implement game instances without using the SGAME platform the Learning Objects must be stored together with the game instances. In these cases, the game instances can be exported as SCORM packages if the SCORM player (together with the SCORM Gateway) is provided and handled by the SGAME API.

Lastly, it is worth pointing out that the assembly model presented in section 8.3 of this chapter can allow game instances to integrate Learning Objects compliant with other e-Learning standards besides SCORM such as IMS QTI and Moodle XML.

8.5.2.7 Limitations

This section describes the main limitations of the SGAME model designed to integrate Learning Objects into web games in order to create educational web games.

- Only those Learning Objects which are very small in terms of learning time needed to complete them are appropriate to be integrated into the educational web games. Furthermore, although the IEEE LOM standard defines a metadata field to indicate this time, it is not defined in most of the Learning Objects available in LORs.
- SGAME only defines how to integrate Learning Objects packaged according to the SCORM e-Learning standard. Nonetheless, by applying the model to integrate, combine and assemble Learning Objects presented in section 8.3 of this chapter, it would be possible to integrate Learning Objects compliant with other e-Learning standards such as IMS QTI and Moodle XML.
- Internet connection is required to play the educational web games created using authoring tools because the integrated Learning Objects are always delivered from a web server. Nevertheless, it would be possible to package these games in SCORM packages so that it could be used offline.
- The only information that can be used to determine whether a player has successfully completed an asset or a SCO that do not report tracking data is the time the player spent on the Learning Object. Furthermore, there is no way to automatically identify which SCOs will report enough tracking data to determine the players' success and which ones will not, and hence users should provide this information.
- Although the SGAME API is simple to integrate and use, converting web games into game templates is not automatic and requires some effort by the game developers. Besides, in order to allow educators to create educational web games through authoring tools, these game templates should be released under licenses that provide free and perpetual rights to use, modify and redistribute them.

8.5.3 Validation and Results

In order to validate the SGAME model, a prototype of a web-based platform was implemented. This web-based platform, which was named "SGAME platform", provides an authoring tool that allows users to create educational web games by integrating SCORM packaged Learning Objects into existing web games according to the SGAME model. The source code of the SGAME platform (including an implementation of the SGAME API) has been released under an open source license and is available at http://github.com/agordillo/sgame. The SGAME platform is open for contributions from the educational community as well as from the game developers' community. This section describes the current version of the platform and presents an example of an educational web game created with it.

8.5.3.1 SGAME platform

The main feature offered by the SGAME platform is a straightforward authoring tool to create educational web games by integrating SCORM packaged Learning Objects into existing web games. Figure 8.14 shows this authoring tool, which is provided on the frontpage of the SGAME platform. The usage of the authoring tool is very simple: the user has to choose a game template, one or more SCORM packages, and then click on the "Create" button. The user can preview the Learning Objects contained in the SCORM packages before creating the educational web game. After clicking on the "Create" button, a form will be popped up to let the user indicate a title and an avatar for the game. After submitting the form, the educational web game will be created and the user will be redirected to a page in which he/she will be able to play it. Next section presents one example of a game created on the SGAME platform. The event mapping of the created games is automatically generated by the SGAME platform in such a way that each of the events defined by the game template is mapped to all the Learning Objects contained in the SCORM packages selected by the user. Future plans for the platform include implementing new features to allow users to define these event mappings as well as to edit the metadata of the Learning Objects from the user interface. Each created game has its own URL so it can be easily shared. Furthermore, all the educational web games that are created with the authoring tool of the SGAME platform are included in a gallery allowing users to easily access them.

Figure 8.14: SGAME Platform

The current version of the SGAME platform provides three game templates that users can use to create educational web games through the authoring tool. Two of these game templates, “Onslaught! Arena” and “Sokoban”, are open source games that have been modified to use the SGAME API. The other game template, called “Natural Park”, is a game prototype that was developed from scratch. These three game templates are very different: Onslaught! Arena is a medieval fantasy shooter game in which the player controls a fighter and has to shoot different kinds of monsters, Sokoban is a puzzle game where the player must push boxes onto certain squares, and Natural Park is a very simple RPG-like game where the player controls a character that has to explore a natural park by interacting with different objects and non-player characters. Future versions of the platform will allow users to upload their own game templates as defined by the SGAME model.

The SGAME platform also provides several SCORM packaged Learning Objects that users can use to create educational web games through the authoring tool. Some of these Learning Objects were created using authoring tools such as Articulate Quizmaker and ViSH Editor, while others were existing open-licensed Learning Objects that were obtained from the Web. These Learning Objects include both examples of assets and SCOs. Besides using the Learning Objects offered by the platform, users can upload their own SCORM packages to the SGAME platform in order to integrate the Learning Objects contained in them into the games.

The SGAME platform also provides an implementation of the SGAME API, which is used by the game templates to integrate the Learning Objects. This implementation meets all the mandatory requirements specified by the SGAME model. As explained before, SGAME defines the functions the SGAME API must offer and how this API must behave. However, SGAME intentionally does not define some aspects of the SGAME API in order to allow some flexibility in its implementation. Next, this section describes how these aspects were implemented in the SGAME API used in the SGAME platform. When an event is mapped to a list of Learning Objects, the SGAME API selects the Learning Object to be shown to a player when that event is triggered by randomly choosing one Learning Object among those on the list that have not been shown yet. When all Learning Objects have been shown, the process starts again from scratch and all Learning Objects on the list can be shown to the player again. The SGAME API also allows to map an event to all Learning Objects included in the game. For assets, the *success* parameter is calculated according to the algorithm recommended by the SGAME model using the following parameters: $\alpha = 0.5$, $t_{MAX} = 60$ seconds, and $t_{default} = 15$ seconds. For SCOs, the *success* parameter is calculated according to the algorithm recommended by the SGAME model but using $s_{required} = s_{default} = 0.8$. Thus, the SGAME API assumes that all SCOs integrated into the game report a success status or a score if a player successfully completes them. Future versions of the SGAME platform will allow users to specify for which SCOs the *success* parameter should be calculated using the same algorithm as for assets.

Lastly, it is worth mentioning that the SGAME API includes a traffic light in the windows that display the Learning Objects in order to provide feedback to the players (see right side of Figure 8.15). This traffic light is always red when a Learning Object is launched. If when a player closes a window the traffic light is not green, the SGAME API will report a *success* parameter equal to false and hence that player will not be rewarded. For assets, the colour of the traffic light changes depending on the time during which they are displayed. When an asset has been displayed for approximately 50% of the required time, the traffic light turns to amber. The traffic light will turn to green when such an asset has been displayed for the required time. For SCOs, the colour of the traffic light will turn to green only when they report enough tracking data to calculate a *success* parameter equal to true.

8.5.3.2 Educational web game created with the SGAME platform

This section presents an example of an educational web game created with the SGAME platform according to the SGAME model. This game was created by using the "Onslaught! Arena" game template and several quizzes created with Articulate Quizmaker, which were exported as SCORM packages and uploaded to the SGAME platform. Figure 8.15 shows on the left side a screenshot of the game taken while the user is playing, and on the right side a screenshot of the game taken while a Learning Object integrated into it is shown to the user.

The game is a medieval fantasy shooter game in which the player controls a fighter and has to shoot different kinds of monsters to survive and get gold. During the game, the player can pick up new weapons that can help him/her to succeed. Each time the player tries to pick up a new weapon (see left side of Figure 8.15) a Learning Object is popped up (see right side of Figure 8.15). The player will only get the weapon by successfully completing the presented Learning Object. Since the weapons have limited ammo, the player needs to keep picking up new weapons in order to succeed in the game. Thereby, players will succeed in the game only by consuming and passing the integrated Learning Objects.

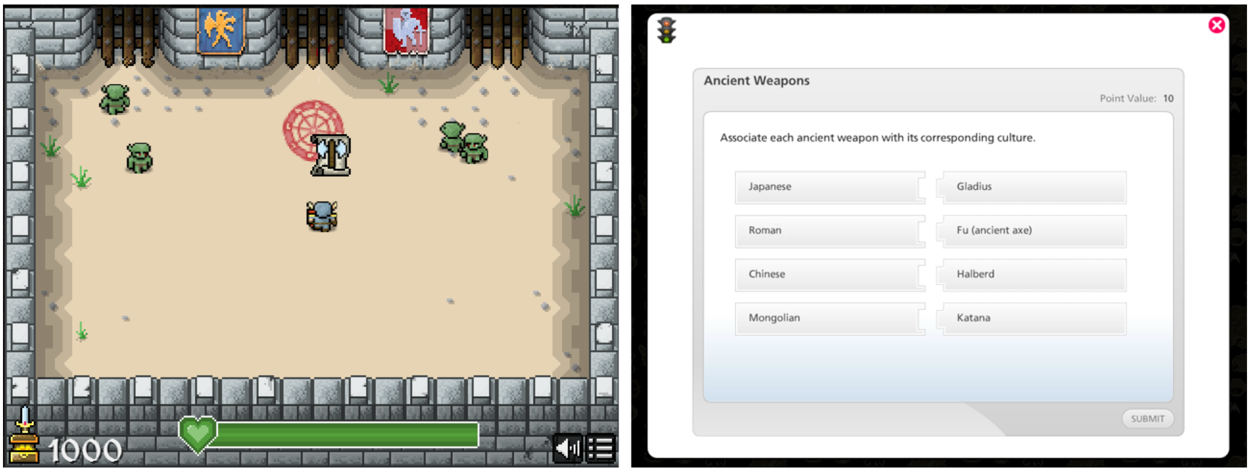

Figure 8.15: Educational web game created with the SGAME platform
by integrating Learning Objects into a web game

8.6 Conclusions

This chapter presents three different integration models for Learning Objects together with the results of the implementations that were made to validate them.

Firstly, the chapter presents a model for e-Learning authoring tools to facilitate the creation of Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards such as SCORM, IMS CP, IMS QTI and Moodle XML, as well as generic web applications which do not follow any e-Learning specification. The model addresses the integration of metadata, the integration of content, and the integration of the communications between the Learning Objects and the VLEs. The Learning Objects created according to this model, regardless of the number of Learning Objects used to assemble them, will behave as a single Learning Object in the eyes of the VLEs into which they are integrated. Therefore, authoring tools that implement this model will be able to use Learning Objects built conforming to different e-Learning standards as building blocks to create new ones, which, at the same time, will also adhere to an e-Learning standard. The model was implemented and validated in a real-world Learning Object authoring tool called ViSH Editor.

The results of the design and implementation of this model prove that, although e-Learning standards have been designed mainly to integrate Learning Objects into VLEs as standalone Learning Objects, it is possible to exploit the affordances of these standards to facilitate authoring tools the authoring of Learning Objects by aggregation in such a way that the different aggregated Learning Objects behave as one single Learning Object in the eyes of the VLEs into which they are integrated. These results also show that different integration approaches are needed to create Learning Objects by aggregation depending on the specification used to package or create the Learning Objects to be integrated. Taking into account the results reported in chapter 4 of this thesis which suggest that the quality of Learning Objects can be enhanced by integrating other resources, it can be stated that the model to integrate, combine and assemble Learning Objects presented in this chapter can be used to improve existing Learning Object authoring tools, thereby pushing the current state of the art.

Secondly, the chapter presents a model to integrate Learning Objects provided by Learning Object Repositories (LORs) into web videoconferencing services. By applying this model to a LOR, the sharing, co-viewing and co-browsing of their Learning Objects through the use of web videoconferencing services can be enabled. Thereby, teachers and learners can share, co-view and co-browse Learning Objects at the same time that real-time communication is provided. The model allows to automatically integrate into web videoconferencing services Learning Objects provided by LORs that can be represented using a standard HTML5 element or that can be created with authoring tools, as long as these LORs, tools and services meet certain requirements defined by the model. In order to validate the model, it was implemented in two different repositories to enable the Learning Objects created with an authoring tool to be integrated into three web videoconferencing services: MashMeTV, Google Hangouts, and a web videoconferencing service developed based on Licode. One of these implementations was used in real-world learning experiences.

The results of the design and the implementations of the model to integrate Learning Objects provided by LORs into web videoconferencing services presented in this chapter show that it is possible to achieve this integration in an automatic way if certain requirements are met by the Learning Objects, the LORs and the web videoconferencing services. These results also show that it is possible to create Learning Objects through authoring tools offered by LORs so that users can automatically share, co-view and co-browse the created Learning Objects through the use of web videoconferencing services. Therefore, this model could incentivize the use of Learning Objects in videoconferencing services. Lastly, it is worth noting that, as a result of this work, the main requirements and limitations to be considered when integrating Learning Objects into the web videoconferencing context have been identified.

Finally, this chapter presents a model to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games in order to create educational web games. This model enables the development of authoring tools that allow educators to use existing web games to create educational web games whose learning content can be customized by integrating SCORM packaged Learning Objects. Educators can create the Learning Objects to integrate into the games from scratch by using Learning Object authoring tools or they can reuse existing Learning Objects. Thereby, the created games can be used in different subjects and contexts. In the educational web games created according to this model, the integrated Learning Objects will be shown to the players when they perform specific actions or when certain conditions are met. The games will be able to reward the players based on their interactions with the Learning Objects. Thus, these games can be designed so that players will succeed only by successfully completing the integrated Learning Objects. In order to validate the model, an open source web-based platform was developed which provides an authoring tool that allows educators to create educational web games by integrating SCORM packaged Learning Objects into web games that act as game templates.

The results of the design and implementation of this model to integrate SCORM packaged Learning Objects into web games shows one way of how e-Learning standards like SCORM can be used in order to facilitate the integration of Learning Objects into web games. As a result of this work, several possibilities, requirements and limitations to integrate Learning Objects into web games were identified. The model can build a bridge between the educational community and the game developers' community. On the one hand, it allows educators to create customizable educational web games through authoring tools by using game templates that game developers can create by converting existing web games. On the other hand, it allows game developers to create educational web games by integrating SCORM packaged Learning Objects that educators can create using authoring tools. The educational web games created according to this model could be very useful for Game-Based Learning. Future studies should investigate the acceptance and effectiveness in terms of learner engagement and learning outcomes of these games.

The first research question of the thesis covered in this chapter was the following: How can Learning Objects be assembled by integrating and combining other ones? This question can be answered based on the first Learning Object integration model proposed in this chapter, which provides a generic and robust solution to create Learning Objects by integrating and combining other ones compliant with multiple e-Learning standards through authoring tools. According to this solution, Learning Objects can be assembled by integrating and combining other ones through an authoring tool in such a way that the assembled Learning Objects behave as one single Learning Object in the eyes of the VLEs into which they are integrated, but only if the authoring tool implements such a solution and the integrated Learning Objects are compliant with certain e-Learning standards such as SCORM, IMS CP and IMS QTI. The authoring tool should solve three issues: the integration of metadata, the integration of content, and the integration of communications. The integration of metadata can be solved by giving the author the freedom of defining the metadata of the assembled Learning Object through the authoring tool. The integration of content should be solved in a different way depending on the type of Learning Object to be integrated. For integrating Learning Objects defined through XML files, the authoring tool can store the data of the XML files and render the Learning Objects using these data through the use of web applications called players. For integrating Learning Objects packaged according to SCORM or IMS CP, the authoring tool can store the packages on a web server, extract the Learning Objects contained in the packages, and deliver the Learning Objects through HTML documents containing a player and the URLs of their resources. Lastly, to achieve the integration of the communications between the integrated Learning Objects and the VLEs, the authoring tool should provide the assembled Learning Object with a component capable of gathering all relevant tracking data of the integrated Learning Objects, combine these data, and notify them in a unified way to the VLE into which it is integrated using the API of an e-Learning standard such as SCORM or xAPI. Instead of communicating with the VLE, the integrated Learning Objects should communicate with this component. Thereby, the assembled Learning Object will be able to report a single overall progress, overall score, completion status and success status to the VLE. The reported data can be calculated based on the gathered tracking data and settings specified by the author through the authoring tool. In conclusion, Learning Objects can be assembled by integrating and combining other ones using authoring tools that support suitable integration models as long as the Learning Objects that are to be integrated are compliant with certain e-Learning standards.

The second research question of the thesis covered in this chapter was the following: How can Learning Objects be integrated into contexts in which educational technology is not typically present such as web videoconferencing or web games? This question can be answered based on the lessons learned from the design and implementation of the models presented in this chapter to integrate Learning Objects into web videoconferencing services and web games. The work presented in this chapter shows that it is possible to integrate Learning Objects into contexts such as web videoconferencing and web games by developing suitable integration approaches and exploiting the affordances of e-Learning standards. However, this work suggests that developing a generic approach to integrate Learning Objects into any context in which educational technology is not typically present is not possible. Therefore, in order to integrate Learning Objects into one of these contexts, the particular characteristics and constraints of the context should be analyzed, and based on this analysis a specific integration approach for that context should be developed. In this regard, it is worth pointing out that developing a suitable integration approach for a certain context requires analyzing not only the technological constraints imposed by the context, but also educational aspects that could influence on the integration of Learning Objects. For instance, in the context of games, since educational video games should have an adequate balance between entertainment and educational value, only those very small Learning Objects in terms of learning time needed to complete them should be integrated in order to prevent players from being interrupted for long periods of time while they are playing. Integration approaches for Learning Objects should rely on existing e-Learning standards whenever possible. Furthermore, these approaches should also clarify the efforts required in the different systems involved in the integration, the requirements that these systems must meet, and the limitations of the proposed solution. In conclusion, there are cases in which Learning Objects can be suitably integrated into a context in which educational technology is not typically present by developing a specific integration approach for that context, which should take into account the particular characteristics and constraints of the context, the affordances of e-Learning standards that can be exploited to facilitate the integration, the efforts required in the different systems involved, the requirements that these systems must meet, and the limitations of the integration that can be achieved.

This chapter makes four main contributions. The first contribution is a model for e-Learning authoring tools that provides a generic and robust solution to create Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards as well as generic web applications. This innovative model can be used to improve existing Learning Object authoring tools. Therefore, the model can help to overcome a major barrier to the use and adoption of Learning Objects: the lack of authoring tools which effectively support Learning Object authoring by aggregation. The second contribution of the chapter is a model to integrate Learning Objects provided by LORs into web videoconferencing services, which aims to enable the sharing, co-viewing and co-browsing of Learning Objects through the use of these services. This model could incentivize the use of Learning Objects in videoconferencing services. The third contribution of the chapter is SGAME, a model to integrate SCORM packaged Learning Objects into web games in order to create educational web games. SGAME enables the development of authoring tools that allow educators to use existing web games to create customizable educational web games. Finally, the fourth contribution is the SGAME platform, an open source web-based platform that provides an authoring tool that allows users to create educational web games by integrating SCORM packaged Learning Objects into existing web games according to the SGAME model. Although this platform is still a prototype, it has allowed to validate the SGAME model as well as showing the potential of the proposed approach to create educational web games by integrating Learning Objects into existing web games. Both the SGAME model and the SGAME platform can help to alleviate one of the main barriers hampering the introduction, use and adoption of educational video games in educational contexts: the lack of authoring tools to create customizable educational video games that bear the features of entertainment video games. Therefore, this chapter also makes an important contribution to Game-Based Learning. Finally, it is worth highlighting that, although several works have addressed different stages of the Learning Object life cycle such as authoring, distribution, evaluation, use and reuse, little attention has been given to the integration stage. This chapter contributes to the integration of Learning Objects by presenting three integration models for Learning Objects: one to face the challenge of achieving an easy and effective Learning Object authoring by aggregation process, and two to facilitate the integration of Learning Objects into contexts in which educational technology is not typically present.

Chapter 9

Validation and Results

This thesis makes several contributions to the authoring, distribution, evaluation and integration of Learning Objects. Previous chapters present these contributions and provide details about how they have been validated. In this chapter, in order to provide an additional validation, several projects and learning experiences in which different contributions of this thesis have been validated are presented. On the one hand, four projects are described: two European projects and two private funded projects. On the other hand, a total of five learning experiences are reported: one in secondary education, one in higher education, one in a MOOC (Massive Open Online Course), one in a SPOC (Small Private Online Courses), and one in a blended course in which a project-based learning methodology was used. Based on the reported learning experiences, this chapter also aims to examine the use of Learning Objects in different educational environments.

This chapter also lists all the publications that have been produced as a result of this thesis. These publications include 3 articles in international journals indexed in the JCR (Journal Citation Reports), 2 articles in other international journals, 1 book chapter, and 11 international conference papers.

Several of the contributions of this thesis are e-Learning systems that have been published as open source projects. This chapter also provides a brief description of these open source projects, including the awards they have received. The open source projects developed in the scope of this thesis include the ViSH e-Learning platform presented in chapter 3, the ViSH Editor authoring tool presented in chapter 4, the LOEP platform presented in chapter 5, the EuropeanaRS recommender system described in chapter 7, and the SGAME platform described in chapter 8.

This chapter is arranged as follows. In section 9.1, the projects in which several contributions of this thesis have been validated are described. Section 9.2 reports the learning experiences in which Learning Objects were used in various educational environments. Section 9.3 lists the publications produced as a result of this thesis. In section 9.4, a brief description of the contributions of this thesis published as open source projects is provided. Finally, section 9.5 gives some concluding remarks.

9.1 Validation in Projects

9.1.1 European Projects

9.1.1.1 GLOBAL excursion

GLOBAL excursion (Extended Curriculum for Science Infrastructure Online) [54] was a European project funded by the European Commission under the Seventh Framework Programme. The main goal of this project was to enhance science teaching in European schools. Another objectives of the project were to provide access to e-Infrastructure resources and other resources from the world of science, connect classrooms and scientists, improve science curricula by enriching schools' existing teaching and learning materials, and foster the authoring, distribution and sharing of OER (Open Educational Resources) about science.

The goals of the GLOBAL excursion project were reached by providing an innovative platform called Virtual Science Hub (ViSH) in order to offer teachers and their pupils as well as scientists and policy makers a package of activities, materials and tools for enabling the integration of scientific content and e-Infrastructures into school curricula. The initial requirements for the ViSH platform were collected through the application of a participatory design process that involved technology developers, teachers and scientists [55]. In this participatory design, the development team of ViSH and the future users engaged to work together, exchanged perspectives and defined a set of requirements. The ViSH platform was the main outcome of the GLOBAL excursion project.

The ViSH platform was developed in the scope of this thesis and is presented in chapter 3. Nevertheless, it should be clarified that the development of ViSH has continued after the GLOBAL excursion project ended, and that many new features, enhancements and changes have been implemented over the last years. Therefore, the current version of the ViSH platform, which is the one described in chapter 3 and currently available at http://vishub.org, presents notable differences with respect to the versions used in the GLOBAL excursion project. More information about the development and use of ViSH during the GLOBAL excursion project can be found in [370]–[374].

As part of the promotional activities of the GLOBAL excursion project, a competition was organized in which any user registered in the ViSH platform was able to participate by creating and publishing a Learning Object using the ViSH Editor authoring tool available on the platform. This tool was developed in the scope of this thesis and is presented in chapter 4. Competition had 10 categories in which users can submit their Learning Objects. More than 130 Learning Objects were submitted. The two best Learning Objects in each category as well as the three best overall Learning Objects were awarded. The jury of the competition used a system called LOEP to evaluate the quality of the submitted Learning Objects. This system, which has been also developed in the scope of this thesis, is presented in chapter 5.

The model to integrate Learning Objects into web videoconferencing services described in chapter 8 of this thesis was used in the GLOBAL excursion project to enable the integration of Learning Objects published on the ViSH platform into a web videoconferencing service called MashMeTV. Thanks to this integration, MashMeTV was used during the GLOBAL excursion project to hold online meetings with students, teachers and scientists, in which Learning Objects available on the ViSH platform were shared, co-viewed and co-browsed. More information about this experience is provided in chapter 8.

Finally, this section presents the main results of an online questionnaire that was conducted in the GLOBAL excursion project to evaluate the ViSH platform. This questionnaire was distributed to all users registered in ViSH and served as the main evaluation instrument. A total of 55 teachers filled in the questionnaire. These teachers were from 17 different countries, including Spain (21.8%), England (10.9%), Austria (9.1%), Belgium (9.1%), Hungary (9.1%), Italy (9.1%), Portugal (5.5%) and Romania (5.5%). The main results of the questionnaire are shown in Table 9.1, including for each question the number of responses (N). The full results of the questionnaire are available in the deliverable D6.1 [411] of the project.

Table 9.1: Results of the GLOBAL Excursion Teacher Questionnaire

Question	**N**	**Very well**	**Rather well**	**Neither well nor badly**	**Rather badly**	**Very badly**
How well do the working methods presented by the ViSH fit into the teaching culture you are accustomed to?	31	9.7%	51.6%	19.3%	12.9%	6.5%
How effective or ineffective do you find the ViSH to be in helping ...		**Very effective**	**Rather effective**	**Neither effective nor ineffective**	**Rather ineffective**	**Very ineffective**
your students in reaching the learning goals according to the lessons plans?	41	19.5%	43.9%	22.0%	9.8%	4.9%
you creating teaching material that increases the students' interest in science?	39	30.8%	38.5%	23.1%	2.6%	5.1%
you creating teaching material that makes your students better understand science?	30	16.7%	50.0%	20.0%	6.7%	6.7%
		Very good	**Rather good**	**Neither good nor bad**	**Rather bad**	**Very bad**
How good or bad do you think is the QUANTITY of science content which is provided on the ViSH?	30	10.0%	36.7%	33.3%	6.7%	13.3%
How good or bad do you think is the QUALITY of science content which is provided on the ViSH	30	6.7%	70.0%	20.0%	3.3%	0.0%
		Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**
Compared to other software you know of, the ViSH is more promising (in terms of usefulness)	30	10.0%	43.3%	36.7%	3.3%	6.7%
		Yes	**No**			
Would you recommend the ViSH to colleagues and friends?	30	86.7%	13.3%			

The results of the GLOBAL excursion teacher questionnaire showed that, in general, ViSH fits into teachers' accustomed teaching culture and is effective in helping teachers to create teaching material for their students, which increases the students' interest in science and helps students to understand science better as well as to reach the learning goals. These results also indicated that the quality of the offered content was perceived as good but the quantity should be increased. In this regard, it should be pointed out that the quantity of content in ViSH has increased markedly over the last years. This fact is clearly illustrated in the quantitative analysis of the ViSH platform presented in chapter 3. Around 53% of the teachers stated that ViSH was more promising in terms of usefulness compared with other educational tools. Lastly, 86.7% of the teachers said "yes" when they were asked if they would recommend ViSH to colleagues and friends. In summary, the results of the questionnaire showed that, in general, teachers perceived ViSH as a useful and effective educational tool that fits into their teaching culture.

9.1.1.2 Europeana Cloud

Europeana Cloud [58] was a European project co-funded by the European Union, through the ICT Policy Support Programme as part of the Competitiveness and Innovation Framework Programme. The main objectives of the project included: establish a cloud-based system for the Europeana repository [57] and its aggregators capable of storing both metadata and content, provide a new service supporting researchers, develop new tools for researchers to discover and make use of Europeana content permitting innovative research, and provide access at Europeana to 2.4 million new metadata records and 5 million new digital objects with a clear research focus. All these goals were reached by the Europeana Cloud project, which developed a storage service for metadata and digital media capable of scaling up to store massive amounts of data and to/from which data can be written and retrieved over an API, a new service named Europeana Research giving individual researchers and research infrastructures access to cultural heritage material, and new tools for researchers.

In the Europeana Cloud project, a total of eight tool prototypes were developed for the use of Europeana content by researchers in digital humanities. A description of all these tools can be found at [59]. The tools were developed using a user-centered design approach, and were deployed in realistic testbeds to evaluate and validate their usefulness.

One of the tools developed in the Europeana Cloud project was the Newspaper Exploration Environment (see Figure 9.1), an interactive data visualisation tool to facilitate exploration of digitised newspapers through faceted search across coordinated multiple views and recommendations, creating an environment that supports both targeted search and serendipitous discovery. This tool allows users to search for newspaper issues by inputting query terms as well as to use three filters: a list of languages, a timeline widget to select years of publications, and a list of newspaper titles and their number of issues.

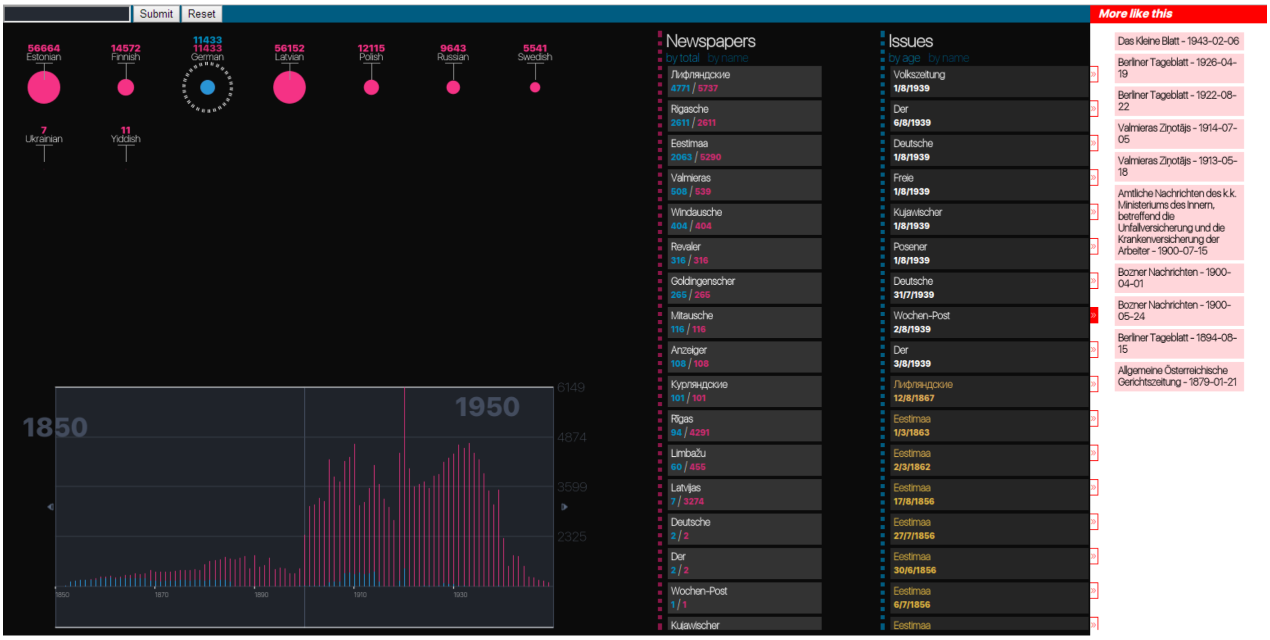

Figure 9.1: Newspaper Exploration Environment

All visualization widgets operate as coordinated views (e.g. the selection of a language will overlay the timeline with data from that selected language). When the user clicks on a newspaper issue from the results list, the tool opens the European Library website (http://www.theeuropeanlibrary.org), providing direct access to the scans and the text obtained using OCR (Optical Character Recognition) of the selected newspaper issue. More information about the tool is provided in [59].

The Newspaper Exploration Environment also has a recommendation feature. When a user clicks on the arrow next to a newspaper issue from the results list, the column "More like this" is populated with recommended newspaper issues. These recommendations are generated by using the EuropeanaRS recommender system described in chapter 7 of this thesis. The Newspaper Exploration Environment requests the recommendations of newspaper issues by using the API provided by EuropeanaRS. On each recommendation request, the tool includes the number of desired recommendations and the metadata of the newspaper issue for which the user has requested recommendations. Since the tool does not generate user profiles, no information about the users is included in the recommendation requests. When EuropeanaRS receives a recommendation request from the Newspaper Exploration Environment with metadata of a newspaper issue, it generates recommendations of similar newspaper issues and sends them to the tool, which shows them to the user in the column entitled "More like this". As described in chapter 7, EuropeanaRS takes into account the title, description, language and year of publication of the newspaper issues in order to generate recommendations.

An online evaluation of the Newspaper Exploration Environment was conducted in the Europeana Cloud project to evaluate the usefulness of the tool for searching and exploring newspaper issues. This evaluation consisted of two options: a short evaluation where participants watched a video explaining the tool and filled out a questionnaire, and a more elaborate evaluation where participants used the tool for 15-30 minutes and filled out the same questionnaire with extra questions regarding usability. A total of 8 people participated, 4 for each type of evaluation, 3 males and 5 females, 26 to 53 years of age (M=41.6, SD=10.6), of which 4 were digital humanities researchers, 2 were lecturers, 1 was a manager and 1 was a developer. Table 9.2 presents the main results of the online evaluation of the Newspaper Exploration Environment, including for each question the mean value (M) and the standard deviation (SD). More information about this evaluation is included in the deliverable D3.3 [412] of the Europeana Cloud project.

Table 9.2: Results of the Newspaper Exploration Environment Questionnaire (N=8)

Question	**M**	**SD**
Please rate the usefulness of the following features of the Newspaper Exploration Environment 1 (not useful at all) – 7 (extremely useful)		
Text search	5.4	1.6
Language visualisation	5.8	1.0
Timeline visualisation	6.1	0.6
Listing of newspapers	5.4	1.3
Listing of newspaper issues	5.1	1.6
Recommendations	4.8	2.1
Please indicate your level of agreement on each of the following statements about the Newspaper Exploration Environment 1 (completely disagree) - 7 (completely agree)		
I would like to use this system as part of my workflow	4.8	2.1
Using the system would be an added value to my work/research	4.6	2.2
Using the system makes work more interesting	5.5	1.3
I have the knowledge necessary to use the system	5.5	1.9
I enjoy working with the system	5.5	1.2
SUS Score (N=4) 0 – 100	79	14.3

The results of the evaluation of the Newspaper Exploration Environment show that, in general, users were satisfied with the different features offered by the tool. All features obtained a rating higher or equal than 4.8 on a 1-7 scale. Results also indicate that users would like to use the tool as part of their workflow and that they believe that it would be an added value and make their work more interesting. Moreover, users were confident they had the knowledge necessary to use the tool and that they would enjoy working with it. The tool obtained an overall SUS score of 79 out of 100, which indicates that it has a high usability.

Regarding the use of EuropeanaRS, users perceived the recommendation feature as somewhat useful (M=4.8, SD=2.1). Nevertheless, it is worth noting that users found the text search and the filters more useful than the recommendations. This finding was expected because, although the recommendations can be very useful for discovering new issues of newspapers, the main purpose of the Newspaper Exploration Environment is to make it easier for users to find specific newspaper issues. It is also worth pointing out that the recommendation feature could be enhanced by generating user profiles throughout the browsing session. In summary, the work presented in this section allowed to validate EuropeanaRS and the recommendation model presented in chapter 7 in a new environment. Results of chapter 7 provide evidence of the effectiveness of EuropeanaRS in recommending Learning Objects. The work presented in this section shows an example of how EuropeanaRS can be successfully used to enrich tools by providing Learning Object recommendations.

9.1.2 Private Funded Projects

9.1.2.1 EducaInternet

The EducaInternet project is funded by Orange and counts with the collaboration of the Spanish public entity Red.es. This project started in January 2015 with the main aim of building an e-Learning platform to learn and teach about safe and responsible use of digital technologies. This goal was reached by developing and providing a new e-Learning platform called EducaInternet, which is publicly available at http://educainternet.es. The Ministry of Education, Youth and Sports of the Madrid Region, Orange and Red.es have organized several learning experiences with the EducaInternet platform and they are planning to organize more in the future. Two of these experiences are described in section 9.2 of this chapter. The EducaInternet project is still ongoing and aims to maintain, enhance and promote the EducaInternet platform, increase the number of educational resources provided by this platform, and deliver new online courses and learning experiences about safe and responsible use of digital technologies.

The EducaInternet platform was built upon the software that runs the ViSH platform. Chapter 3 of this thesis describes in detail the ViSH platform as well as the features provided by the ViSH software. This section briefly describes the EducaInternet platform and presents the results of its evaluation.

9.1.2.1.1 Overview of the EducaInternet platform

The EducaInternet platform (hereafter just EducaInternet) is an e-Learning platform to learn and teach safe and responsible use of digital technologies. It is available at http://educainternet.es and the registration is free and open to everybody. Figure 9.2 shows its frontpage. The main topics covered by EducaInternet are: information management, digital identity, privacy management, netiquette, licenses, access to inappropriate content, cyberbullying, grooming, sexting, identity theft, technoaddictions, dangerous online communities, and virus and fraud protection.

Figure 9.2: Frontpage of the EducaInternet platform

EducaInternet was built upon ViSH, an open source e-Learning platform to create and distribute OER in the form of Learning Objects which is fully described in chapter 3. From a technical point of view, EducaInternet is very similar to ViSH but with a new presentation layer. EducaInternet provides the same features as ViSH: a web portal, a social network, a Learning Object manager, authoring tools, collections and bookmarks, an evaluation system, search services, a recommender system, an Audience Response System, learning analytics, administration features, etc. All these features are described in detail in chapter 3. In this regard, it is worth remarking that EducaInternet uses the ViSH Editor authoring tool presented in chapter 4, the LOEP evaluation system presented in chapter 5, and the recommender system designed for ViSH described in chapter 7. EducaInternet is open source and its source code is available at http://github.com/ging/vish_orange. The code repository of EducaInternet is synchronized with the code repository of ViSH allowing to easily incorporate the new features and enhancements developed in ViSH into EducaInternet.

The main services offered by EducaInternet to end users include the following:

- *Specialized resources to learn about e-Safety and digital citizenship*. A set of resources created by certified experts and organizations are offered to the users in order to allow them to learn about e-Safety and digital citizenship. Figure 9.3 shows one of these resources.
- *Repository of resources*. In addition to the specialized resources, all resources uploaded or created by the community are included in the EducaInternet library. In this library, users can search, view, evaluate, share and download educational resources.

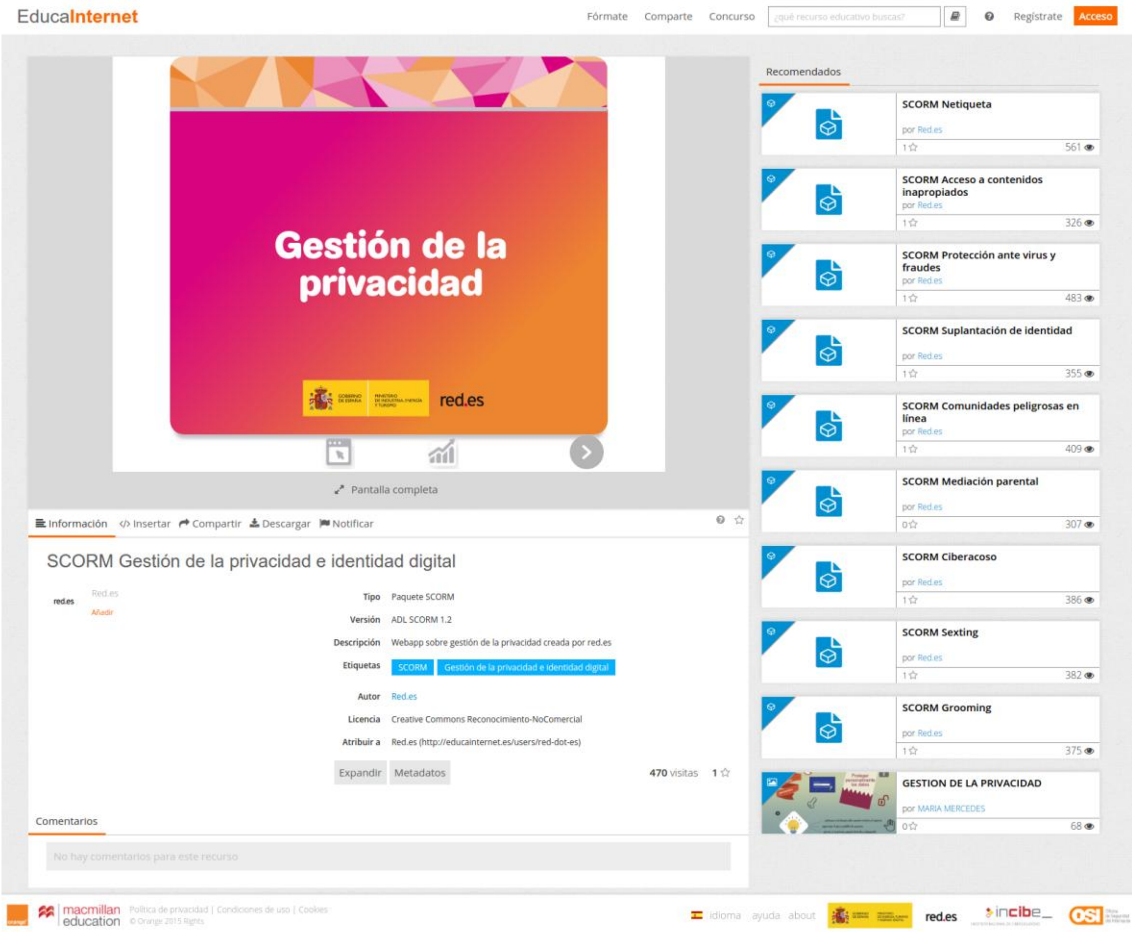

Figure 9.3: Learning Object published on the EducaInternet platform

- *Authoring tools*. EducaInternet offers two authoring tools to allow the users to create their own Learning Objects. One is the ViSH Editor authoring tool presented in chapter 4, which allows to create Interactive Presentations. These Interactive Presentations are called "Teaching Units" in the EducaInternet platform. The other one is the ViSH Lesson Editor authoring tool described in chapter 3, which allows to create lessons in the form of Learning Objects through the combination of different resources and other elements.
- *Online courses*. EducaInternet is integrated with an instance of the Moodle LMS [79], which is used to deliver online courses about safe and responsible use of digital technologies. The operation of the feature that allows EducaInternet to be integrated with Moodle to deliver these courses is explained in section 3.3.2.19 of chapter 3. Several SPOCs (Small Private Online Courses) have been delivered to date. One of these courses is described in section 9.2.3.2. Furthermore, future plans for EducaInternet include delivering not only more SPOCs, but also MOOCs.

EducaInternet has been in production for more than 2 years and has more than 3,000 published resources and around 2,600 registered users. More information about EducaInternet can be found in [379], [413].

9.1.2.1.2 Evaluation and Results

An online survey was conducted among the end users of the EducaInternet platform to collect general feedback. On the one hand, the link to the survey was included in the 'About' menu of the web portal, which can be displayed by clicking on a button placed at the footer. On the other hand, the link to the survey was shared through the Moodle instance of the EducaInternet platform with users who had enrolled in online courses offered by the platform. A total of 503 educators filled in the online survey, 34.3% males and 65.7% females, 23 to 65 years of age (M=44.2, SD=7.8). Table 9.3 shows the main results of the survey.

Table 9.3: Results of the EducaInternet Survey

Question	N	M	SD
Previous experience with other e-Learning systems 1 (none) – 5 (a lot)	503	3.3	1.2
What is your overall opinion of the EducaInternet platform? 1 (awful) – 5 (excellent)	503	4.0	0.6
How would you describe the experience of learning to use EducaInternet? 1 (very difficult) – 5 (very easy)	503	3.8	0.9
Please rate your opinion about the following features of the EducaInternet platform 1 (awful) – 5 (excellent)			
Social network	362	3.4	1.0
Uploading and publication of resources (i.e. Learning Object manager)	482	3.9	1.0
Download of resources	430	3.8	1.0
Resource metadata	408	3.6	1.0
ViSH Editor authoring tool	475	3.5	1.1
ViSH Lesson Editor authoring tool	399	3.7	0.9
Collections	388	3.5	0.9
Evaluation system	424	3.6	1.0
Search service	443	3.6	0.9
Advanced search service	386	3.6	0.9
Catalogue	393	3.5	0.9
Recommender system	358	3.5	1.0
Audience Response System (ARS)	303	3.4	1.0
Homepage of the web portal	451	3.6	1.1
Help and tutorials	466	4.0	1.0
Please rate the usefulness of the following types of resources that you can find in EducaInternet 1 (not useful) – 5 (very useful)			
Files (pictures, videos, audios, PDF files, SCORM packages, ...)	486	4.0	0.9
Links and embeds (i.e. linked or embedded external resources)	478	3.9	0.9
Interactive Presentations (i.e. Learning Objects created with ViSH Editor)	485	4.1	0.9
Lessons (i.e. Learning Objects created with ViSH Lesson Editor)	479	4.1	0.9
Collections of resources	458	3.8	0.9

Question	N	M	SD
EducaInternet can be used for many different activities. Which of the following are more important for you? Please rate the importance of each one using a scale from 1 to 5 1 (unimportant) - 5 (very important)			
Connect with other users and share experiences	482	3.8	1.0
Search for educational resources	485	4.1	0.9
Share resources	480	4.0	0.9
Publish my resources	483	3.7	1.0
Create novel resources	483	3.9	1.0
Create and publish collections of resources	479	3.8	0.9
Use resources in the classroom to support face to face learning	482	4.1	0.9
Use resources as activities or assessments for students	477	4.0	0.9
Use resources in VLEs (e.g. Moodle or Blackboard Learn)	476	3.9	1.0
Use resources for self-learning	480	4.0	0.9
Involve students in the creation and/or evaluation of educational content	478	3.8	1.0
Would you recommend EducaInternet to others?	503	**Yes**	**No**
		93.4%	6.6%

The results of the online survey show that EducaInternet has high user acceptance. Overall opinion recorded a mean of 4.0 on a 1-5 scale and around 93% of the users answered that they would recommend EducaInternet to others. Furthermore, EducaInternet was found easy to use by its end users (M=3.8, SD=0.9). In general, users were satisfied with the different features offered by the platform. All features obtained a rating higher or equal than 3.4 on a 1-5 scale. In this regard, it is worth highlighting that satisfactory ratings were given to the ViSH Editor authoring tool presented in chapter 4 (M=3.5, SD=1.1), the evaluation system provided by using the LOEP platform presented in chapter 5 (M=3.6, SD=1.0), and the recommender system designed for ViSH described in chapter 7 (M=3.5, SD=1.0). Regarding the different types of resources that are offered by EducaInternet, users rated “Interactive Presentations” (i.e. the Learning Objects created with the ViSH Editor authoring tool) and “lessons” (i.e. the Learning Objects created with the ViSH Lesson Editor authoring tool) as the most useful resources (M=4.1, SD=0.9), followed by “files” (M=4.0, SD=0.9), “links and embeds” (M=3.9, SD=0.9), and “collections of resources” (M=3.8, SD=0.9). Finally, educators were also asked about the importance of the different activities that can be performed with EducaInternet. All activities were considered important (all of them were rated above 3.6), but the ones that achieved higher ratings were “search for educational resources” (M=4.1, SD=0.9), “use resources in the classroom to support face to face learning” (M=4.1, SD=0.9), “share resources” (M=4.0, SD=0.9), “use resources as activities or assessments for students” (M=4.0, SD=0.9), and “use resources for self-learning” (M=4.0, SD=0.9). In summary, the results of the EducaInternet survey are very similar to those of the ViSH survey reported in chapter 3.

The EducaInternet survey allowed to evaluate the features provided by ViSH to end users in a new environment (the EducaInternet platform) as well as get feedback from more users. Therefore, the results of this survey provide more evidence about the usefulness of the ViSH features. Furthermore, the work presented in this chapter on the EducaInternet project shows that ViSH can be successfully used to develop new e-Learning platforms capable of effectively supporting the whole Learning Object life cycle.

9.1.2.2 StoryRobin

This project was funded by a private company called “StoryRobin, Inc.” based in California, USA. The aim of the project was to develop a new web-based platform that provides digital educational content generated by the community. Other goals of the platform were to nurture children's creativity, imagination, and critical thinking skills by engaging them in real-life projects. The project was successfully accomplished by using the software that runs the ViSH platform presented in chapter 3 of this thesis to develop the platform. Henceforth, this section provides a brief overview of the developed platform, which was called StoryRobin.

StoryRobin is a community supported platform to engage children in creating educational resources. Its ultimate goal is to provide a repository of e-Learning resources created by the community. The platform is available at http://storyrobin.com (see Figure 9.4), but registration is by invitation only.

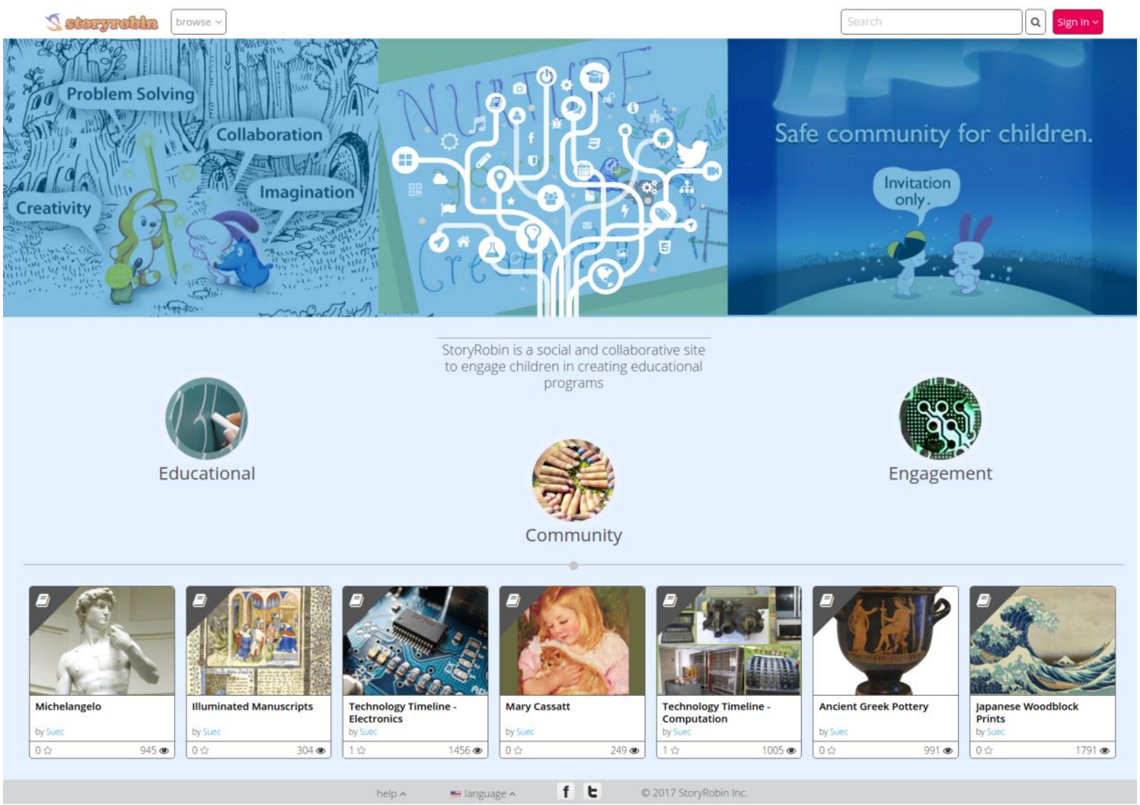

Figure 9.4: Frontpage of StoryRobin

As the EducaInternet platform described in the above section, StoryRobin was built upon the software of ViSH, an open source e-Learning platform which is fully described in chapter 3. From a technical point of view, StoryRobin is very similar to ViSH but with a different presentation layer. StoryRobin offers many features of ViSH including the social network, the Learning Object manager, the ViSH Lesson Editor authoring tool, the ViSH Editor authoring tool presented in chapter 4, the evaluation system provided by using the LOEP platform presented in chapter 5, the recommender system designed for ViSH described in chapter 7, the search services, and the administration features. However, some features of ViSH are disabled in StoryRobin such as the collections and the learning analytics.

The most promoted and important resources of StoryRobin are the lessons created with the ViSH Lesson Editor authoring tool (see section 3.3.2.3.2). These lessons are referred to as "workshops" in the web portal of StoryRobin. Figure 9.5 shows a workshop published on StoryRobin. In the workshops, users can submit pictures and writings. The idea is that these workshops can propose challenges which require children to submit pictures or writings about a certain topic. Furthermore, new challenges can be proposed based on the submitted resources. For example, children can submit pictures to illustrate stories written by other children as well as submit writings inspired by drawings painted by other children.

The work presented in this section shows a new example of how ViSH can be successfully used to develop new e-Learning platforms to create and distribute Learning Objects. Moreover, the fact that ViSH had attracted interest from private companies is a positive sign for the future of the system.

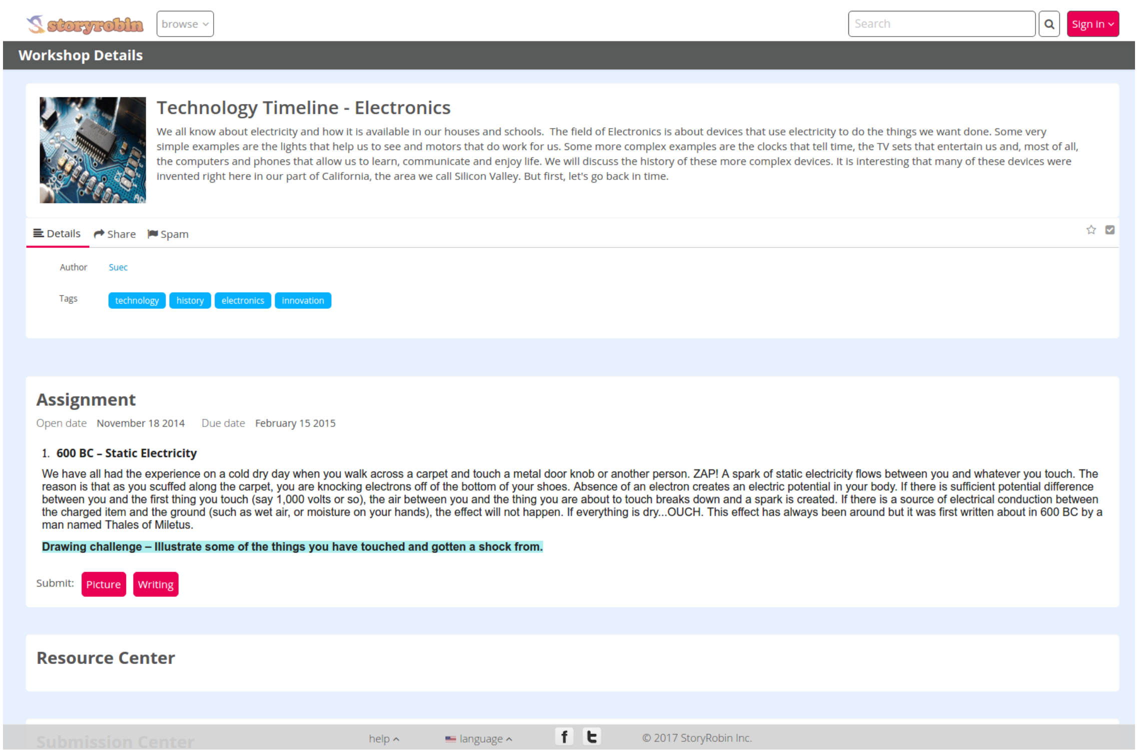

Figure 9.5: Workshop published on StoryRobin

9.2 Validation in Learning Experiences

9.2.1 Secondary Education

9.2.1.1 Teaching computer networks to twelfth grade students

This section reports a study in which a set of Learning Objects were used in a public secondary school to deliver a teaching unit on Internet and computer networks. A total of 38 twelfth grade students participated in the study, 16 males and 22 females, 17 to 18 years of age (M=17.2, SD=0.6). Students took a teaching unit about Internet and computer networks in a 12th grade subject called "Information and Communication Technologies". The teaching unit was completed in five two-hour lessons (10 hours in total), which were conducted in a computer lab with Internet connection. In each lesson, students used one Learning Object. Therefore, five Learning Objects were used in total.

All the Learning Objects used in the lessons were created with the ViSH Editor authoring tool presented in chapter 4, and were published on the ViSH platform presented in chapter 3. These Learning Objects contained a wide variety of resources including text, images, videos, websites, self-graded questions (some created directly with ViSH Editor and some created with other authoring tools and integrated as SCORM packages), Flashcards, and web applications. Figure 9.6 shows one of the Learning Objects used in the lessons.

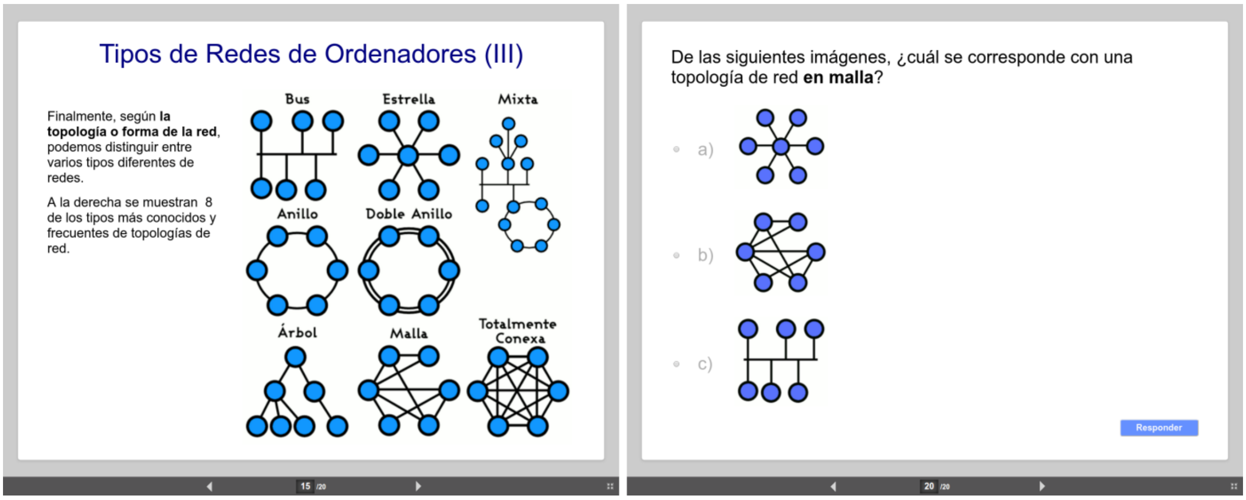

Figure 9.6: Learning Object on computer networks used in a lesson

Students accessed the Learning Objects directly on the ViSH web portal. The teacher was present, encouraged students to pursue the learning activities and provided clarification when it was necessary, but students learned the content exclusively from the Learning Objects.

After each lesson, the Learning Object used in that lesson was evaluated by the students and by the teacher using the WBLT evaluation scales [9], [281]. On the one hand, students evaluated the Learning Object using WBLT-S (WBLT Evaluation Scale for Students). On the other hand, the teacher performed her evaluation using WBLT-T (WBLT Evaluation Scale for Teachers).

WBLT-S is a scale that allows assessing the effectiveness of Learning Objects from a learner's perspective. WBLT-T is a scale similar to WBLT-S but intended to be used by teachers to allow them to evaluate the effectiveness of the Learning Objects they employed in their lectures. Section 2.6 provides more information about WBLT-S and WBLT-T. The students and the teacher filled in the evaluation forms on the ViSH web portal. These evaluation forms are provided by the LOEP system presented in chapter 5 of this thesis. Therefore, the versions of WBLT-S and WBLT-T provided by LOEP were used. These versions require each criterion to be evaluated using a 7-point Likert scale (see chapter 5 for details).

Thereby, the 5 Learning Objects used in the teaching unit were evaluated by the 38 students generating 190 WBLT-S evaluations, and by the teacher generating 5 WBLT-T evaluations. The score of each criterion was calculated by averaging the scores given to the five Learning Objects used in the lessons. Overall scores were calculated on a 0-10 scale using the "WBLT-S Arithmetic Mean" and "WBLT-T Arithmetic Mean" metrics described in chapter 5. The results of the students' evaluations and of the teacher's evaluations are shown, respectively, in Tables 4.7 and 4.8 of chapter 4 of this thesis, which presents a summary of this study as part of the evaluation of the ViSH Editor authoring tool. Learning Objects obtained an average overall score of 8.1 out of 10 from students, and an average overall score of 9.5 out of 10 from the teacher. Furthermore, all WBLT-S and WBLT-T criteria were rated on average above 5.7 on a 1-7 scale.

Finally, after completing the five lessons, students took an exam about the concepts presented in the teaching unit. The exam was on paper and consisted of four exercises: a test with 10 questions of true-false type, a network map in which students had to identify different elements, a fill in the gap exercise and a matching quiz. Students' exam grades recorded a mean of 9.2 out of 10 with a standard deviation of 0.9 (M=9.2, SD=0.9). The minimum grade was 6.0, so all students passed. Figure 9.7 shows the histogram of these grades.

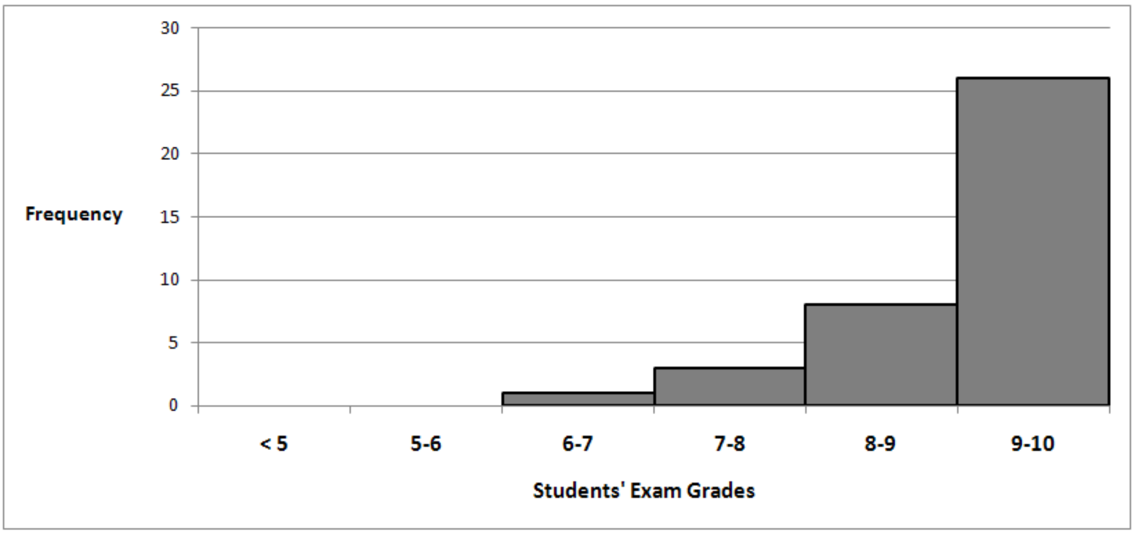

Figure 9.7: Histogram of exam grades achieved by the students

The results of this study show that both students and the teacher were very satisfied with the Learning Objects used in the teaching unit. The Learning Objects were perceived as easy to use and useful for teaching and learning. Besides, the Learning Objects were able to engage and motivate the students. Therefore, it is not surprising that students reported that they would like to use similar Learning Objects in more occasions. In the comments, students stated that they liked how the lessons were carried out because they were more fun and entertaining than the usual teacher-driven lessons, and that they would like to have more lessons of this type. The teacher stated that the Learning Objects were very useful to teach technical concepts difficult to teach with traditional methods, and that the learning methodology used was useful and motivational. The teacher particularly found useful that students were able to learn at their own pace. Only one technical problem was reported: in one of the lessons the Learning Objects took long time to load. The teacher indicated that this problem was due to the school network connection. Lastly, it is worth highlighting that the learning outcomes achieved by the students in this study were outstanding. The exam grades evidence that the students learned the concepts taught by the Learning Objects.

Based on the results of this study, it can be suggested that Learning Objects created with the ViSH Editor authoring tool can be very effective in terms of learner engagement and academic performance. In the learning experience reported in this section, students consumed the Learning Objects directly from the ViSH web portal at their own pace. Therefore, this study also provides evidence that OER repositories like the ViSH platform can be very useful to support teaching and learning in schools. Finally, this study also shows that Learning Objects can facilitate teachers the integration of ICT in the classroom, enable students to work at their own pace and stimulate independent learning facilitating the use of more engaging learning methodologies, and help to introduce new concepts difficult to teach with traditional methods.

9.2.2 Higher Education

9.2.2.1 Teaching web development to undergraduates

This section reports a study which examined the use of several Learning Objects in a computer science course at UPM (Universidad Politécnica de Madrid). This course is a core course for third year students enrolled in the Bachelor of Engineering in Telecommunication Technologies and Services at UPM. It introduces students to web development covering the HTML, CSS and JavaScript programming languages, as well as the Node.js JavaScript runtime environment. The course is worth 4.5 ECTS credits and lasts one semester. It is divided in two parts: the first part mainly covers HTML, CSS and JavaScript, and the second part covers web development with Node.js. Each part is evaluated separately, has the same weight in the final grade, and has to be passed with a grade equal or higher than five to pass the course.

A total of four Learning Objects were used in the first part of the course as optional materials to support students in achieving their learning outcomes. These Learning Objects were created by the teachers using an open source authoring tool called CODEditor [414], which was specifically created for the course. The Learning Objects included several examples of code, step-by-step tutorials and self-evaluation exercises on HTML, CSS and JavaScript. In these self-evaluation exercises, students are presented with a textual statement and a piece of code. To pass the exercises, students have to modify the provided skeleton of code or write a piece of code from scratch so that the code meets the requirements specified in the statement. Students can execute the code they have written to get immediate feedback at any time.

Once created, the four Learning Objects were integrated into the course's Moodle platform as SCORM packages. Thereby, the performance of the learners in the Learning Objects could be tracked and recorded. Figure 9.8 shows one of the Learning Objects used in the course. In addition to the Learning Objects, solutions to some of the self-evaluation exercises were provided to the students through the Moodle platform.

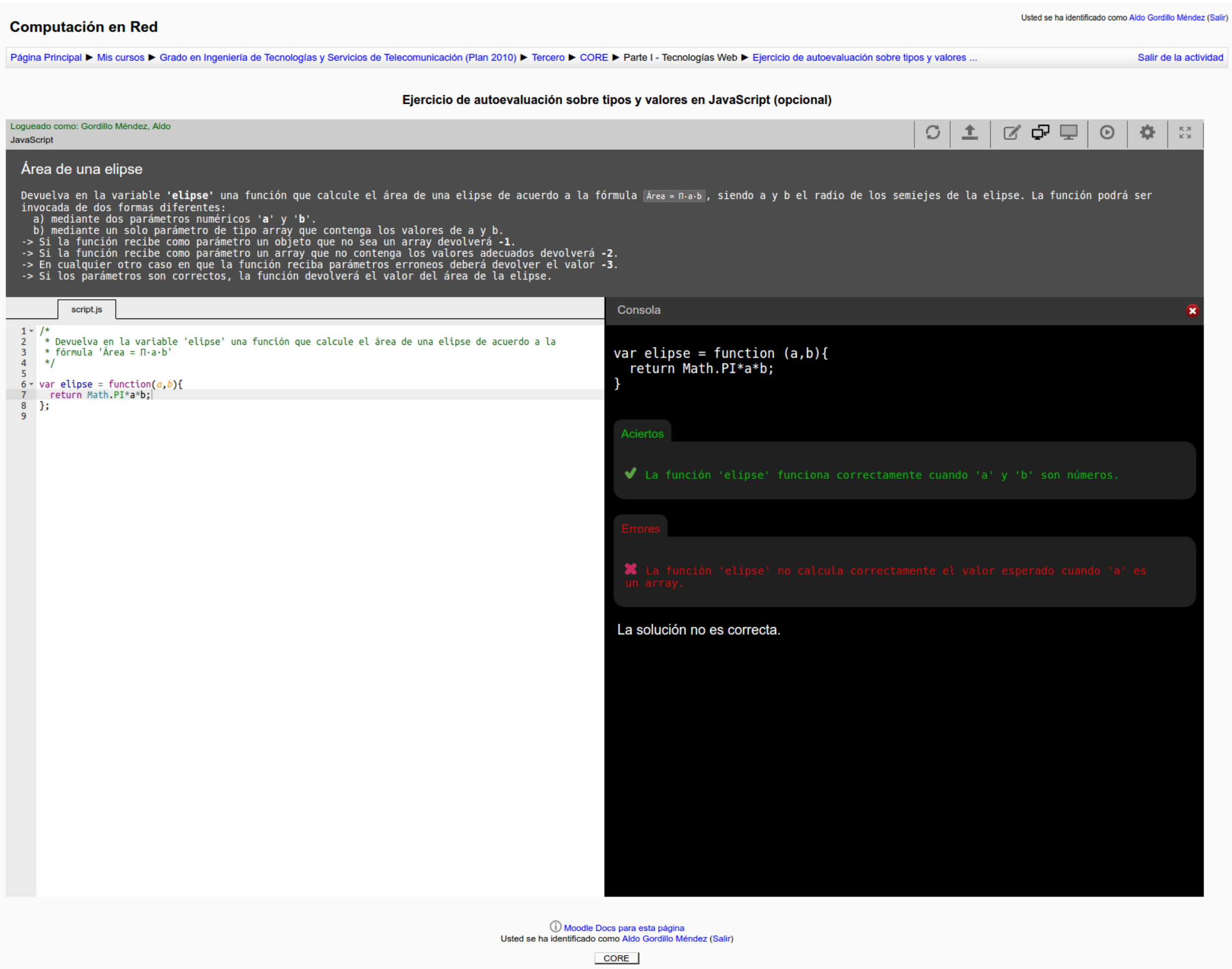

Figure 9.8: Learning Object used in the computer science course

The aim of using the Learning Objects was to reinforce the concepts taught in class, to allow students to practice solving programming problems, and to give students opportunities for self-evaluation. The use of the Learning Objects was optional for students and their grades did not count towards the final grade of the course. However, students were encouraged to use the Learning Objects and complete all the tutorials and self-evaluation exercises. For each student attempt at a Learning Object, the time spent by the student and a score on a 0-100 scale were recorded. Students were allowed to have as many attempts as they wanted. The grade for each Learning Object was the highest score achieved by the student in an attempt. In order to allow students to evaluate the used Learning Objects as a whole according to WBLT-S, a link to an online evaluation form was included in the Moodle platform of the course. This evaluation form was provided by the LOEP system presented in chapter 5 of this thesis.

All the Learning Objects used in the course, as well as the solutions provided for some exercises and the authoring tool used to create the Learning Objects, were published under open licenses on the ViSH platform described in chapter 3 of this thesis. Thereby, all resources used in this learning experience are freely available to any teacher, student or educational institution interested in using them.

At the end of the first part of the course, students took a practical exam in a computer lab. This exam consisted of two equally weighted exercises: one HTML and CSS exercise, and one JavaScript exercise. Students had one hour to complete the exam. The weight of this exam in the final grade of the first part of the course was 50% (i.e. its weight in the final grade of the course was 25%). The exam was taken by a total of 240 students.

Thereafter, an online survey was conducted among the students of the course to collect general feedback about the Learning Objects provided as supporting materials. A link to this survey was shared through the Moodle platform of the course, and teachers asked students who had used the Learning Objects to participate.

A total of 52 students completed the course survey about the Learning Objects, 67.3% males and 32.7% females, 20 to 29 years of age (M=20.8, SD=1.5). The main results are shown in Table 9.4. Furthermore, 20 WBLT-S evaluations of the Learning Objects conducted by the students were collected. Table 9.5 shows the results of these evaluations. Overall score was calculated on a 0-10 scale using the “WBLT-S Arithmetic Mean” metric described in chapter 5.

Results show that in general students had positive attitudes towards the use of Learning Objects in the course. Overall opinion obtained a mean of 3.7 on a 1-5 scale and the average overall score was 8.4 out of 10. Students found the Learning Objects easy to use and helpful for their learning. It is also worth commenting that students agreed that the Learning Objects were well integrated with the other course materials into the Moodle platform. Students also stated that they would like to use Learning Objects of this kind in more occasions, as well as use them in the classroom, in practical exams and in other programming courses.

Table 9.4: Results of the Course Survey about Learning Objects (N=52)

Question	M	SD
Please indicate your level of agreement on each of the following statements about the Learning Objects used in the course 1 (strongly disagree) - 5 (strongly agree)		
I have a positive overall opinion about the Learning Objects	3.7	0.8
The Learning Objects were useful	3.7	0.9
The Learning Objects were easy to use	3.7	0.7
I have improved my programming skills thanks to the Learning Objects	3.5	1.0
The Learning Objects were well integrated with the other course materials into the Moodle platform	3.7	0.9
I would like teachers to use Learning Objects of this kind in the classroom	3.8	1.1
I would like this kind of Learning Objects to be used to conduct practical exams	3.5	1.1
I would like to use this kind of Learning Objects in other programming courses	4.0	0.9

Table 9.5: Results of the WBLT-S Evaluations of the used Learning Objects (N=20)

	M	SD
Overall score (WBLT-S Arithmetic Mean quality metric) 0 – 10	8.4	1.2
WBLT-S criteria 1 – 7		
1. The learning object was well organized	6.4	0.8
2. The learning object was easy to use	5.8	1.0
3. The instructions in the learning object were easy to follow	5.9	1.1
4. The help features of the learning object were useful	5.7	1.3
5. Working with the learning object helped me learn	6.4	0.8
6. The feedback from the learning object helped me learn	6.0	1.1
7. The graphics and animations form the learning object helped me learn	5.7	1.2
8. The learning object helped teach me a new concept	6.0	0.9
9. Overall, the learning object helped me learn	6.4	0.9
10. I like the overall theme of the learning object	6.0	1.0
11. I found the learning object to be engaging	6.1	1.1
12. The learning object made learning fun	5.8	1.0
13. I would like to use learning objects like this again	6.5	0.9

The comments from the survey revealed that students really liked the immediate feedback of the self-graded exercises included in the Learning Objects and that they found these exercises useful for exam preparation. Some students also commented that the help features of the Learning Objects should be improved because they found it difficult to get started with them. In order to address this issue, future editions of the course could provide videotutorials explaining how to use the Learning Objects.

The Learning Objects were used by a total of 76 students out of the 240 who took the practical exam at the end of the first part of the course. Each of these students spent on average around 2.1 hours interacting with the Learning Objects on the Moodle platform of the course. Thereby, approximately a total of 160 learning hours were delivered by these Learning Objects.

In order to analyze the impact of the Learning Objects on student performance, the exam grades achieved by the students who did not use the Learning Objects were compared to those achieved by the students who used the Learning Objects. Table 9.6 presents the results of this comparison. An independent samples t-test was conducted to determine if there was a significant difference in the grades achieved between the two groups of students. Besides, Cohen's d effect size was used to determine the practical significance of the difference in grades. When using Cohen's d as a measure of effect size, a value of 0.2 indicates a small, 0.5 a medium, and over 0.8 a large effect size [386].

Results show that students who used Learning Objects achieved better grades in the practical exam than those who did not use Learning Objects. The difference between grades was found to be statistically significant (p-value < 0.05) with a close to medium effect size (Cohen's $d = 0.45$). Taking into account that students who used Learning Objects significantly outperformed those who did not, it can be suggested that the Learning Objects used in the course had positive effects on student achievement.

The findings of this study indicate that the examined Learning Objects are effective resources for learning web development. These Learning Objects had positive impacts on student attitudes and achievements in a higher education course. Furthermore, students were satisfied with how the Learning Objects were integrated into the course's LMS. It should be emphasized that all the resources used in the learning experience reported in this study, including the authoring tool used to create the Learning Objects, are available under open licenses on the ViSH platform. Thus, this study also provides evidence that the ViSH platform can be very useful for meeting the current demands of computer science education. Finally, this study shows that Learning Objects can be successfully used as supporting materials to allow students to practice solving programming problems in a self-paced way, to give students opportunities for self-evaluation, and to provide teachers with more detailed student tracking data.

Table 9.6: Grades achieved by the Students in the Practical Exam

Students who did not use Learning Objects (N=164)		**Students who used Learning Objects (N=76)**		**Independent samples t-test p-value (2-tailed)**	**Cohen's d effect size**
M	**SD**	**M**	**SD**		
5.2	2.2	6.1	1.9	0.001	0.45

9.2.3 Online Courses

9.2.3.1 MOOC about Web Development

The present section examines the case of a MOOC (Massive Open Online Course) about web development delivered through the Miriada X platform [90], in which a set of Learning Objects were used as supporting materials. This MOOC was developed by UPM (Universidad Politécnica de Madrid) and, at the time of writing, has been run seven times on Miriada X. The data presented in this section correspond to the fourth edition of the course, which was held in 2015.

The MOOC is structured into 10 modules and runs over a period of 5 weeks. It requires 10 hours of work per week (i.e. 50 hours of work in total). Each week two new modules are available to students. Each module consists of several video lectures of 10 minutes length on average, self-graded quizzes, optional peer-reviewed assignments, and one mandatory peer-reviewed assignment. Furthermore, each module provides a downloadable file with the slideshows and examples used in the video lectures, as well as a link to a Learning Object that allows to view, run and edit the examples of code corresponding to the module. Since one link is provided in each module, students use a total of 10 different Learning Objects of this kind in the MOOC. Figure 9.9 shows one of them. These Learning Objects used in the MOOC as supporting materials were published under open licenses on the ViSH platform presented in chapter 3 of this thesis. Students access these Learning Objects directly on the ViSH web portal by using the links provided through the Miriada X platform.

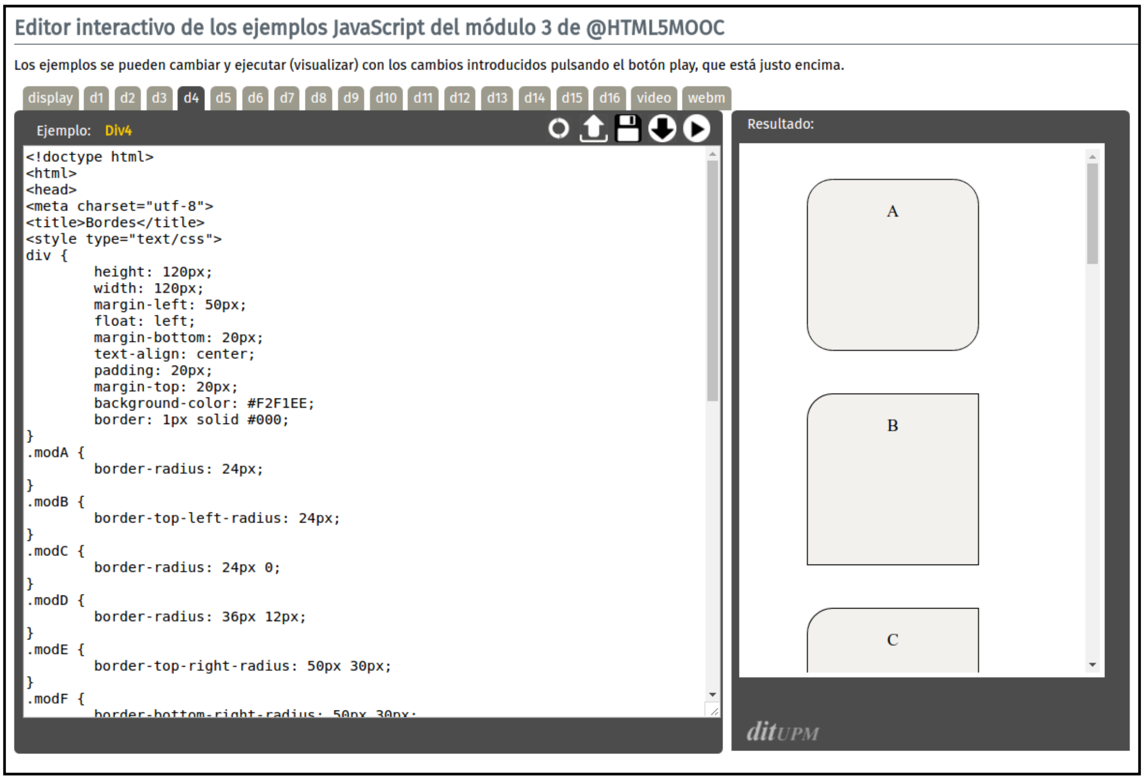

Figure 9.9: Learning Object used in the MOOC about web development

The 10 Learning Objects used as supporting materials were developed from scratch by the instructors of the MOOC. All of them are web applications with the same layout. A series of tabs are displayed at the top of the application (see Figure 9.9). Each tab allows students to load a different example of an HTML page, which can include not only HTML code but also CSS and JavaScript code. On the one hand, the code of the page is shown in a box at the left side. On the other hand, the result of executing the code is shown in other box at the right side. Students can also edit the code provided by the examples and execute it to view the output. Each module provides one Learning Object that includes the examples of code used in it.

A total of 15,932 students were enrolled in the MOOC, of which 1,360 (8.5%) completed it. This completion rate of 8.5% was not unexpected since MOOCs have been found to have completion rates from 0.7% to 52.1% with an average value of around 13% [104], [105].

The Learning Objects used in the MOOC as supporting materials can be evaluated by students according to WBLT-S through the ViSH web portal. A total of 480 evaluations of these Learning Objects had been collected until the end of the fourth edition of the MOOC. Table 9.7 presents the results of these evaluations. The score of each criterion was calculated by averaging the scores given to the 10 Learning Objects, and the overall score was calculated on a 0-10 scale using the “WBLT-S Arithmetic Mean” metric described in chapter 5.

Learning Objects obtained an average overall score of 8.4 out of 10 from students, and all WBLT-S criteria were rated on average above 5.8 on a 1-7 scale. In view of the results of the WBLT-S evaluations, it is clear that in general students had positive attitudes towards the use of the Learning Objects in the MOOC, and that they found these resources easy to use, engaging and beneficial for their learning. Students also stated that they would like to use Learning Objects like the ones used in the MOOC as supporting materials again. Many positive comments were made by the students. There seemed to be a consensus that the Learning Objects were very intuitive and easy to use. Students particularly liked the possibility of editing the code and immediately seeing the results of its execution. Some students also liked that the Learning Objects were available online and not having to install any software. A very positive finding was that several students claimed that the Learning Objects helped them learn how to apply the theoretical concepts explained in the videos to practice. Students’ comments suggest that the Learning Objects were particularly useful for programming beginners. Although most comments were positive, some students complained about the layout of the applications and that they did not work well in some web browsers. Some students also stated that some examples were difficult to understand, and other students suggested to include in the applications solved exercises. In this regard, future editions of the MOOC could use Learning Objects that include step-by-step tutorials and self-graded exercises on HTML, CSS and JavaScript like the ones used in the learning experience described in the above section.

Table 9.7: Students' Scores of the Learning Objects used in the MOOC as supporting materials based on WBLT-S (N=10)

	M	SD
Overall score (WBLT-S Arithmetic Mean quality metric) 0 – 10	8.4	0.2
WBLT-S criteria 1 – 7		
1. The learning object was well organized	6.1	0.2
2. The learning object was easy to use	6.2	0.2
3. The instructions in the learning object were easy to follow	6.0	0.2
4. The help features of the learning object were useful	6.0	0.1
5. Working with the learning object helped me learn	6.1	0.2
6. The feedback from the learning object helped me learn	5.9	0.2
7. The graphics and animations form the learning object helped me learn	6.0	0.1
8. The learning object helped teach me a new concept	6.0	0.2
9. Overall, the learning object helped me learn	6.1	0.2
10. I like the overall theme of the learning object	6.2	0.2
11. I found the learning object to be engaging	6.1	0.2
12. The learning object made learning fun	6.0	0.1
13. I would like to use learning objects like this again	6.2	0.2

Miriada X sent an online course satisfaction survey to all enrolled students after the end of the MOOC. This survey was completed by 1,161 students, 80.2% males and 19.8% females, of which 16.80% were under 25 years old, 41.26% were between 25 and 35 years old, 26.01% were between 36 and 45 years old, 12.66% were between 46 and 55 years old, and 3.27% were over 55 years old. Around 65.7% of the students stated that they had not previously enrolled in a MOOC. With regard to the MOOC workload, respondents answered as follows: 19.6% less than 3 hours a week, 38.4% between 3 and 5 hours a week, 22.3% between 5 and 7 hours a week, 12.1% between 7 and 10 hours a week, and 7.6% more than 10 hours a week. Table 9.8 shows the main results of the course satisfaction survey conducted by Miriada X, including for each question the number of responses.

These results show that students were in general satisfied with the effectiveness and usefulness of the MOOC. Course effectiveness obtained an average rating of 4.0 on a 1-5 scale. The resources that students found most useful were the videos. Most students also found very useful the attached downloadable documentation (i.e. the slideshows and examples used in the video lectures), the notification emails, and the links to other resources on the Web (i.e. the Learning Objects to view, run and edit the examples of code available on the ViSH platform). The other content and functionalities of the MOOC were also found useful by the students, but to a lesser extent.

Table 9.8: Results of the MOOC Survey conducted by Miriada X

Question	N	M	SD	
Rate the effectiveness of the course in your training 1 (very bad) - 5 (very good)	1,068	4.0	0.9	
Have the content and functionalities made available in this course been useful to you?		**Very useful**	**Useful**	**Not very useful**
Videos	1,062	63.0%	31.8%	5.2%
Attached downloadable documentation	1,058	53.0%	39.4%	7.6%
Links to other resources on the Web	1,043	50.3%	41.9%	7.8%
Rubrics for peer assessment	1,032	34.0%	48.6%	17.3%
Feedback from peer assessment	1,023	28.3%	43.3%	28.3%
Feedback from quizzes	1,019	35.9%	46.3%	17.8%
Forums	977	32.1%	46.8%	21.1%
Notification emails	1,050	51.8%	40.4%	7.8%

The results of the students' evaluations and of the course satisfaction survey indicate that there were positive responses from students towards the Learning Objects used as supporting materials in the MOOC with respect to perceived benefits for engagement and learning. These Learning Objects were found more useful than the feedback on peer-reviewed assignments and the feedback provided by the self-graded quizzes. Based on the presented results, it can be suggested that these Learning Objects gave added value to the MOOC. In the MOOC described in this section, the students accessed the examined Learning Objects from an OER repository called ViSH, on which they had been previously published under open licenses. Thus, the work presented in this section provides evidence that OER repositories like ViSH can be very helpful to support learning in MOOCs, and that open Learning Objects can be used to provide successful learning experiences at low cost. Finally, this work also shows that Learning Objects can be successfully used as supporting materials in MOOCs to help students learn how to apply theoretical concepts explained in the video lectures to practice, as well as to motivate and help beginners get started with web development.

9.2.3.2 SPOC about e-Safety

This section presents a case study of a SPOC (Small Private Online Course) about e-Safety based on Learning Objects delivered through the EducaInternet platform described in section 9.1.2.1 of this chapter. SPOCs are online courses with the same characteristics as MOOCs, except that the number of participants is relatively small and the enrolment and access is only allowed for a specific set of people. The SPOC described in this section was developed by UPM (Universidad Politécnica de Madrid), with the collaboration of the Spanish public entity Red.es, the Ministry of Education, Youth and Sports of the Madrid Region, Orange, and leading experts in e-Safety, digital citizenship and copyright law. At the time of writing, this SPOC has been run twice on EducaInternet. The data presented in this section correspond to the second edition of the course, which was held in 2016.

The SPOC is hosted on an instance of the Moodle LMS [79] integrated into the EducaInternet platform. Thus, users need to register on EducaInternet in order to enrol in it. The SPOC is structured into 4 modules and runs over a period of 6 weeks. It requires 5 hours of work per week (i.e. 30 hours of work in total). The first and second module are made available to participants, respectively, in the first and second week of the course, and the third and fourth module are made available, respectively, in the fourth and fifth week. Each module has one Interactive Presentation created with the ViSH Editor authoring tool presented in chapter 4 of this thesis that includes video lectures of around 8 minutes length on average and links to external websites. Therefore, four Interactive Presentations are used in the SPOC in total. The video lectures included in the Interactive Presentations are recordings from experts in e-Safety, digital citizenship and copyright law. Some of these video lectures were created as Enriched Videos with ViSH Editor and have integrated resources such as quizzes and websites. Figure 9.10 shows an Enriched Video used in the SPOC. In addition to an Interactive Presentation, each module has two to four interactive Learning Objects that cover specific topics (e.g. privacy management, netiquette and grooming) and that include multimedia content, self-graded questions, practical cases, and links to additional materials. A total of 10 of these Learning Objects are used in the SPOC. These Learning Objects were developed by Red.es and had been published on EducaInternet under open licenses. Figure 9.11 shows one of them. A forum is also included in each module to allow participants to ask and answer questions, raise concerns, engage in discussions, and share information relevant to the course. Modules also include some additional videos and links, videotutorials that explain how to perform the activities, and additional downloadable materials to use in the classroom.

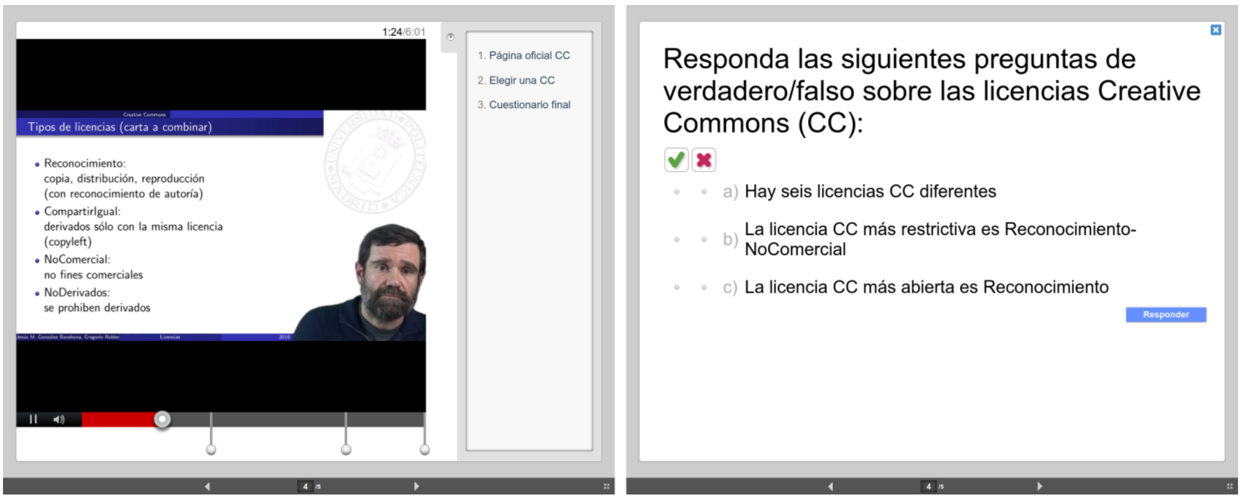

Figure 9.10: Enriched Video used in the SPOC about e-Safety

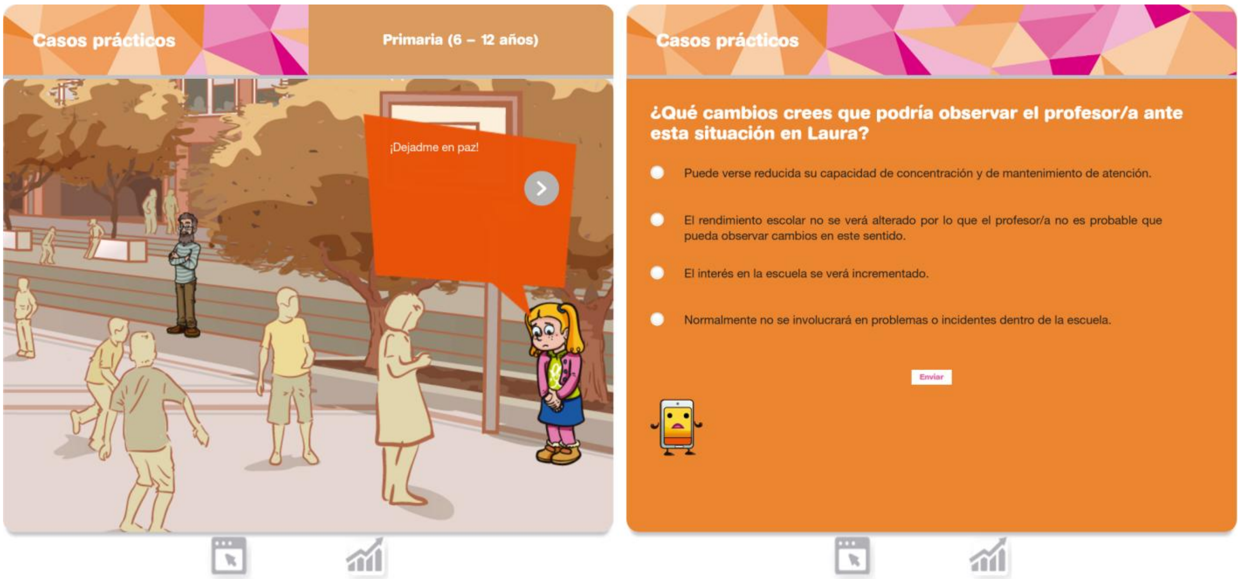

Figure 9.11: Learning Object developed by Red.es used in the SPOC about e-Safety

At the end of each module, there is a mandatory quiz about the concepts covered by the module. Besides, the SPOC has two mandatory peer-reviewed assignments, one at the end of the second module, and another one at the end of the fourth module. The second of these assignments requires participants to create a Learning Object about one of the topics covered by the SPOC. Several authoring tools are recommended to the participants to perform this assignment, including ViSH Editor. Lastly, there are also some optional non-graded activities in the different modules, which do not count towards the final grade of the SPOC.

The SPOC was offered by the Ministry of Education, Youth and Sports of the Madrid Region as an official course to all teachers of public and private schools of the Madrid Region. It was worth two official continuing education credits. A total of 634 teachers were enrolled in the SPOC, of which 565 (89.1%) successfully completed it. It is worth noting that this completion rate is substantially higher than the ones usually found in MOOCs [104], [105]. Most likely the main reason of this high completion rate is that the SPOC was offered as an official course whose successful completion was awarded with two continuing education credits recognized by the Ministry of Education, Youth and Sports of the Madrid Region.

During the SPOC, some messages were posted on the announcements forum asking participants to evaluate the 4 Interactive Presentations that include video lectures and the 10 interactive Learning Objects developed by Red.es used in the SPOC. A total of five links to WBLT-S evaluation forms were shared in the forum: one for each Interactive Presentation, and one to allow participants to evaluate the 10 Learning Objects developed by Red.es as a whole. All evaluation forms were provided by the LOEP platform presented in chapter 5 of this thesis.

In total, 143 evaluations of the Interactive Presentations and 317 evaluations of the Learning Objects developed by Red.es were collected. Tables 9.9 and 9.10 present respectively the results of these evaluations.

Table 9.9: Participants' Scores of the Interactive Presentations used in the SPOC based on WBLT-S (N=4)

	M	**SD**
Overall score (WBLT-S Arithmetic Mean quality metric) 0 – 10	8.1	0.3
WBLT-S criteria 1 – 7		
1. The learning object was well organized	6.1	0.2
2. The learning object was easy to use	6.1	0.3
3. The instructions in the learning object were easy to follow	6.0	0.1
4. The help features of the learning object were useful	6.0	0.2
5. Working with the learning object helped me learn	6.1	0.3
6. The feedback from the learning object helped me learn	5.6	0.3
7. The graphics and animations form the learning object helped me learn	5.7	0.1
8. The learning object helped teach me a new concept	6.2	0.2
9. Overall, the learning object helped me learn	6.1	0.3
10. I like the overall theme of the learning object	5.9	0.4
11. I found the learning object to be engaging	5.7	0.4
12. The learning object made learning fun	5.3	0.3
13. I would like to use learning objects like this again	5.7	0.3

Table 9.10: Results of the WBLT-S Evaluations of the Learning Objects developed by Red.es used in the SPOC (N=317)

	M
Overall score (WBLT-S Arithmetic Mean quality metric) 0 – 10	8.2
WBLT-S criteria 1 – 7	
1. The learning object was well organized	6.0
2. The learning object was easy to use	5.7
3. The instructions in the learning object were easy to follow	5.8
4. The help features of the learning object were useful	5.9
5. Working with the learning object helped me learn	6.2
6. The feedback from the learning object helped me learn	5.7
7. The graphics and animations form the learning object helped me learn	5.9
8. The learning object helped teach me a new concept	6.1
9. Overall, the learning object helped me learn	6.2
10. I like the overall theme of the learning object	6.1
11. I found the learning object to be engaging	5.9
12. The learning object made learning fun	5.4
13. I would like to use learning objects like this again	5.8

The score of each criterion presented in Table 9.9 was calculated by averaging the scores given to the four evaluated Interactive Presentations. The score of each Interactive Presentation was calculated by averaging the scores from the WBLT-S evaluations received by that Interactive Presentation. The score of each criterion presented in Table 9.10 was calculated by averaging the scores from the 317 WBLT-S evaluations obtained through the WBLT-S evaluation form that asked participants to evaluate the 10 Learning Objects developed by Red.es as a whole. Standard deviation is included in Table 9.9 to show the variation among scores of Interactive Presentations, but not in Table 9.10 because the Learning Objects developed by Red.es were evaluated as a whole through one single WBLT-S evaluation form. In both cases, the overall score of the Learning Objects was calculated on a 0-10 scale using the “WBLT-S Arithmetic Mean” metric described in chapter 5.

On the one hand, the Interactive Presentations that include video lectures obtained an average overall score of 8.1 out of 10 and an average rating higher than 5.2 on a 1-7 scale in all WBLT-S criteria. On the other hand, the Learning Objects developed by Red.es achieved an average overall score of 8.2 and were rated on average higher than 5.3 in all WBLT-S criteria. These results make clear that, in general, SPOC participants found the different Learning Objects used throughout the course well organized, easy to use, engaging, and useful for their learning. Moreover, participants reported that they would like to use similar Learning Objects in more occasions. Participants commented that they really liked the video lectures because the different concepts were clearly explained. They found particularly interesting the topics on copyright and content licenses. Some suggestions were made to enhance the Interactive Presentations including adding more self-evaluation questions and additional educational resources to support the explanations from the videos. Regarding the Learning Objects developed by Red.es, participants especially liked the included practical cases. Furthermore, positive comments were made about the completeness of the information, the self-graded questions and the referenced additional materials. In general, participants seemed to like the interactivity and variety of content of these Learning Objects. Some participants also stated that these Learning Objects were enjoyable and motivating. Comments from the evaluations also suggest that participants liked that the Learning Objects used in the SPOC enabled them to work independently at their own pace. Although the majority of comments were positive, there were some critical comments. Some participants stated that the Learning Objects developed by Red.es have too much information and require too much time to be completed. In this regard, some participants also complained about not being able to suspend an attempt at a Learning Object and resume it later.

An online survey was conducted at the end of the SPOC to gather general feedback from participants. A link to the survey was shared through the Moodle instance and a message was posted on the announcements forum asking participants to fill it in. The survey was completed by 426 participants, 32.1% males and 67.9% females, 25 to 65 years of age (M=44.0, SD=7.8). Most participants (79%) stated that they had never enrolled in a MOOC. Participants were also asked to rate their digital skills on a scale from 1 (very low) to 5 (very high). This question obtained a mean value of 3.4 with a standard deviation of 0.9. Regarding the total number of hours spent on the SPOC, participants answered as follows: 4.1% less than 20 hours, 21.0% between 20 and 30 hours, 20.8% between 30 and 40 hours, 24.2% between 40 and 50 hours, and 29.9% more than 50 hours. In this regard, 21.8% of the participants deemed this number of hours excessive while 75.8% believed that it was adequate, and only 2.4% stated that it was insufficient. According to the participants' comments, most of the participants who considered the number of hours dedicated to the course excessive were participants with low computer skills who had difficulty completing the peer-reviewed assignments. Table 9.11 shows the main results of the SPOC survey, including for each question the number of responses.

Table 9.11: Results of the SPOC Survey

Question	**N**	**M**	**SD**
What is your overall opinion of the course? 1 (awful) – 5 (excellent)	426	4.1	0.7
Please indicate your level of agreement on each of the following statements about the course 1 (strongly disagree) - 5 (strongly agree)			
The structure of the course is adequate	425	4.1	0.8
The guidance provided to the student allows to easily follow the course	422	4.0	1.0
The course workload is adequate	423	3.5	1.1
The course has allowed me to improve my knowledge on safe and responsible use of digital technologies	425	4.4	0.8
The course has allowed me to improve my digital skills	424	4.1	1.0
I will be able to use the materials I created in this course in my classroom	423	3.8	1.1
Please rate the usefulness of the following content, activities, functionalities and tools of the course 1 (not useful) – 5 (very useful)			
Videos from experts (included in the Interactive Presentations)	426	4.3	0.8
Learning Objects developed by Red.es	425	4.2	0.8
Videotutorials	425	4.4	0.8
Additional downloadable materials	423	4.1	0.9
Links to other resources on the Web	424	4.2	0.8
Self-graded quizzes	424	4.1	0.8
Peer-reviewed assignments	426	3.8	1.0
Optional activities	409	3.5	0.9
Forums	415	3.6	1.1
Notifications	419	4.1	1.0
The EducaInternet platform	423	4.2	0.9
Would you recommend this course to a colleague?	422	**Yes** 92.7%	**No** 7.3%

These results show that participants were in general satisfied with the SPOC. Overall opinion recorded a mean of 4.1 on a 1-5 scale and nearly 93% of the participants answered that they would recommend the SPOC to colleagues. The SPOC was found to be adequately structured and easy to follow. A very positive finding was that participants stated that the SPOC allowed them to improve their knowledge on safe and responsible use of digital technologies as well as their digital skills. Besides, many participants agreed that they will be able to use the Learning Objects they had created for the peer-reviewed assignments in their teaching. Although most participants considered that the course workload was adequate, some complained about the time required to complete the peer-reviewed assignments. All materials used in the SPOC were found very useful by the participants, who rated them above 4.0 on a 1-5 scale. In this regard, it is worth remarking that the videos from experts included in the Interactive Presentations together with other resources obtained an average rating of 4.3, and the Learning Objects developed by Red.es obtained an average rating of 4.2. The activity that was found most useful was the quizzes, followed by the peer-reviewed assignments and the optional activities. The notifications and the forums were also found useful by the participants. Lastly, participants also indicated that the EducaInternet platform used to deliver the SPOC was very useful.

In addition to provide access to the SPOC, the EducaInternet platform was used to perform different activities. For instance, the second peer-reviewed assignment required participants to create a Learning Object about one of the topics covered by the SPOC and publish it on the EducaInternet platform under an appropriate license. Some videotutorials were provided to help participants to complete this assignment by using the ViSH Editor authoring tool available on EducaInternet, but participants were free to use other tools. In order to get feedback from the participants about the EducaInternet platform and its features, other survey was conducted. As with the previous survey, a link was shared through the Moodle instance and a message was posted on the announcements forum asking participants to fill it in. An overview of the results of this survey, which was filled in by a total of 290 participants, is presented in Table 9.12.

The results presented in Table 9.12 show that the teachers who enrolled in the SPOC had positive attitudes towards the EducaInternet platform. Overall opinion recorded a mean of 3.9 on a 1-5 scale and around 93% of the teachers stated that they would recommend EducaInternet to others. Regarding usability, most teachers agreed that learning to use EducaInternet was easy. In general, teachers were satisfied with the features offered by the platform that they used throughout the SPOC. All these features obtained a rating higher than 3.4 on a 1-5 scale. In this regard, it is worth pointing out that satisfactory ratings were given to the ViSH Editor authoring tool presented in chapter 4 (M=3.5, SD=1.1), the evaluation system provided by using the LOEP platform presented in chapter 5 (M=3.6, SD=1.0), and the recommender system designed for ViSH described in chapter 7 (M=3.5, SD=1.0).

Table 9.12: Results of the EducaInternet Survey completed by the SPOC Participants

Question	N	M	SD
What is your overall opinion of the EducaInternet platform? 1 (awful) – 5 (excellent)	290	3.9	0.6
How would you describe the experience of learning to use EducaInternet? 1 (very difficult) – 5 (very easy)	290	3.8	0.9
Please rate your opinion about the following features of the EducaInternet platform 1 (awful) – 5 (excellent)			
Uploading and publication of resources (i.e. Learning Object manager)	290	4.0	0.9
Download of resources	269	3.8	1.0
ViSH Editor authoring tool	290	3.5	1.1
ViSH Lesson Editor authoring tool	258	3.7	0.9
Evaluation system	264	3.6	1.0
Search service	290	3.6	0.9
Recommender system	238	3.5	1.0
Homepage of the web portal	276	3.6	1.0
Help and tutorials	283	4.1	1.0
Would you recommend EducaInternet to others?	290	**Yes** 93.4%	**No** 6.6%

Finally, pre-tests and post-tests were used to evaluate the learning effectiveness of the SPOC. These tests were included in the Moodle instance: the pre-test was included as the first activity of the SPOC, and the post-test was included as the last activity. The questions on both tests were the same. A total of 535 participants who successfully completed the SPOC took both the pre- and post-test. Results are presented in Table 9.13. A paired samples t-test was conducted to compare the pre-test and post-test scores. Besides, Cohen's d effect size was calculated to determine the magnitude of the score differences. When using Cohen's d as a measure of effect size, a value of 0.2 indicates a small, 0.5 a medium, and over 0.8 a large effect size [386].

The results of the pre- and post-test indicate that the average learning gain from pre-test to post-test was around 32%. The score increase was statistically significant and meaningful with respect to effect size, which was found to be large. Based on these results, it is clear that participants did significantly improve their knowledge of the topics taught in the SPOC.

Table 9.13: Pre-post Test Score Differences (N=535)

Pre-test		Post-test		Average learning gain	Paired samples t-test p-value (2-tailed)	Cohen's d effect size
M	SD	M	SD			
5.5	1.5	8.7	1.1	32%	< 0.001	1.76

In conclusion, the findings of this case study show that participants had positive attitudes towards the SPOC about e-Safety based on Learning Objects, and that this online course was effective in helping participants learn. Participants found the different Learning Objects used throughout the SPOC engaging and useful for their learning. Since the case study presented in this section examined a SPOC that had the same characteristics as a MOOC (except that enrolment and access was only allowed for teachers of public and private schools of the Madrid Region), it can be suggested that its findings can be generalized not only to other SPOCs, but also to MOOCs. Thus, it can be suggested, according to these findings, that it is possible to develop effective MOOC-like courses based on an appropriate set of Learning Objects. One characteristic of these online courses is that instructor feedback to individual students is not possible. For this reason, Learning Objects can be a very useful component for them due to their capacity of enabling students to work at their own pace and of fostering learner-centred approaches.

This case study provides evidence that the EducaInternet platform, which was built upon the software that runs the ViSH platform described in chapter 3 of this thesis, can be successfully used to deliver SPOCs as well as to conduct learning activities in online courses. Besides, it has allowed to validate in a real-world environment the feature provided by ViSH to integrate Moodle in order to deliver online courses. The findings reported in the above section show that OER repositories can be very helpful to support learning in MOOCs. The findings of this section show that OER repositories can also be used to deliver effective MOOC-like courses if they are suitably integrated with LMSs.

9.2.4 Other Experiences

9.2.4.1 Learning by doing: an experience in a blended course for teachers about e-Safety

This section describes a learning by doing experience in a blended course for teachers about e-Safety. The course was organized in 2015 by the Ministry of Education, Youth and Sports of the Madrid Region. It was worth one official continuing education credit, had 80 places, and was offered to all teachers of public and private schools of the Madrid Region. The course covered topics related to e-Safety and digital citizenship (see [413] for further details).

The duration of the course was 25 hours, of which 12 were face to face and the remaining 13 were online. The course was scheduled in two weeks, two days a week, three hours a day. Thereby, teachers attended the course a total of four days, three hours per day. The course combined classroom lectures from leading experts in e-Safety and digital citizenship with practical sessions, in which teachers used two e-Learning systems to create and publish Learning Objects: the EducaInternet platform described in section 9.1.2.1 of this chapter, and the ViSH Editor authoring tool described in chapter 4. The first two hours of each day were dedicated to the lectures of the experts, while the last hour of each day was dedicated to perform practical activities using the e-Learning systems. Teachers also dedicated all online hours to use the e-Learning systems introduced in the course and complete the practical activities and assignments. Therefore, teachers had 8 hours (32%) dedicated to theory and 17 hours (68%) dedicated to practice.

The final assignment of the course consisted of creating an Interactive Presentation that explained a concept related to the topics that had been covered in the course. Teachers had to use the ViSH Editor Learning Object authoring tool to create the Interactive Presentation, and then the EducaInternet platform to publish it. The idea was that teachers should create Interactive Presentations explaining interesting concepts related to e-Safety and digital citizenship, so that these Learning Objects could be reused by the teachers after the course completion to teach the concepts to their students. The goals of this final task were diverse: motivate teachers by involving them in the creation of a Learning Object that is likely going to be used in real scenarios, allow teachers to delve into the topics in which they are most interested in, involve teachers in constructive investigations and knowledge sharing, and lastly encourage teachers to practice and enhance their skills with e-Learning authoring tools and OER repositories.

Project-Based Learning (hereafter PBL) is a learning methodology that organizes learning around projects, where these projects are defined as complex tasks based on challenging questions or problems that involve students in design, problem-solving, decision making or investigative activities, that give students the opportunity to work relatively autonomously over an extended period of time, and that culminate in realistic products or presentations [415]. The final assignment of the course described in this section fulfils, to a greater or lesser extent, the main characteristics of a PBL project: it covers central concepts, the performed activities are orchestrated in the service of intellectual purposes, it involves participants in a constructive investigation, it is student-driven to some significant degree, and proposes a real-life challenge where the solution (i.e. the created Learning Object) can and is likely going to be used in real environments. Given that, this learning experience can be considered to some degree as an application of PBL. Nevertheless, it is worth pointing out that PBL projects are complex tasks in which students usually work over extended periods of time. In this case, participants only dedicated 13 hours to create the Learning Object, and it may be questionable whether this task was complex compared to the projects usually carried out in PBL experiences.

A total of 80 teachers were enrolled in the course, of which 65 (81.3%) complete it. Of these 65 teachers who completed the course, 27 (41.5%) were male and 38 (58.5%) were female, and they ranged from 29 to 58 years of age (M=44.0, SD=7.6). They considered that they had little experience using VLEs (M=2.5, SD=1.2, 1-5 scale) and medium experience using ICT in education (M=3.5, SD=1.0, 1-5 scale).

In order to pass the final assignment, each of the 65 teachers who completed the course created an Interactive Presentation with the ViSH Editor authoring tool and published it on the EducaInternet platform. Thereby, a total of 65 Learning Objects were authored and published on EducaInternet. One of these Learning Objects is shown in Figure 9.12.

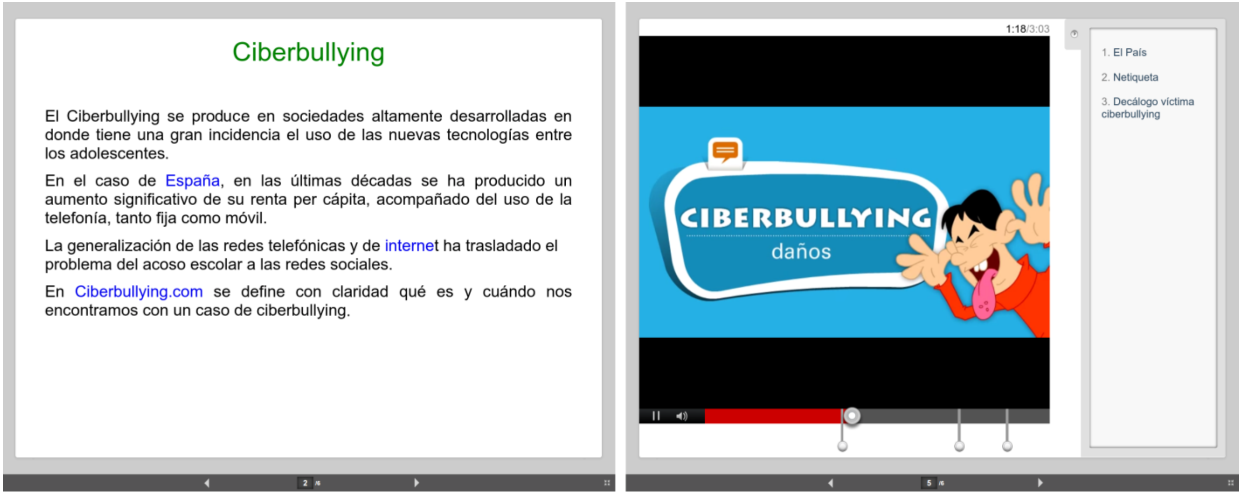

Figure 9.12: Learning Object created with ViSH Editor by a course participant

Several actions were carried out to evaluate the presented learning experience. Firstly, two questionnaires were conducted among the 65 teachers who completed the course in order to collect feedback about the used e-Learning systems. The first questionnaire included questions related to the EducaInternet platform while the second one included questions related to the ViSH Editor authoring tool. Secondly, three aspects of the 65 Learning Objects created in the course were analyzed: their pedagogical quality, the quality of the metadata with which they were tagged, and their usage statistics (number of visits and downloads) on the EducaInternet platform. Lastly, teachers filled out another questionnaire about the course where they gave general feedback. Henceforth, this section presents the results of these evaluations.

Tables 9.14 and 9.15 show, respectively, an overview of the results of the questionnaires on EducaInternet and ViSH Editor. These results show that, in general, participants were very satisfied with the e-Learning systems used in the course. The overall opinion of EducaInternet recorded a mean of 4.0 on a 1-5 scale and almost all teachers answered that they would recommend it to others. Furthermore, teachers thought that EducaInternet was easy to use and were satisfied with the different features offered by it, which obtained ratings higher than 3.6 on a 1-5 scale. On the other hand, the overall opinion of ViSH Editor obtained a mean of 4.0 on a 1-5 scale and around 92% of the teachers answered that they would recommend it to others. Teachers also stated that learning to use the ViSH Editor authoring tool was easy. Lastly, teachers were also satisfied with the different features offered by ViSH Editor to create Learning Objects. All these features were rated above 3.4 on a 1-5 scale.

Table 9.14: Results of the EducaInternet Questionnaire completed by the Course Participants (N=65)

Question	M	SD
What is your overall opinion of the EducaInternet platform? 1 (awful) – 5 (excellent)	4.0	0.6
How would you describe the experience of learning to use EducaInternet? 1 (very difficult) – 5 (very easy)	3.8	0.8
Please rate your opinion about the following features of the EducaInternet platform 1 (awful) – 5 (excellent)		
Uploading and publication of resources (i.e. Learning Object manager)	4.0	0.9
Download of resources	3.9	1.0
ViSH Editor authoring tool	4.0	1.0
Evaluation system	4.0	0.8
Search service	3.7	0.9
Recommender system	3.8	0.9
Homepage of the web portal	3.8	0.9
Help and tutorials	4.1	0.9
Would you recommend EducaInternet to others?	**Yes**	**No**
	98.5%	1.5%

Table 9.15: Results of the ViSH Editor Questionnaire completed by the Course Participants (N=65)

Question	M	SD
What is your overall opinion of ViSH Editor? 1 (awful) – 5 (excellent)	4.0	0.6
How would you describe the experience of learning to use ViSH Editor? 1 (very difficult) – 5 (very easy)	4.0	0.8
Please rate your overall experience using various features of ViSH Editor 1 (awful) – 5 (excellent)		
Writing text	3.8	0.8
Adding multimedia resources	3.9	0.8
Uploading your own files	3.9	0.9
Creating quizzes	3.7	1.0
Creating Flashcards	3.6	1.0
Creating Virtual Tours	3.5	1.0
Creating Enriched Videos	3.8	1.1
Help and walkthroughs	4.1	0.8
Would you recommend ViSH Editor to others?	**Yes**	**No**
	92.1%	7.9%

The pedagogical quality of the created Learning Objects was evaluated using LORI (Learning Object Review Instrument) 1.5 [273]. This Learning Object evaluation model considers the following nine criteria (also termed LORI items): content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, reusability, and standards compliance. When using LORI, reviewers have to rate each item using a 5-point scale and also they can provide comments with their reviews. More information about LORI can be found in section 2.6 of this thesis. The evaluations were conducted by a group of six experienced reviewers by using the LOEP system presented in chapter 5 of this thesis. Each Learning Object was evaluated on average by three reviewers. As quality metric to calculate the quality scores of the Learning Objects, the “LORI Weighted Arithmetic Mean” metric proposed and validated in chapter 5 of this thesis was used. This metric calculates the overall score of a Learning Object on a 0-10 scale as the weighted arithmetic mean of all LORI items scores, giving different importance to each criterion. The used weights were those obtained through a survey among the reviewers of the ViSH platform (i.e. the collected weights as termed in chapter 5). When a Learning Object is scored higher or equal to five according to the LORI Weighted Arithmetic Mean quality metric used in this evaluation, such a Learning Object can be considered of high enough quality to be used for education. Further details on this LORI metric can be found in [385] as well as in chapter 5 of this thesis. Figure 9.13 shows the histogram of quality scores obtained by the 65 Learning Objects created by the teachers for the final assignment of the course according to the “LORI Weighted Arithmetic Mean” metric used in this evaluation.

The average score was 5.4 out of 10 with a standard deviation of 1.5. The quality score of 42 (64.6%) of the Learning Objects exceeded the quality threshold of 5. Thereby, it can be stated that 64.6% of the teachers who completed the course achieved to create Learning Objects with an acceptable pedagogical quality for teaching and learning e-Safety and digital citizenship. Only 18.5% of the teachers created Learning Objects with quality scores below 4. Regarding the type of resources used to create the Interactive Presentations, 96.9% of the teachers included some image, video or audio, 47.7% of them embedded at least one external resource like a website, 35.4% of them enriched their Learning Object with self-graded quizzes, and 61.5% of them created other interactive Learning Object like a Flashcard or a Enriched Video and integrated it into the presentation.

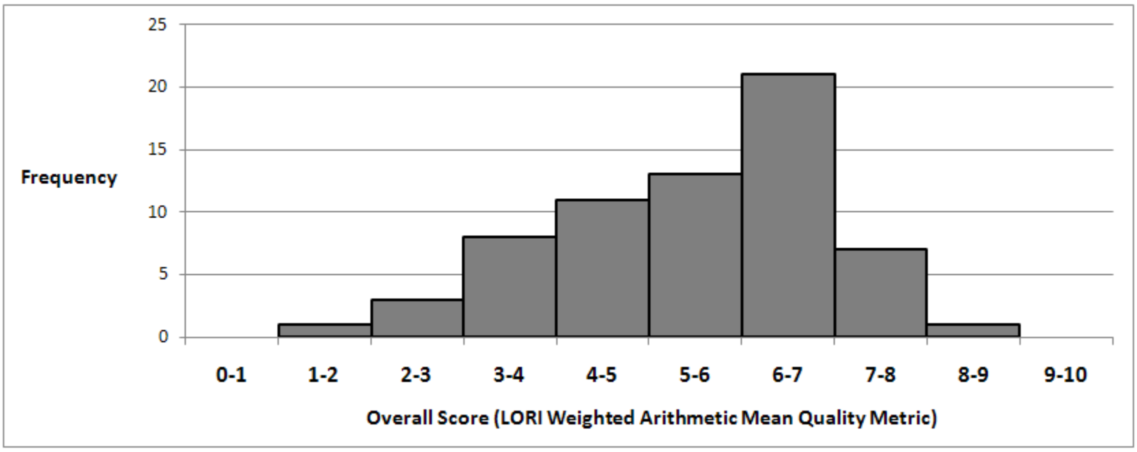

Figure 9.13: Histogram of LORI scores obtained by the Learning Objects created in the course

The quality of the metadata of the Learning Objects created by the teachers was measured by using the “LOM Metadata Quality Metric” described in chapter 5 of this thesis. This metric calculates overall metadata quality scores on a 0-10 scale by averaging the scores yielded by five metrics that measure metadata quality according to the following criteria: completeness, conformance, consistency, coherence and findability. These five metrics were defined based on the metadata quality metrics proposed by Ochoa [26], and are fully explained in chapter 5. The calculations were automatically performed by LOEP, which obtained the metadata from EducaInternet. Figure 9.14 shows the histogram of metadata quality scores obtained by the 65 Learning Objects created by the teachers.

The average of the scores was 6.6 out of 10 with a standard deviation of 1.0. On this occasion, the metadata quality of 92.3% of the Learning Objects recorded values higher than 5. Based on this result, it can be stated that in general teachers tagged the Learning Objects created with the ViSH Editor authoring tool with good metadata in terms of completeness, conformance, consistency, coherence and findability.

The number of visits and downloads of the 65 Learning Objects created in the course since their publication on EducaInternet until about 13 months later were retrieved from the EducaInternet database. These usage statistics can be helpful to figure out if the Learning Objects were used after their creation and to what extent. The total number of visits was 58,754, with an average of 904 visits per Learning Object and a standard deviation of 552. Moreover, the Learning Objects were downloaded a total of 9,715 times. Each Learning Object was downloaded 149 times on average with a standard deviation of 16. These data indicate that the Learning Objects have been used several times after their creation. A key goal of the course was that the Learning Objects created by the teachers could be reused by other colleagues to teach concepts related to e-Safety and digital citizenship to their students. Taking into account the obtained usage statistics, it can be suggested that this goal was achieved, and that the final assignment of the course succeeded in incorporating a real-life challenge where the solution has the potential to be used in real environments.

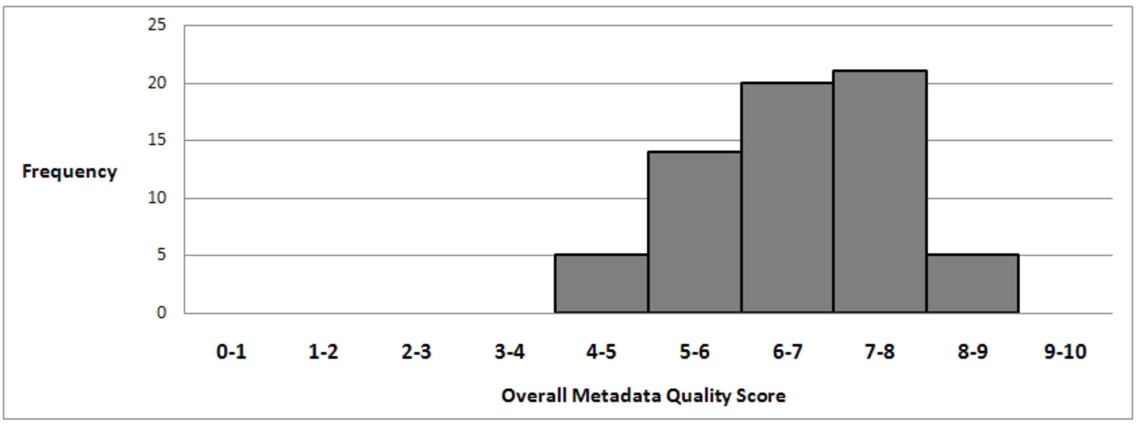

Figure 9.14: Histogram of metadata quality scores obtained by the Learning Objects created in the course

Finally, the results of the questionnaire in which participants gave general feedback about the course are presented in Table 9.16. The teachers' general opinion of the course was very positive. All aspects were rated higher than 3.8 on a 1-5 scale. The content, methodology and activities used in the course were considered appropriate and received good feedback. In general, teachers liked the combination of classroom lectures with practical sessions as well as the learning by doing approach adopted for the final assignment. Regarding the comments about the e-Learning systems, teachers liked the ease of use and intuitiveness of EducaInternet and ViSH Editor. They also liked the concept of a community of shared Learning Objects as well as the offered possibilities to create and use these educational resources. Some teachers reported that the authoring tool needs more flexibility and asked for more features. With respect to the PBL project, a few teachers reported that they did not like the final assignment while many others were satisfied with the learning by doing approach. In general, teachers suggested that more time should be dedicated to the practical sessions since they had to learn how to use the tools as well as many new concepts. Several participants also proposed to use an even more practical methodology, to create different work groups for the practical sessions by dividing the participants based on their computer skills, and to carry out the assignments collaboratively.

Table 9.16: Results of the Questionnaire about the Course (N=65)

Question	**M**
Please rate each of the following aspects of the course 1 (deficient) – 5 (excellent)	
Suitability and achievement of the goals of the course	4.3
Type, quantity and complexity of the content	4.5
Coherence between the goals of the course and the content	4.5
Suitability of the methodology for conveying the learning content	4.3
Suitability of the methodology for encouraging participation and personal reflection	3.9
Quantity of activities to achieve the course goals	4.1
Quality of the proposed activities	4.1
Organization (duration, coordination and scheduling)	4.1
Utility of the documentation and resources provided for practice	4.3
Pedagogical performance of the teachers	4.3

This section presents results from an experience in a blended course for teachers in which a PBL methodology was used in order to involve participants in the creation of Learning Objects. This experience is an example of how Learning Objects can be used in combination with PBL. In general, course participants were satisfied with the content, methodology and activities used in the course. However, it is worth noting that a few participants did not like the PBL approach. Nearly 65% of the teachers who completed the course successfully achieved to create a Learning Object with an acceptable quality for teaching and learning e-Safety and digital citizenship, tag that Learning Object with suitable metadata, an publish it on an OER repository. The published Learning Objects were, on average, visited around 900 times and downloaded more than 140 times over around 13 months after their publication. Taking into account all the results of the evaluation of this experience, it can be suggested that the PBL methodology used in the course succeeded, to some degree, in incorporating a real-life challenge where the Learning Objects created by the participants to overcome that challenge can be effectively used for teaching and learning e-Safety and digital citizenship. Finally, the work presented in this section also provides evidence that the EducaInternet platform and the ViSH Editor authoring tool can be successfully used to conduct learning activities in blended courses.

9.3 Publications

This section lists the 17 publications produced as a result of this thesis. These publications include 3 articles in international journals indexed in the JCR (Journal Citation Reports), 2 articles in other international journals, 1 book chapter, and 11 international conference papers. The author of this thesis is the first author in 13 of the 17 publications (including the 3 articles in JCR journals) and second author in the remaining publications.

Articles in international journals indexed in the JCR

- **A. Gordillo**, E. Barra, and J. Quemada, "An easy to use open source authoring tool to create effective and reusable learning objects," *Computer Applications in Engineering Education*, vol. 25, no. 2, pp. 188–199, 2017.
- **A. Gordillo**, E. Barra, and J. Quemada, "A Hybrid Recommendation Model for Learning Object Repositories," *IEEE Latin America Transactions*, vol. 15, no. 3, pp. 462 – 473, 2017.
- **A. Gordillo**, E. Barra, and J. Quemada, "Quality estimation of learning objects in repositories of open educational resources based on student interactions," *Educación XX1*, in press.

Articles in other international journals

- **A. Gordillo**, E. Barra, and J. Quemada, "Enhancing Web-Based Learning Resources With Existing and Custom Quizzes Through an Authoring Tool," *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, vol. 10, no. 4, pp. 215–222, 2015.
- E. Barra, **A. Gordillo**, and J. Quemada, "Virtual Science Hub: An Open Source Platform to Enrich Science Teaching," *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, vol. 8, no. 3, pp. 741 – 746, 2014.

Book Chapters

- E. Barra, **A. Gordillo**, and J. Quemada, "Plataforma Social y Colaborativa para la creación de Recursos Educativos Abiertos (Open Educational Resources)," in *Global e-learning (2[a] edición)*, A. Landeta Etxeberria, Ed. Centro de Estudios Financieros, 2015.

International Conference Papers

- **A. Gordillo**, E. Barra, and J. Quemada, "A model based on e-Learning standards to combine, integrate and assemble Learning Objects," in *Proceedings of the 8th International Conference on Education and New Learning Technologies (EDULEARN 2016)*, 2016.
- **A. Gordillo**, E. Barra, and J. Quemada, "Learning by doing: an experience with a novel e-Learning platform and a Learning Object authoring tool in a teachers' course about e-Safety," in *Proceedings of the 8th International Conference on Education and New Learning Technologies (EDULEARN 2016)*, 2016.
- E. Barra, **A. Gordillo**, M. E. Blas, J. Guijarro, and I. Vazquez, "EducaInternet: A Platform to Teach and Learn Safe and Responsible Use of Digital Technologies," in *Proceedings of the 8th International Conference of Education, Research and Innovation (ICERI 2015)*, 2015.
- **A. Gordillo**, E. Barra, and J. Quemada, "A flexible open source web platform to facilitate Learning Object evaluation," in *Proceedings of the 2014 Frontiers in Education Conference (FIE 2014)*, 2014.
- **A. Gordillo**, E. Barra, and J. Quemada, "Towards a Learning Object pedagogical quality metric based on the LORI evaluation model," in *Proceedings of the 2014 Frontiers in Education Conference (FIE 2014)*, 2014.
- **A. Gordillo**, E. Barra, and J. Quemada, "Enhancing web-based learning resources with quizzes through an Authoring Tool and an Audience Response System," in *Proceedings of the 2014 Frontiers in Education Conference (FIE 2014)*, 2014.
- **A. Gordillo**, E. Barra, and J. Quemada, "Facilitating the creation of interactive multi-device Learning Objects using an online authoring tool," in *Proceedings of the 2014 Frontiers in Education Conference (FIE 2014)*, 2014.
- E. Barra, **A. Gordillo**, D. Gallego, and J. Quemada, "Integration of SCORM packages into web games," in *Proceedings of the 2013 Frontiers in Education Conference (FIE 2013)*, 2013.
- **A. Gordillo**, E. Barra, D. Gallego, and J. Quemada, "A model for integrating learning object repository resources into web videoconference services," in *Proceedings of the 2013 Frontiers in Education Conference (FIE 2013)*, 2013.

- **A. Gordillo**, E. Barra, D. Gallego, and J. Quemada, "An online e-Learning authoring tool to create interactive multi-device learning objects using e-Infrastructure resources," in *Proceedings of the 2013 Frontiers in Education Conference (FIE 2013)*, 2013.
- **A. Gordillo**, E. Barra, and J. Quemada, "Enhancing K-12 science education through a multi-device web tool to facilitate content integration and e-Infrastructure access," in *Proceedings of the 7th International Technology, Education and Development Conference (INTED 2013)*, 2013.

9.4 Open Source Projects

This thesis makes several contributions in the form of e-Learning systems. All these systems are available under free and open source licenses so that they can be freely used, distributed, studied, adapted and improved by the research and educational communities (see [382] for more information about the benefits of open source software for education). The author of this thesis has been the main contributor (in terms of number of commits and number of lines of code) to all these systems. In this regard, it is worth mentioning that some of them were developed exclusively by the author while others were developed in collaboration with other members of the Next Generation Internet research group of the Telematic Systems Engineering Department at UPM (Universidad Politécnica de Madrid). The e-Learning systems contributed by this thesis have been published as open source projects. This section provides a brief description of each of these open source projects, including the awards they have received.

ViSH

ViSH is an e-Learning platform to create and distribute OER in the form of Learning Objects. It provides a wide variety of features including authoring tools, search services, a social network, a catalogue, collections, bookmarks, an evaluation system, a recommender system, an Audience Response System, learning analytics, and integration with LMSs. Chapter 3 provides a detailed description of ViSH. The ViSH platform is available at http://vishub.org and is offered to the entire educational community for free. A transfer process has been initiated in order to offer ViSH as an institutional service of UPM, which will ensure its long-term sustainability. The source code of ViSH is available at http://github.com/ging/vish. Furthermore, the source code of the Learning Object recommender system for ViSH described in chapter 7 is also included in this repository. ViSH received the award to the best open source project in the senior category at the 9th edition of the Free Software University Contest.

Lastly, it is worth mentioning that ViSH was used to develop a new e-Learning platform called EducaInternet (see section 9.1.2.1), which was also published as an open source project. EducaInternet is publicly available at http://educainternet.es, and its source code is available at http://github.com/ging/vish_orange.

ViSH Editor

ViSH Editor is an easy to use web-based authoring tool to create Learning Objects. A complete description of the tool is given in chapter 4 of this thesis. ViSH Editor is publicly available at http://vishub.org, the website of the ViSH e-Learning platform. Its source code is available at http://github.com/ging/vish_editor (client side) and http://github.com/ging/vish (server side). ViSH Editor was used to develop a platform called IDeM, which won the first prize in the first edition of the "actúaloop competition for innovation in research social networks" organized by Frontiers and UPM. A description of IDeM can be found in chapter 8.

LOEP

LOEP is the first system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. This system is presented in chapter 5. An instance of LOEP, used by ViSH and EducaInternet, is currently deployed at http://loep.upm.es. Nevertheless, the access to this instance is restricted to administrators and appointed reviewers of the ViSH and EducaInternet platforms. The source code of LOEP is publicly available at http://github.com/agordillo/LOEP. This open source project was awarded with a special mention in the senior category at the 10th edition of the Free Software University Contest.

EuropeanaRS

EuropeanaRS is a recommender system implemented as a standalone web application capable of generating recommendations of Learning Objects retrieved from the Europeana repository. Chapter 7 describes EuropeanaRS including a detailed description of the recommendation model used for its implementation. EuropeanaRS is open source and its source code is available at http://github.com/agordillo/EuropeanaRS. This recommender system was used to develop a platform called IDeM, which won the first prize in the first edition of the "actúaloop competition for innovation in research social networks" organized by Frontiers and UPM. Chapter 8 provides a description of the IDeM platform.

SGAME Platform

The SGAME platform is a web-based platform that provides an authoring tool that allows users to create customizable educational web games by integrating Learning Objects packaged according to the SCORM e-Learning standard into existing web games. This platform as well as the model it uses to integrate Learning Objects into games are described in chapter 8. The source code of the SGAME platform is available at http://github.com/agordillo/sgame. Finally, it is worth remarking that the SGAME platform will be deployed on the Web and offered to the entire educational community for free in the near future thanks to an educational innovation project on Game-Based Learning funded by UPM.

9.5 Conclusions

This chapter presents some projects and learning experiences in which several contributions of this thesis have been validated. Besides, the chapter lists the publications that have been produced as a result of this thesis and describes the contributions published as open source projects.

First, four projects are described: two European projects and two private funded projects. Thereafter, a total of five learning experiences are reported: one in secondary education, one in higher education, one in a MOOC, one in a SPOC, and one in a blended course in which Learning Objects were used in combination with a project-based learning methodology. These projects and learning experiences allowed to validate several of the contributions of this thesis to the authoring, distribution, evaluation and integration of Learning Objects in new environments. The results presented in this chapter provide more evidence of the value of these contributions.

The use of Learning Objects in different educational environments has been examined based on the reported learning experiences. In summary, the results of these experiences show that an appropriate use of Learning Objects can have significant positive impacts on student attitudes and learning in different educational environments.

Although many previous studies examined the acceptance and instructional effectiveness in terms of student engagement and academic performance of Learning Objects across different educational environments [3]–[23], [203]–[206] (see section 2.3.4), there is a lack of studies examining the use of Learning Objects in novel educational environments such as MOOCs and OER repositories, as well as in combination with different instructional strategies. Therefore, the results presented in this chapter concerning the use of Learning Objects in various educational environments are an important contribution to the field of Technology-Enhanced Learning. On the one hand, the chapter reports experiences where Learning Objects were used in a MOOC and in a SPOC, as well as experiences in which students consumed Learning Objects directly from an OER repository. On the other hand, an experience in a blended course in which Learning Objects were used in combination with a project-based learning methodology has been reported. Future studies could examine the use of Learning Objects in other novel educational environments such as quasi-MOOCs or in combination with other learning methodologies such as flipped classroom and inquiry-based learning.

Chapter 10

Conclusions

This thesis presents results of the design, implementation and evaluation of various systems, metrics and models to facilitate and enhance the authoring, distribution, evaluation and integration of Learning Objects. Several barriers that hamper the use and adoption of Learning Objects are identified, and solutions to address these barriers are proposed, implemented and evaluated. Moreover, this thesis examines the use of Learning Objects in different educational environments, including secondary and higher education, as well as MOOCs (Massive Open Online Courses). The work presented in this thesis shows that the proposed solutions are effective and can help to fully exploit the potential of Learning Objects, and that Learning Objects can have significant positive impacts on student attitudes and learning.

The main outcome of this thesis is the design, implementation and evaluation of an ecosystem of web applications for authoring, distributing, evaluating and integrating Learning Objects, including an e-Learning platform which supports the whole Learning Object life cycle, an easy to use authoring tool to create Learning Objects, a platform that provides systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems, a hybrid Learning Object recommender system, and an application that allows users to create educational web games by integrating Learning Objects into existing web games. All these systems have been released under open source licenses. Thereby, they can be freely used, distributed, studied, adapted and improved by the research and educational communities.

As part of the development of the aforementioned systems, various metrics and models have been designed and evaluated, including evaluation models and quality metrics for Learning Objects, a metric to estimate the quality of Learning Objects based on learners' interactions, a model to generate Learning Object recommendations, and three models to integrate Learning Objects into e-Learning authoring tools, web videoconferencing services and web games.

This chapter concludes this thesis with a summary of the answers to the research questions, a recapitulation of the main contributions and some suggestions for further research. The chapter is structured as follows. The first section provides a summary of the answers to the research questions of this thesis, which were stated in chapter 1 and answered in detail throughout the remaining chapters. The section after that summarizes the main contributions made by this thesis to the authoring, distribution, evaluation and integration of Learning Objects, as well as other contributions to the Technology-Enhanced Learning field. Finally, the last section of this chapter provides some proposals for future research on Learning Objects.

10.1 Research Questions

Research Question 1: Which features need to be considered in the implementation of a system to create and distribute Learning Objects?

Chapter 3 describes the architecture and the main features of ViSH, an e-Learning platform to create and distribute Learning Objects. The results of the evaluation presented in this chapter provide evidence that the ViSH platform is an effective system to create and distribute Learning Objects, and that it has succeeded in building a relatively large community of users that creates and shares Open Educational Resources (OER) in the form of Learning Objects with the entire world. This chapter also provides a feature comparison, which shows that the features implemented by ViSH encompass almost all the features implemented by existing Learning Object Repositories (LORs). Taking all this into account, this research question can be answered based on the features implemented in the ViSH platform, which have proven to be effective in creating and distributing Learning Objects.

Firstly, LORs must implement features to allow the storage, searching and retrieval of Learning Objects. The storage feature should support a wide range of file formats, including support for Learning Objects created according to e-Learning standards as well as links. Of crucial importance for LORs is also to allow users to publish Learning Objects under open licenses as well as to describe these Learning Objects with appropriate metadata. Regarding the search feature, ranking metrics must be used to facilitate users to find suitable Learning Objects. These metrics can combine different indicators with the relevance to the search query such as the popularity and quality of the Learning Objects. Other features that can be implemented to facilitate users to discover Learning Objects are a catalogue, a browser, a recommender system or a tool to perform federated searches. LORs should allow users to view and download the published Learning Objects and their metadata directly in their web portals whenever possible. Regarding this, it would be useful to provide the Learning Objects and their metadata by using e-Learning standards. Moreover, it would be desirable to provide users with information such as popularity indicators, quality evaluations and comments.

To support the authoring stage of the Learning Object life cycle, LORs should also offer authoring tools to its users. Furthermore, to enable and foster the creation and maintenance of a community of users, the use of a social network is advisable. Other features that a LOR might consider to implement are collections, bookmarks, learning analytics, educational tools (e.g. an Audience Response System), integration with Learning Management Systems (LMSs), and administration features. Besides features for end users, LORs should also consider to provide features for external applications such as a search API or an OAI-PMH target. Finally, it is also important for a LOR to be distributed under an open source license to allow its customization and improvement, as well as to facilitate its long-term sustainability.

Research Question 2: Can educators create effective and reusable Learning Objects easily if they are provided with suitable authoring tools? And if so, which characteristics should be taken into account in the implementation of these tools?

This question can be answered based on the findings of chapter 4, which presents an authoring tool to create Learning Objects called ViSH Editor. The architecture, the Learning Object model and the main features of the ViSH Editor Learning Object authoring tool are detailed in this chapter. Besides, the chapter provides a complete evaluation of the authoring tool addressing three factors: the user acceptance and usability of the tool, the quality and learning effectiveness of the Learning Objects created with such a tool, and the reusability of these Learning Objects. The results of this evaluation show that educators can create effective and reusable Learning Objects easily if they are provided with suitable authoring tools. Nevertheless, it is worth pointing out that there is no authoring tool that can guarantee that the educational resources created with it have a suitable quality and learning effectiveness, although these tools can help authors to make this happen.

Regarding the characteristics that should be taken into account in the implementation of Learning Object authoring tools, the work presented in chapter 4 suggests that these tools should be easy to use even for users with little computer skills, should be able to create Learning Objects effective in terms of learner engagement and academic performance, and should be able to create these Learning Objects in such a way that they can be easily reused in different e-Learning systems and educational environments.

Firstly, Learning Object authoring tools should provide a user friendly interface that allows any user to easily create Learning Objects. Of crucial importance for these tools is also to provide features to integrate and combine different types of content and resources including text, images, audios, videos, websites, web applications and Learning Objects packaged or created according to e-Learning standards. Learning Object authoring tools should also provide features to create questions and other assessment resources, as well as novel e-Learning resources. Furthermore, features to enrich existing e-Learning resources are also advisable. Lastly, in order to create Learning Objects with high reusability, authoring tools should allow to export the created Learning Objects to e-Learning standards such as SCORM to enable their integration into Virtual Learning Environments (VLEs) and other e-Learning systems. In this regard, the tools should also allow authors to describe the Learning Objects with appropriate metadata according to a metadata standard like IEEE LOM. Moreover, it would be desirable for these tools to allow the creation of granular Learning Objects according to an open Learning Object model. Finally, it is also important for a Learning Object authoring tool to be distributed under an open source license to allow its customization and improvement.

Research Question 3: How can the quality of Learning Objects be evaluated, measured and transformed into quality scores that can be understood by humans and automatically processed by information systems? Can these quality scores be used to filter low quality Learning Objects and to enhance search services as well as recommender systems?

Chapter 5 shows the results of the evaluation of a system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. This evaluation included three experiments in which several evaluation models and quality metrics for Learning Objects were tested. The first experiment evaluated the perceived usefulness of an evaluation model called LORI (Learning Object Review Instrument) to assess Learning Object quality. The second experiment evaluated the effectiveness of several Learning Object quality metrics in providing quality-based sorting of Learning Objects to users, as well as the effectiveness of these metrics in distinguishing between high and low quality Learning Objects. Lastly, the third experiment investigated if quality scores of Learning Objects calculated by using quality metrics can be effectively used to enhance Learning Object recommender systems.

Based on the results of chapter 5, it can be stated that the quality of Learning Objects can be effectively evaluated, measured and transformed into quality scores that can be understood by humans and automatically processed by information systems by using appropriate Learning Object evaluation models, quality metrics and systems. In this regard, it must be considered that the validity of the quality scores strongly depends on the evaluation model and quality metric used to generate them. There are other factors that might also influence on this validity such as the qualifications and training of the reviewers who perform the evaluations.

Regarding the second part of the research question, it can be suggested, based on the results of the experiments reported in chapter 5, that Learning Object quality scores calculated by using appropriate Learning Object evaluation models, quality metrics and systems can be effectively used to filter low quality Learning Objects, and to enhance Learning Object search services as well as Learning Object recommender systems.

LORI was found to be an effective Learning Object evaluation model for those LORs that can have reviewers to evaluate the submitted Learning Objects. Furthermore, chapter 5 shows that a Learning Object quality metric that automatically calculates quality scores based on user interactions can achieve good effectiveness in sorting Learning Objects by quality as well as in filtering low quality Learning Objects. However, this effectiveness was found to be notably lower than the one that can be achieved by using LORI quality metrics. Lastly, another relevant finding of chapter 5 is that measures of reusability or metadata quality should not be used as measures of overall quality of Learning Objects.

Research Question 4: Which features should have a system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems?

Chapter 5 presents the results of the design, implementation and evaluation of LOEP, the first system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. The work presented in this chapter shows that LOEP is capable of providing systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems in an open, low cost, reliable and effective way. Therefore, this question can be answered by enumerating and describing those features that were implemented in LOEP.

Firstly, a Learning Object evaluation system should support multiple evaluation models and quality metrics. The evaluation models should be targeted to different audiences such as reviewers, learners, teachers and end users, and should be able to evaluate Learning Objects according to different criteria such as pedagogical quality, usability, reusability and metadata quality. Furthermore, the implementation of automatic evaluation models should be considered. Whenever possible, Learning Object evaluation systems should rely on evaluation models and quality metrics that have been effectively tested. In this regard, section 2.6 of this thesis provides a comprehensive review of the most relevant Learning Object evaluation models and quality metrics that have been proposed. Moreover, chapter 5 proposes two new evaluation models and several new quality metrics for Learning Objects. Learning Object evaluation systems should also allow the implementation of new models and metrics.

Other key feature that Learning Object evaluation systems should have is interoperability with e-Learning systems. These evaluation systems should allow the Learning Objects of the e-Learning systems to be evaluated by appointed reviewers, end users of the e-Learning systems, invited users, and automatic evaluation models. Regarding evaluations from appointed reviewers, a useful feature is to allow administrators to create assignments to distribute the evaluations among the reviewers, either manually or using matching algorithms. The use of the evaluation system should be transparent for the end users of the e-Learning systems. A Learning Object evaluation system should also allow e-Learning systems to obtain, store and use the quality evaluations and scores generated by it, as well as any other evaluation data that may be useful. Thereby, the e-Learning systems will be able to use these evaluation data to implement quality control mechanisms, enhance their features to search and discover Learning Objects, and implement new services.

Lastly, other features that could be useful for Learning Object evaluation systems are the visualization and downloading of evaluation data, Learning Object search by evaluation criteria, generation of statistics, and comparison of Learning Objects based on evaluation data.

Research Question 5: Is there any relationship between the learners' interactions with a Learning Object and its quality? And if so, is it possible to estimate the quality of Learning Objects based on the interactions that learners have with them?

This research question was addressed in chapter 6, which reports on a study that investigated the relationships between the learners' interactions with Learning Objects in open environments and the quality of the Learning Objects, and that defined and evaluated a predictive metric to estimate the quality of Learning Objects based on the interactions that learners have with them. In this study, a total of 146,291 distinct sessions of learner interactions with 256 different Learning Objects distributed through an OER repository were analyzed. The quality of the Learning Objects was measured by using the LORI evaluation model.

Simple linear regression analyses were used to individually study the relationship between each interaction variable and the quality of the Learning Objects. The study analyzed a total of 11 learner-Learning Object interaction variables and identified 9 of them as significant predictors of quality: average total time spent on the Learning Object, average time spent on each slide, average minimum time spent on one slide, average maximum time spent on one slide, average number of mouse clicks, average number of answered quizzes, total number of visits, permanency rate, and favorites rate. Therefore, the answer to the first part of the research question is that, in general, in open environments such as OER repositories, there is a relationship between some interactions of the learners with a Learning Object and the quality of such a Learning Object.

After identifying the interaction variables that are significant predictors of quality, these interaction variables were used as a basis for defining a predictive quality metric by using a multiple linear regression analysis. The predictive quality metric was defined considering three interaction variables: normalized average time spent, normalized permanency rate, and normalized average frequency of mouse clicks. The results of the multiple linear regression analysis show that 95% of the variability of the quality of the Learning Objects can be explained by the three considered interaction variables. The quality scores calculated using the predictive quality metric were compared to those measured through LORI. Based on the results of this comparison, the second part of the research question can be answered by stating that, in general, it is possible to estimate, with a moderate error, the quality of Learning Objects based on the interactions that learners have with them in open environments such as OER repositories. Lastly, the effectiveness of the predictive metric in distinguishing between high quality and low quality Learning Objects was evaluated. The results of this evaluation suggest that the predictive quality metric is highly reliable in identifying low quality Learning Objects.

Research Question 6: What kind of recommendation model is suitable for implementing Learning Object recommender systems? Which factors need to be contemplated in their implementation?

Chapter 7 proposes a hybrid Learning Object recommendation model for LORs that combines content-based, demographic and context-aware techniques, and that uses as knowledge sources Learning Object metadata, user profiles, and Learning Object quality and popularity scores. This recommendation model was designed to support a wide variety of use cases by taking into account the most common features of LORs. Chapter 7 also describes the implementation of two recommender systems (RSs) based on the proposed recommendation model, and reports the results of the evaluations of such RSs in two different scenarios. The two RSs were evaluated in terms of accuracy, utility, user satisfaction and usability. Besides, an A/B test was conducted to compare, in the context of a real-world LOR, the recommendations generated by one of these RSs with random suggestions. Based on the results of the evaluations of these RSs, it can be suggested that the proposed recommendation model is suitable for implementing Learning Object RSs for LORs. Other suitable Learning Object recommendation models can be found in the literature, but most of them have not been evaluated in the context of a real-world application, or have been evaluated using a prototype implementation of the RS, or have been evaluated only in one environment.

Regarding the factors that need to be taken into account to implement Learning Object RSs, several issues should be considered including: the environment in which the RS will operate, the use cases of the RS, the knowledge sources to use, the modelling of the Learning Objects, the generation of user profiles, the recommendation techniques to use, the way of showing the recommendations to end users, and how these users can interact and give feedback to the RS.

Important factors that need to be contemplated when implementing a Learning Object RS include, among others, the characteristics of the Learning Objects the system will recommend (e.g. quantity, diversity, distribution, stability, reusability, and quality and quantity of metadata), the data included in the user profiles (e.g. Learning Objects that users liked or found interesting in the past, demographic information, explicit information about tastes, needs or interests, social data, and educational data), the way of generating recommendations for anonymous users, and the contextual information to use. Other factors that need to be taken into account are the accuracy, utility, acceptance, diversity, coverage and serendipity of the recommendations, as well as the system scalability. Learning Object RSs should also consider educational aspects such as pedagogical quality of recommended Learning Objects. Lastly, these systems should also consider aspects such as usability, interaction adequacy, interface adequacy, trust, control, transparency, perceived usefulness and user satisfaction. Further details on the factors that should be considered in the implementation of Learning Object RSs can be found in chapter 7.

Research Question 7: How can Learning Objects be assembled by integrating and combining other ones?

This question can be answered based on the first integration model for Learning Objects proposed in chapter 8, which provides a generic and robust solution to create Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards through authoring tools.

According to this solution, Learning Objects can be assembled by integrating and combining other ones through an authoring tool in such a way that the assembled Learning Objects behave as one single Learning Object in the eyes of the VLEs into which they are integrated, but only if the authoring tool implements such a solution and the integrated Learning Objects are compliant with certain e-Learning standards such as SCORM, IMS CP, IMS QTI and Moodle XML. The authoring tool should solve three issues: the integration of metadata, the integration of content, and the integration of communications. The integration of metadata can be solved by giving the author the freedom of defining the metadata of the assembled Learning Object through the authoring tool. The integration of content should be solved in a different way depending on the type of Learning Object to be integrated. For integrating Learning Objects defined through XML files according to e-Learning specifications such as IMS QTI or Moodle XML, the authoring tool can store the data of the XML files and render the Learning Objects using these data through the use of web applications called players. For integrating Learning Objects packaged according to SCORM or IMS CP, the authoring tool can store the packages on a web server, extract the Learning Objects contained in the packages, and deliver the Learning Objects through HTML documents containing a player and the URLs of their resources. Lastly, to achieve the integration of the communications between the integrated Learning Objects and the VLEs, the authoring tool should provide the assembled Learning Object with a component capable of gathering all relevant tracking data of the integrated Learning Objects, combine these data, and notify them in a unified way to the VLE into which it is integrated using the API of an e-Learning standard such as SCORM or xAPI. Instead of communicating with the VLE, the integrated Learning Objects should communicate with this component. Thereby, the assembled Learning Object will be able to report a single overall progress, overall score, completion status and success status to the VLE. The reported data can be calculated based on the gathered tracking data and settings specified by the author through the authoring tool. Chapter 8 provides further details about this solution to facilitate authoring tools the creation of Learning Objects by aggregation.

In conclusion, Learning Objects can be assembled by integrating and combining other Learning Objects using authoring tools that support suitable integration models as long as the Learning Objects that are to be integrated are compliant with certain e-Learning standards.

Research Question 8: How can Learning Objects be integrated into contexts in which educational technology is not typically present such as web videoconferencing or web games?

This research question can be answered based on the lessons learned from the design and implementation of the models presented in chapter 8 to integrate Learning Objects provided by LORs into web videoconferencing services, and to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games in order to create educational web games.

The work presented in chapter 8 shows that it is possible to integrate Learning Objects into contexts such as web videoconferencing and web games by developing suitable integration approaches and exploiting the affordances of e-Learning standards. However, this work suggests that developing a generic approach to integrate Learning Objects into any context in which educational technology is not typically present is not possible. Therefore, in order to integrate Learning Objects into one of these contexts, the particular characteristics and constraints of the context should be analyzed, and based on this analysis a specific integration approach for that context should be developed. In this regard, it is worth pointing out that developing a suitable integration approach for a certain context requires analyzing not only the technological constraints imposed by the context, but also educational aspects that could influence on the integration of Learning Objects. For instance, in the context of games, since educational video games should have an adequate balance between entertainment and educational value, only those very small Learning Objects in terms of learning time needed to complete them should be integrated in order to prevent players from being interrupted for long periods of time while they are playing.

Integration approaches for Learning Objects should rely on existing e-Learning standards whenever possible. Furthermore, these integration approaches should also clarify the efforts required in the different systems involved in the integration, the requirements that these systems must meet, and the limitations of the proposed solution.

In conclusion, there are cases in which Learning Objects can be suitably integrated into a context in which educational technology is not typically present by developing a specific integration approach for that context. These integration approaches should take into account the particular characteristics and constraints of the context, the affordances of e-Learning standards that can be exploited to facilitate the integration, the efforts required in the different systems involved, the requirements that these systems must meet, and the limitations of the integration that can be achieved.

10.2 Main Contributions

The main contribution of this thesis is the design, implementation and evaluation of various systems, metrics and models to facilitate and enhance the authoring, distribution, evaluation and integration of Learning Objects. Moreover, the use of Learning Objects in various educational environments is studied. The ultimate goal of this thesis is to address and overcome several of the main barriers to the use and adoption of Learning Objects by proposing, implementing and evaluating effective solutions for these barriers.

The first contribution of this thesis is the identification of the main barriers hampering the use and adoption of Learning Objects along the different stages of their life cycle. The thesis identifies not only technical challenges but also needs of the educational community concerning the authoring, distribution, evaluation and integration of Learning Objects. Chapter 2, which provides an extensive review of the literature on Learning Objects, identifies a wide variety of barriers as well as current approaches, systems, technologies and standards used for the authoring, distribution, evaluation and integration of Learning Objects. Besides, this chapter makes another contribution by providing a new definition of the term “Learning Object” and a simplified representation of the Learning Object life cycle.

The following sections summarize the main contributions of this thesis to the authoring, distribution, evaluation and integration of Learning Objects, as well as other contributions to Technology-Enhanced Learning.

10.2.1 Contributions to the Authoring of Learning Objects

This thesis makes four main contributions to the authoring of Learning Objects.

The first contribution is an open source e-Learning platform to create and distribute Learning Objects called ViSH, which is described in chapter 3. ViSH consists of a Learning Object Repository (LOR) enriched with features to effectively support the whole Learning Object life cycle, including authoring tools. The evaluation presented in chapter 3 provides evidence that ViSH is an effective system to create and distribute Learning Objects.

The second contribution is the ViSH Editor open source authoring tool presented in chapter 4, which has proven to be able to allow educators to create effective and reusable Learning Objects easily. This tool fully supports the authoring stage of the Learning Object life cycle. Besides, it also supports the reuse and maintenance stage because it allows updating the authored Learning Objects and reusing them to create other new ones. Educators can use ViSH Editor to create their own Learning Objects from scratch, as well as to modify other Learning Objects created with the tool available under certain open licenses in LORs. Thus, ViSH Editor can help to overcome two major barriers to the use and adoption of Learning Objects: the limited availability of suitable Learning Objects, and the need to customize these Learning Objects to adapt them to specific contexts.

The third contribution is the evaluation of ViSH Editor reported in chapter 4, which has provided evidence that educators can create effective and reusable Learning Objects easily if they are provided with suitable authoring tools. Besides, several characteristics that should be considered in the implementation of such tools have been identified. Therefore, the results presented in this thesis can drive future development of better Learning Object authoring tools. Although there are some works in the literature that have evaluated open source Learning Object authoring tools, none of them have conducted an evaluation addressing all the aspects evaluated in this thesis. Therefore, this work can also be useful for developers and other researchers interested in evaluating Learning Object authoring tools. Besides, the evaluation of a Learning Object authoring tool in the context of a LOR in which users freely create and share open Learning Objects also constitutes a novel contribution.

The last contribution of this thesis to the authoring of Learning Objects is a model that enables authoring tools to create Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards as well as generic web applications. This model, which is described in chapter 8, can be used to improve existing Learning Object authoring tools. Therefore, this contribution can help to overcome the lack of authoring tools which effectively support Learning Object authoring by aggregation.

10.2.2 Contributions to the Distribution of Learning Objects

This thesis makes a total of seven main contributions to the distribution of Learning Objects.

The first of these contributions is an open source e-Learning platform to create and distribute Learning Objects called ViSH, which is presented in chapter 3. ViSH consists of a LOR enriched with new features, which have been designed and implemented in order to satisfy the needs of the educational community and support the whole Learning Object life cycle, including the management of open Learning Objects. The features provided by ViSH include a web portal, a social network, a Learning Object manager, Learning Object authoring tools, collections and bookmarks, a Learning Object evaluation system, quality, popularity and ranking metrics, search services, a catalogue, a Learning Object recommender system, an Audience Response System, learning analytics, a metadata provider, administration features, courses and integration with LMSs. The evaluation presented in chapter 3 provides evidence that ViSH is an effective system to create and distribute Learning Objects, and that it has succeeded in building a relatively large community of users that creates and shares open Learning Objects with the entire world. The software that runs the ViSH platform is open source and can be used for developing new LORs. Thus, this thesis makes an important contribution to the distribution of Learning Objects by providing a software system for developing LORs capable of effectively supporting the whole Learning Object life cycle.

The second contribution of this thesis to the distribution of Learning Objects is the quantitative analysis of the ViSH platform reported in chapter 3, which provides more evidence for the better understanding of the Learning Object life cycle and the requirements, gaps and opportunities for LORs.

The third contribution is the identification of a wide range of features that should be considered in the implementation of LORs in order to effectively distribute Learning Objects. This identification was carried out based on the results of the evaluation of the different features of the ViSH platform exposed in chapter 3.

The fourth contribution is the proposal of some solutions to address barriers that hamper the distribution of Learning Objects. In addition to the architecture of the ViSH platform and the main features it provides, chapter 3 describes different solutions that were adopted in the ViSH platform to overcome various barriers to the distribution of Learning Objects, which can be also applied to other e-Learning systems. These solutions include ranking, quality and popularity metrics for Learning Objects as well as features to implement quality control mechanisms in LORs.

The fifth contribution of this thesis to the distribution of Learning Objects is the proposal of a hybrid Learning Object recommendation model for LORs that combines content-based, demographic and context-aware techniques, along with the use of Learning Object quality and popularity metrics. This model supports three main use cases: recommend a list of Learning Objects to a particular user, recommend to a user Learning Objects similar to other one, and perform a personalized search of Learning Objects. In order to generate the recommendations, four knowledge sources are considered: Learning Object metadata, user profiles, quality scores, and popularity scores. Chapter 7 describes this model in detail. Besides, this chapter describes how two recommender systems have been implemented based on that model for two different LORs and reports the results of the evaluations of these systems. The reported results indicate that the proposed recommendation model can be used to implement effective Learning Object recommender system. Thus, this model contributes to addressing the difficulty that users have in finding suitable Learning Objects in the different LORs available on the Web, which is one of the main barriers to the use and adoption of Learning Objects. Lastly, it is also worth mentioning that, as part of this contribution, metrics have been proposed to calculate similarity scores between Learning Objects, and between user profiles and Learning Objects.

Based on the Learning Object recommendation model proposed in chapter 7, two open source Learning Object recommender systems were implemented for two different LORs. These recommender systems constitute the sixth contribution of this thesis to the distribution of Learning Objects. The two Learning Objects recommender systems have proved to be effective in recommending Learning Objects, and therefore they can be helpful in the distribution stage of the Learning Object life cycle. Furthermore, the design of the proposed recommendation model and the implementation of these systems based on it allowed to identify several factors that should be considered in the implementation of Learning Object recommender systems. Therefore, the results presented in this thesis can drive future development of better Learning Object recommender systems.

The last contribution of this thesis to the distribution of Learning Objects is the evaluation of the Learning Object recommendation model proposed in chapter 7. On the one hand, this model was evaluated in two different scenarios. On the other hand, this model was evaluated in the context of a real-world application. Many Learning Object recommendation models have been proposed in the literature, but most of them were not evaluated in the context of a real-world application, or were evaluated only in one environment, or were evaluated using a prototype. In fact, many Learning Object recommendation models reported in the literature have not been evaluated through trials that involved human users, or have not been evaluated at all.

10.2.3 Contributions to the Evaluation of Learning Objects

This thesis makes four main contributions to the evaluation of Learning Objects.

The first contribution is an open source platform called LOEP, which is the first system designed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. LOEP fully supports the evaluation stage of the Learning Object life cycle and can be used by e-Learning systems in many different scenarios and contexts. Besides, it resolves the limitations of existing Learning Object evaluation tools. Chapter 5 gives a complete description of LOEP and presents an evaluation of this system. The work exposed in this chapter shows that LOEP is capable of providing systematic evaluation of Learning Objects to e-Learning systems in an open, low cost, reliable and effective way. Furthermore, LOEP has proven to be able to allow e-Learning systems to implement quality control mechanisms and enhance features to search and discover Learning Objects. Therefore, LOEP can help to overcome one of the major barriers to the use and adoption of Learning Objects: the need for LORs to have tools, models and metrics to systematically evaluate and measure the quality of Learning Objects in order to implement effective quality control mechanisms and enhance features to search and discover Learning Objects. Moreover, the development of LOEP has allowed to identify a wide range of features that should be considered in the implementation of systems aimed to provide systematic evaluation of Learning Objects and generation of quality scores to e-Learning systems. Therefore, the work presented in this thesis can drive future development of better Learning Object evaluation systems.

The second contribution of this thesis to the evaluation of Learning Objects is the proposal of new evaluation models and quality metrics for Learning Objects. Chapter 5 proposes new quality metrics for LORI, the most widely used Learning Object evaluation model. In addition to these new metrics, different weight vectors for the LORI items are proposed, a contribution that has been demanded by the research community. Chapter 5 also proposes quality metrics for other existing Learning Object evaluation models. Besides, this chapter proposes two new evaluation models for Learning Objects. The first model allows to automatically evaluate and measure the metadata quality of Learning Objects whose metadata are compliant with the IEEE LOM standard. A set of metadata quality metrics are used to calculate the quality scores for the evaluated Learning Objects. The second proposed model allows to automatically estimate the quality of Learning Objects based on the interactions that learners have with them. This model uses a quality metric for Learning Objects based on learning analytics to calculate the quality scores. Chapter 6 describes how this metric was defined, evaluated and implemented. The work presented in this chapter shows that this Learning Object quality metric can be used by OER repositories to support the evaluation stage of the Learning Object life cycle in a sustainable way and with an acceptable effectiveness. Thus, this metric helps to address one of the key barriers to the use and adoption of open Learning Objects: the lack of sustainable and effective quality control mechanisms in OER repositories. Lastly, chapter 3 shows how an OER repository uses quality scores calculated according to several Learning Object quality metrics to define a new quality metric as well as to define ranking metrics. This chapter also shows how these scores can be used to implement a quality control mechanism in an OER repository.

The third contribution is the evaluation of several evaluation models and quality metrics for Learning Objects provided in chapter 5, which provided insights into the benefits for LORs of evaluating Learning Objects, a research topic on which not much work has been done. The results of this evaluation show that the quality of Learning Objects can be effectively evaluated, measured and transformed into quality scores if appropriate evaluation systems, models and quality metrics are used. These results also show that these quality scores can be effectively used to filter low quality Learning Objects and to enhance Learning Object search services as well as Learning Object recommender systems.

The last contribution of this thesis to the evaluation of Learning Objects is an investigation of the relationships between the learners' interactions with Learning Objects in OER repositories and the quality of the Learning Objects. The results of this investigation are reported in chapter 6. A total of 9 out of 11 learner-Learning Object interaction variables were identified as significant predictors of quality. For the first time, these findings provide a theoretical basis for the selection of relevant data about the interactions between learners and Learning Objects in OER repositories.

10.2.4 Contributions to the Integration of Learning Objects

Four main contributions are made by this thesis to the integration of Learning Objects.

The first contribution is a model for e-Learning authoring tools that provides a generic and robust solution to create Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards such as SCORM, IMS CP, IMS QTI and Moodle XML, as well as generic web applications. The model addresses the integration of metadata, the integration of content, and the integration of the communications between the Learning Objects and the VLEs. Learning Objects created according to this model, regardless of the number of Learning Objects used to assemble them, will behave as a single Learning Object in the eyes of the VLEs into which they are integrated. Authoring tools that implement this model will be able to use Learning Objects built conforming to different e-Learning standards as building blocks to create new ones, which, at the same time, will also adhere to an e-Learning standard. Thus, this contribution can help to overcome one of the biggest challenges in the Learning Object domain: achieving an easy and effective Learning Object authoring by aggregation process. The model was implemented and validated in a real-world Learning Object authoring tool. Chapter 8 describes this model and its implementation in detail.

The second contribution to the integration of Learning Objects is a model to integrate Learning Objects provided by LORs into web videoconferencing services, which aims to enable the sharing, co-viewing and co-browsing of Learning Objects through the use of these services. As a result of the development of this model, the main requirements and limitations to be considered when integrating Learning Objects into the web videoconferencing context were identified. In order to validate the model, it was implemented in two distinct repositories to enable the Learning Objects created with an authoring tool to be integrated into three different web videoconferencing services. The model as well as its implementations are described in chapter 8. The work described in this chapter suggests that the model could incentivize the use of Learning Objects in videoconferencing services.

The third contribution of this thesis to the integration of Learning Objects is a model to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games in order to create educational web games. This model was named SGAME and is presented in chapter 8. The SGAME model enables the development of authoring tools that allow educators to use existing web games to create educational web games whose learning content can be customized by integrating SCORM packaged Learning Objects. In the educational web games created according to SGAME, players can be rewarded based on their interactions with the integrated Learning Objects. Thus, these games can be designed so that players will succeed only by successfully completing the integrated Learning Objects. As a result of the development of SGAME, several possibilities, requirements and limitations to integrate Learning Objects into web games were identified.

The last contribution of this thesis to the integration of Learning Objects is the SGAME platform described in chapter 8, which consists of an open source web-based platform that provides an authoring tool that allows users to create educational web games by integrating SCORM packaged Learning Objects into existing web games according to the SGAME model. This platform enabled the validation of the SGAME model as well as showing the potential of the approach proposed in this thesis to create educational web games by integrating Learning Objects into existing web games.

10.2.5 Other Contributions to Technology-Enhanced Learning

In addition to the above contributions to the authoring, distribution, evaluation and integration of Learning Objects, other contributions are made in this thesis to other areas of Technology-Enhanced Learning.

Chapter 8 presents a model called SGAME to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games in order to create educational web games. This chapter also describes the SGAME platform, an open source web-based platform that provides an authoring tool that allows users to create educational web games by integrating Learning Objects into existing web games according to the SGAME model. Both the SGAME model and the SGAME platform can help to alleviate one of the main barriers hampering the introduction, use and adoption of educational video games in educational contexts: the lack of authoring tools to create customizable educational video games that bear the features of entertainment video games. Therefore, the SGAME model and the SGAME platform are not only contributions to the integration of Learning Objects as indicated in the above section, but also contributions to the field of Game-Based Learning.

Finally, this thesis makes an important contribution to the field of Technology-Enhanced Learning by examining the use of Learning Objects in various educational environments. Chapter 9 describes learning experiences in secondary and higher education, as well as in a MOOC, a SPOC (Small Private Online Course), and in a blended course in which a project-based learning methodology was used. The results of this chapter show that an appropriate use of Learning Objects can have significant positive impacts on student attitudes and learning in different educational environments.

10.3 Future Research

This thesis addresses open questions and challenges in the field of Learning Objects. Furthermore, it opens up new opportunities for future research. In this section, some proposals of interesting directions for future research on Learning Objects are presented.

In chapter 4 of this thesis, an open source authoring tool called ViSH Editor that allows authors to create different types of Learning Objects is presented. The results of this chapter show that authors notably appreciate the features for creating novel Learning Objects such as Flashcards, Virtual Tours and Enriched Videos. Besides, these results also show that these Learning Objects can be effective in terms of learner engagement and academic performance and that they can be effectively used to enrich other Learning Objects. Therefore, an interesting future work would be to further improve the ViSH Editor authoring tool (or to develop a new authoring tool) to create more interactive Learning Objects such as 3D Flashcards or augmented reality Learning Objects, and evaluate the acceptance and instructional effectiveness of these Learning Objects. Another interesting research topic related to the authoring of Learning Objects is the authoring of adaptive Learning Objects capable of tailoring their behaviour according to the learners' profile.

Continuing with the authoring of Learning Objects, future research could also address the design, implementation and evaluation of proactive context-aware recommender systems for Learning Object authoring tools that push recommendations of e-Learning resources to the users while they are creating Learning Objects. A first step towards this direction has been made by designing a theoretical recommendation model [324], but further research is needed to evaluate the effective use of this kind of recommender systems in real-world authoring tools. In this regard, it would be interesting to conduct an A/B test to determine the differences between the creation process of Learning Objects using an authoring tool providing a recommender system of this kind and the creation process using the same tool but without using the recommender system.

Regarding the distribution of Learning Objects, the work presented in this thesis shows that LORs are very complex systems which have to provide a wide variety of features and services in order to be effective. Examples of these features and services are authoring tools, Learning Object managers, search tools, recommender systems, catalogues, evaluation systems, social networks, educational tools such as Audience Response Systems, learning analytics systems and metadata providers. Taking this into account, a valuable direction for future work is to design an open modular architecture for LORs that enable the creation of these systems by aggregating a range of open systems that interact with each other over the Internet. Thereby, the different systems that make up a LOR could be developed by different organizations, and they could also be individually reused and easily interchanged. This thesis makes a step in this direction by presenting an authoring tool, an evaluation system and a recommender system that provide features to be integrated into e-Learning systems. However, much further work is required to define an open modular architecture for LORs.

Search services of LORs can directly use quality metrics to sort Learning Objects by quality or to create compound ranking metrics that combine quality with other indicators. The results of an experiment reported in this thesis indicate that Learning Object quality metrics can be effectively used to provide quality-based sorting of Learning Objects. However, the benefits for Learning Object search services of using compound ranking metrics that combine quality with other indicators have not been investigated. Therefore, future experiments should address this open issue.

This thesis presents a hybrid recommendation model for LORs which, according to the results provided in chapter 7, can be used to implement effective Learning Object recommender systems. Future work could enhance the proposed model by introducing new techniques such as collaborative filtering and social recommendation techniques, or new contextual information and user feedback. Another possible future work would be to adapt the model to recommend sequences of Learning Objects or courses.

Chapter 5 of this thesis presents LOEP, the first system designed to provide systematic evaluation of Learning Objects to e-Learning systems according to multiple Learning Object evaluation models and quality metrics. This contribution opens up several opportunities for future research on evaluation of Learning Objects. The major challenge that should be overcome in the near future is the development of an interoperable metadata model that would make it possible to represent, store, manage, share and reuse evaluation data of Learning Objects. For this reason, future plans for LOEP include the definition of such a metadata model. In this regard, a possible option is to define the metadata model through an application profile of the IEEE LOM standard. The use of this metadata model will allow LOEP to exchange data about Learning Object quality evaluations with other e-Learning systems in an interoperable way. Another challenge opened by this work is the mapping between evaluation data generated according to different Learning Object evaluation models, and the comparison of Learning Objects evaluated with different evaluation models. Successfully solving this challenge would allow Learning Objects from different e-Learning systems that have been evaluated using distinct criteria to be effectively transferred to LORs together with information about their quality. Another future work that could be undertaken is to extend LOEP with a new evaluation tool and a web videoconferencing service to facilitate collaborative evaluation of Learning Objects. An attractive option would be to provide a tool that supports the convergent participation model for Learning Object evaluation recommended by LORI [282], [283].

In addition to presenting the LOEP system, chapter 5 reports the results of three experiments in which several evaluation models and quality metrics for Learning Objects were tested. Although undoubtedly the findings of these experiments are an important contribution to the evaluation of Learning Objects, further research needs to be done to evaluate more models and quality metrics for Learning Objects that were not evaluated in this thesis. Besides, the relationship between Learning Object quality and learner performance should be studied too. A reasonable hypothesis is that if two Learning Objects address the same learning objectives, the Learning Object with higher quality score will be more effective in terms of learner performance. However, such a hypothesis has not been tested yet.

Another challenge opened by this thesis is to improve the quality metric for Learning Objects based on learning analytics proposed in chapter 6, which allows to automatically estimate the quality of Learning Objects based on the interactions that learners have with them. This metric uses the same interaction variables to calculate quality scores for all types of Learning Objects. Therefore, it could be improved by using clustering analysis to classify Learning Objects into different types so that specific metrics could be applied to each of them. This enhancement would allow, for instance, to use a specific metric for those Learning Objects that contain quizzes that also takes into account the number of answered quizzes, which is an interaction variable that has been identified as a strong significant predictor of quality. Furthermore, it would also be interesting to conduct an A/B test to compare, in the context of a real-world OER repository, the usefulness for search services and recommender systems of this quality metric based on learning analytics with the usefulness of other Learning Object quality metrics that calculate scores based on human evaluations. The usefulness for OER repositories of a mixed approach for quality assurance that combines peer review and the proposed quality metric could also be a subject for future research. Lastly, it is worth noting that the issue of how many sessions of learner interactions a Learning Object needs to have in order to reliably estimate its quality according to the proposed quality metric based on learning analytics has not been addressed in this thesis, and hence this issue remains open.

A study that investigated the relationships between the learners' interactions with Learning Objects in OER repositories and the quality of the Learning Objects is reported in this thesis. This study allowed to define the Learning Object quality metric based on learning analytics mentioned above. Besides, the findings of this study provide for the first time a theoretical basis for the selection of relevant data about the interactions between learners and Learning Objects in OER repositories. Nonetheless, the relationships between the learners' interactions with Learning Objects and the quality of the Learning Objects can be radically different in closed environments such as private LMSs, or even in different open environments such as MOOC platforms where resources are exclusively consumed in the context of online courses. Therefore, future studies should not only verify if the findings of this study are generalizable to other open environments, but also investigate these relationships in new environments.

The work presented in this thesis on the integration of Learning Objects also opens up new possibilities for further research. Chapter 8 proposes a model for e-Learning authoring tools that provides a generic and robust solution to create Learning Objects by integrating and combining other Learning Objects compliant with multiple e-Learning standards including SCORM, IMS CP, IMS QTI and Moodle XML. However, there are several e-Learning standards that are not covered by the proposed model. Therefore, this model could be extended by addressing the integration of Learning Objects compliant with other e-Learning standards such as IMS CC, IMS LTI and xAPI.

This thesis also presents a model called SGAME to integrate Learning Objects packaged according to the SCORM e-Learning standard into web games, as well as an open source web-based platform called "SGAME platform" that provides an authoring tool to create educational web games by integrating Learning Objects into existing web games according to the SGAME model. This work initiated a new research line on Game-Based Learning in the Next Generation Internet research group (to which the author of this thesis belong) of the Telematic Systems Engineering Department at UPM (Universidad Politécnica de Madrid). A new system that integrates the ViSH Editor authoring tool and the authoring tool of the SGAME platform was developed in the context of an undergraduate thesis project. Furthermore, funding has been received from UPM to carry out an educational innovation project on Game-Based Learning. One of the goals of this project is to improve the SGAME platform developed in the scope of this thesis and offer it to the entire educational community. Many of the possible improvements of the SGAME platform described in chapter 8 will be implemented. Besides, the ViSH Editor authoring tool will be integrated into the SGAME platform in order to allow users to integrate the Learning Objects created with it into the games. Ideas for future work include extending the SGAME model to allow the integration of Learning Objects compliant with other e-Learning standards besides SCORM, implementing a version of the SGAME API for Android and iOS native applications, designing a recommender system for the SGAME platform that provides suggestions of educational games, game templates and Learning Objects to be integrated into game templates, developing an evaluation model to assess the quality of the educational games, and define an interoperable metadata model to describe these games. Lastly, it is worth pointing out that this thesis has not investigated the acceptance and effectiveness in terms of learner engagement and learning outcomes of the games created according to the SGAME model as well as their application in Game-Based Learning. Therefore, this work can be extended by addressing this issue. The aforementioned educational innovation project on Game-Based Learning aims to make a first step towards this direction.

The work presented in this thesis shows that it is possible to integrate Learning Objects into contexts such as web videoconferencing and web games by developing suitable integration approaches and exploiting the affordances of e-Learning standards. Future studies could address the integration of Learning Objects into other contexts such as social networks, music and video streaming services, augmented reality applications and virtual worlds. Furthermore, novel technologies like the Internet of things create opportunities to integrate Learning Objects into new contexts such as smart cities and houses.

Many studies have examined the acceptance and instructional effectiveness in terms of student engagement and academic performance of Learning Objects across different educational environments. A brief overview of several of these studies conducted in recent years is provided in this thesis. Besides, this thesis reports results from several experiences in which Learning Objects were used in various educational environments, including MOOCs and SPOCs. However, more research is needed to examine the use of Learning Objects in new educational environments such as quasi-MOOCs. These online courses are very different from traditional MOOCs because they consist of collections of linked Learning Objects intended to support specific learning objectives, there is no instructor, and there is no (or barely any) social interaction or feedback beyond the one provided by the Learning Objects. Finally, another interesting topic is the use of Learning Objects in combination with different instructional strategies. This thesis presents results from an experience in a blended course in which a project-based learning methodology was used. A valuable direction for future research would be to examine the use of Learning Objects in combination with other learning methodologies such as flipped classroom and inquiry-based learning.

Appendix A
Usability Metrics

This appendix includes the definitions of the usability metrics used in the usability evaluations of the ViSH platform and the ViSH Editor authoring tool. The results of these evaluations are presented, respectively, in chapters 3 and 4 of this thesis.

A.1 Introduction

All metrics defined in this appendix (with the exception of learnability) yield usability scores taking into account a single lab session, in which one participant performs a total of N_T tasks with the system being evaluated. Final usability scores should be calculated by averaging the scores obtained for all participants. Lastly, it is worth pointing out that all main metrics yield a score on a 0-100 percentage scale.

A.2 Task Completion

A participant may or may not succeed in completing a task. The task completion metric is defined according to the following equation:

$$C_T = \frac{N_{T_S}}{N_T} \times 100 \;, \qquad C_T \in [0{,}100] \tag{A.1}$$

where N_{T_S} is the number of tasks successfully completed by the participant, and
N_T the total number of tasks performed by the participant

A.3 Task Efficiency

Task efficiency is calculated by comparing the time spent by the participant to complete the tasks with the time required by an expert to complete the same tasks by using the following equation:

$$E_T = \begin{cases} 0, & N_{T_S} = 0 \\ \dfrac{\sum_{i=1}^{N_{T_S}} MIN\left(\dfrac{TimeExpert_{T_i}}{Time_{T_i}}, 1\right) \times 100}{N_{T_S}}, & N_{T_S} > 0 \end{cases} \;, \qquad E_T \in [0{,}100] \tag{A.2}$$

where N_{T_S} is the number of tasks successfully completed by the participant,
T_i is the i-th task successfully completed by the participant,
$TimeExpert_{T_i}$ is the time required by an expert to complete T_i, and
$Time_{T_i}$ is the time spent by the participant to complete T_i

A.4 Clicks Efficiency

Clicks efficiency is calculated by comparing the number of mouse clicks required by the participant to complete the tasks with the minimum number of mouse clicks required to do so by using the following equation:

$$E_C = \begin{cases} 0, & N_{T_S} = 0 \\ \dfrac{\sum_{i=1}^{N_{T_S}} \dfrac{MinClicks_{T_i}}{Clicks_{T_i}} \times 100}{N_{T_S}}, & N_{T_S} > 0 \end{cases}, \quad E_C \in [0{,}100] \tag{A.3}$$

where N_{T_S} is the number of tasks successfully completed by the participant,
T_i is the i-th task successfully completed by the participant,
$MinClicks_{T_i}$ is the minimum number of mouse clicks required to complete T_i, and
$Clicks_{T_i}$ is the number of mouse clicks required by the participant to complete T_i

A.5 Learnability

Unlike the other metrics, the learnability metric yields scores taking into account multiple lab sessions in which a same participant performs the same N_T tasks with the system being evaluated. Final learnability scores should be calculated by averaging the scores obtained for all participants. Each of the lab sessions performed by the same participant is called “trial”. For each trial, three different usability scores can be calculated by using the task completion (C_T), task efficiency (E_T) and clicks efficiency (E_C) metrics.

The learnability score for a participant that has performed N_{TR} trials is calculated as the average of the improvements of the scores yielded by the C_T, E_T and E_C metrics, between the last and first trial performed by the participant in comparison with the maximum improvement that the participant could have achieved. The learnability metric is defined as follows:

$$L = \frac{\Delta C_T + \Delta E_T + \Delta E_C}{3}, \quad L \in [0{,}100] \tag{A.4}$$

where ΔC_T , ΔE_T and ΔE_C are defined according to the following equations:

$$\Delta C_T = \begin{cases} \dfrac{C_{T_{N_{TR}}} - C_{T_1}}{100 - C_{T_1}}, & C_{T_1} < 100 \\ 100, & C_{T_1} = 100 \end{cases}, \quad \Delta C_T \in [0{,}100] \tag{A.5}$$

$$\Delta E_T = \begin{cases} \dfrac{E_{T_{N_{TR}}} - E_{T_1}}{100 - E_{T_1}}, & E_{T_1} < 100 \\ 100, & E_{T_1} = 100 \end{cases}, \quad \Delta E_T \in [0{,}100] \tag{A.6}$$

$$\Delta E_C = \begin{cases} \dfrac{E_{C_{N_{TR}}} - E_{C_1}}{100 - E_{C_1}}, & E_{C_1} < 100 \\ 100, & E_{C_1} = 100 \end{cases}, \quad \Delta E_C \in [0{,}100] \tag{A.7}$$

where N_{TR} is the number of trials performed by the participant, and
C_{T_i} , E_{T_i} and E_{C_i} are, respectively, the scores yielded by the metrics C_T, E_T and E_C
for the i-th trial

A.6 Task Satisfaction

In order to calculate task satisfaction scores by using this metric, participants have to indicate, right after performing each task, their emotions with the use of expressive cartoon figures and the intensity of each of these emotions on a 1-5 scale. In the usability evaluations reported in this thesis the cartoon figures provided by the LEMtool [380] were used (see Figure A.1). These cartoon figures express four positive (joy, desire, fascination and satisfaction) and four negative (sadness, disgust, boredom, and dissatisfaction) emotions using facial expressions and body postures.

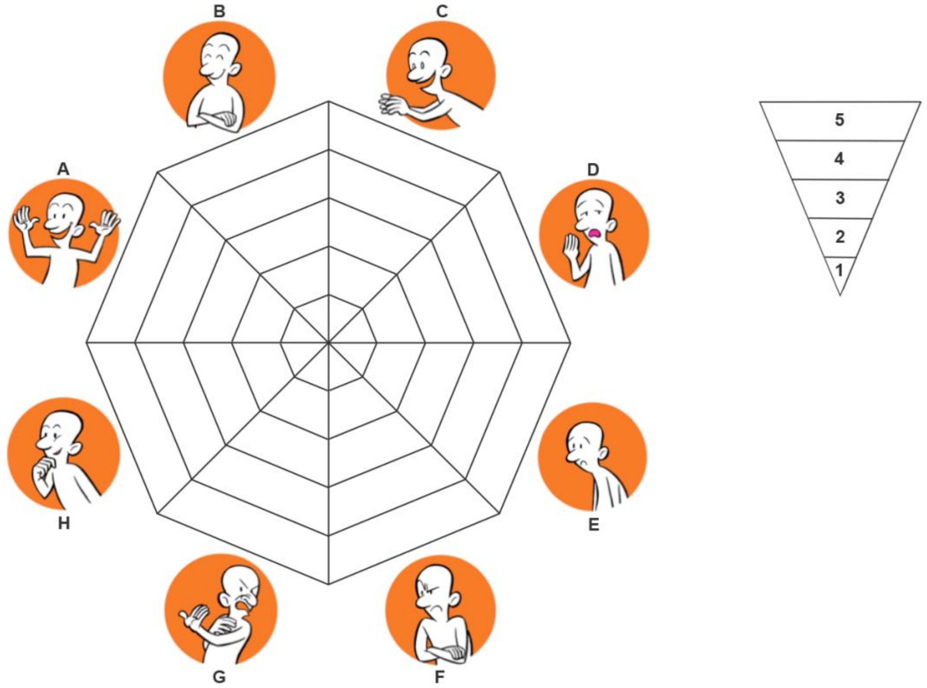

Figure A.1: Cartoon figures used in the usability evaluations

Based on the emotions reported by a participant on a 1-5 scale, the task satisfaction metric calculates the scores according to the next equation:

$$S_T = \frac{\sum_{i=1}^{N_T} \left(1 + \frac{\sum_{j=1}^{N_{E_i}} (-1)^a \times \frac{I_{ij}}{5}}{N_{E_i}}\right) \times 50}{N_T} \quad , \qquad S_T \in [0,100] \tag{A.8}$$

where N_T is the total number of tasks performed by the participant,

N_{E_i} is the number of emotions reported for the i-th task,

$a = 0$ for positive emotions and $a = 1$ for negative emotions, and

I_{ij} is the intensity on a 1-5 scale of the j-th emotion reported for the i-th task

A.7 Overall Satisfaction

The overall satisfaction of the system being evaluated is calculated by using the System Usability Scale (SUS) [279]. Thus, in order to calculate the overall satisfaction scores, participants need to fill out the SUS questionnaire after performing all the tasks. The SUS questionnaire consists of 10 items to be answered on a 5-point Likert scale, where half of the items are positively worded and the other half are negatively worded. SUS defines a metric that yields a score on a 0-100 scale representing a composite measure of the overall usability of the system being evaluated. This metric is the one used to calculate the overall satisfaction score given by each participant, and can be expressed as follows:

$$S_O(\{s_1, \dots, s_{10}\}) = \frac{5}{2} \times \left(\sum_{i \in \{1,3,5,7,9\}} (s_i - 1) + \sum_{i \in \{2,4,6,8,10\}} (5 - s_i) \right), \quad S_O \in [0,100] \tag{A.9}$$

where s_i is the score on a 1-5 scale given by the participant to the i-th item of the SUS questionnaire

Lastly, the overall satisfaction scores (i.e. SUS scores) given by all participants should be averaged in order to calculate the final overall satisfaction score of the system.

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