VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
INSTITUTE OF MATHEMATICS AND INFORMATICS

Jevgenij KURILOV

DIGITAL LIBRARY OF EDUCATIONAL RESOURCES AND SERVICES COMPONENTS INTEROPERABILITY PROBLEMS

Doctoral Dissertation

Technological Sciences, Informatics Engineering (07T)

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ŠVIETIMO IŠTEKLIŲ IR PASLAUGŲ SKAITMENINĖS BIBLIOTEKOS SUDEDAMŲJŲ DALIŲ SĄVEIKUMO PROBLEMOS
Daktaro disertacija
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Abstract

The main scientific problems investigated in this work deal with the creation of flexible open source e-Learning content and services system (referred here as Digital Library of Educational resources and services – DLE) providing learning customisation possibilities for its users.

Standards and interoperability are key factors in the success of the introduction of such kind of DLEs, and therefore the main research object of the work is investigation and proposal of interoperability guidelines for DLE components. The main problem is not the identification of suitable standards and specifications, but the adoption of these standards and specifications and their application in e-Learning practice. Approaches concerning LOM Standard Application Profiles (APs) and curricula mapping are the main topics created and investigated here because they could provide more quick and convenient Learning Objects (LOs) search possibilities in the repositories for the users.

Another key factor is quality of DLE systems, and therefore one more research object of the work is the effectiveness of methods of DLE components evaluation. DLE components complex evaluation tools suitable for systems based on flexible approach have been created. These tools should include a number of criteria to evaluate LOs reusability level and Virtual Learning Environments (VLEs) adaptation capabilities.

Practice of flexible DLE software creation and development for Lithuanian primary, secondary and vocational education based of flexible approach is presented in more detail.

There have been several tasks under consideration: (1) to formulate and analyse the key principles of creation and development of flexible DLE; (2) to formulate recommendations how to improve e-Learning standards and specifications, namely: (2.1) to provide recommendations for European Learning Resource Exchange system for schools; (2.2) to provide recommendations for curriculum mapping and integration with LOs metadata; (2.3) to provide recommendations for improvement of LOM APs (models); (2.4) to provide recommendations for flexible DLE components and their interoperability; (3) to create LOs complex technical evaluation tool (incl. Reusability / Interoperability criteria); (4) to create VLEs complex technical evaluation tool (incl. Adaptation and Interoperability criteria), and to evaluate popular open source VLEs against this tool; (5) to partly create the practical example of implementation of flexible DLE – DLE for Lithuanian general and vocational education, and to prepare recommendations for its future development.

The thesis is divided into six chapters including the conclusions chapter.

The results of thesis have been announced in 10 conferences in Lithuania and abroad. There have been printed 10 scientific papers, four of which have been printed in periodical refereed scientific editions included into international databases, and two – printed in ISI Proceedings.

Reziumė

Disertacijoje nagrinėjamos mokslinės problemos, susijusios su lanksčios atvirosios el. mokymosi turinio ir paslaugų sistemos kūrimu bendrajam lavinimui ir profesiniam mokymui. Nagrinėjama skaitmeninės švietimo išteklių ir paslaugų bibliotekos (toliau – skaitmeninės bibliotekos) schema ir reikalavimai, pagrindinis dėmesys kreipiamas bibliotekos lankstumui, t. y. biblioteka turi teikti naudotojams individualizuoto mokymosi galimybes.

Skaitmeninės bibliotekos sudedamųjų dalių suderinamumas (sąveikos geba, arba sąveikumas, angl. Interoperability) ir standartai yra esminiai bibliotekos funkcionavimo veiksniai, todėl pagrindinis disertacijos tikslas yra bibliotekos sudedamųjų dalių sąveikumo rekomendacijų kūrimas. Sprendžiami uždaviniai: standartų parinkimas, jų tinkamumas, adaptavimas ir taikymas švietimui. Pagrindinis dėmesys skiriamas mokymo(-si) objektų (MO, angl. Learning Objects) metaduomenų standarto (LOM – angl. Leaning Object Metadata) taikymo modeliui tobulinti ir bendrųjų programų sąryšiui su MO, nes tai leistų naudotojams žymiai sparčiau ir patogiau surasti tinkamus MO.

Daug dėmesio skiriama skaitmeninės bibliotekos sudedamųjų dalių kokybei vertinti, todėl bibliotekos sudedamųjų dalių kompleksinių vertinimo kriterijų, pagrįstų bibliotekos lankstumo ir sudedamųjų dalių sąveikumo rekomendacijomis, parengimas taip pat laikomas darbo tikslu.

Darbe sprendžiami keli pagrindiniai uždaviniai: (1) išanalizuoti pagrindinius lanksčios skaitmeninės bibliotekos kūrimo principus: MO (mokymosi komponentų ir mokymosi vienetų) daugkartinį panaudojamumą (angl. Reusability) ir virtualiųjų mokymosi aplinkų (VMA) pritaikomumą (prisitaikymo galimybes) (angl. Adaptation capabilities); (2) išanalizavus pagrindinius tarptautinius sąveikumo standartus ir specifikacijas, parengti jų adaptavimo ir taikymo švietime rekomendacijas: (2.1) Europos mokymosi išteklių mainų sistemai; (2.2) bendrųjų ugdymo programų sąryšiui su MO; (2.3) LOM standarto taikymo modeliui tobulinti; (2.4) lanksčios bibliotekos sudedamųjų dalių sveikumui; (3) parengti kompleksinę MO techninio vertinimo priemonę, atitinkančią lanksčios skaitmeninės bibliotekos reikalavimus; (4) parengti kompleksinę VMA techninio vertinimo priemonę, atitinkančią lanksčios skaitmeninės bibliotekos reikalavimus; pagal šią priemonę įvertinti populiariausias atvirąsias VMA; (5) sukurti praktinį skaitmeninės bibliotekos funkcionavimo pavyzdį – Lietuvos švietimui skirtą skaitmeninę biblioteką, taip pat parengti siūlymus jos tolimesnei plėtotei.

Disertaciją sudaro šeši skyriai, iš kurių paskutinis – rezultatų apibendrinimas.

Disertacijos tema perskaityta 10 pranešimų Lietuvos bei tarptautiniuose konferencijose ir paskelbti 10 straipsniai, tarp jų: keturi – recenzuojamuose periodiniuose leidiniuose, įtrauktuose į tarptautines duomenų bazes, du – konferencijų medžiagos leidiniuose, referuotuose ISI duomenų bazėje.

Notations

Abbreviations

ARIADNE	the Alliance of Remote Instructional Authoring and Distribution Networks
ASPECT	Adopting Standards and Specifications for Educational Content (eContent*plus* programme's project)
CALIBRATE	Calibrating eLearning in Schools (6th Framework programme's project)
CELEBRATE	Context eLearning with Broadband Technologies (5th Framework programme's project0
CETIS	Centre for Educational Technology Interoperability Standards
DC	Dublin Core
DLE	Digital Library of Educational Resources and Services (the aggregate of knowledge repositories, and services, organized as complex information system)
DRM	Digital Rights Management
EdReNe	Educational Repositories Network (eContent*plus* programme's project)
EUN	European Schoolnet (Consortium of 28 European Ministries of Education, incl. Lithuania)
FIRE	Federation of Internet Resources project
ICT	Information and Communication Technologies
IEEE LTSC	the Learning Technology Standards Committee's of the Institute of Electrical and Electronics Engineers
IEEE LOM	Learning Object Metadata Standard
IMI	Institute of Mathematics and Informatics (Lithuania)
IMS CC	IMS Global Learning Consortium Common Cartridge specification
IMS CP	IMS Content Packaging Specification
IMS LD	IMS Learning Design Specification
IMS LIP	IMS Learner Information Package Specification
IMS QTI	IMS Question and Testing Interoperability Specification
IMS RDCEO	IMS Reusable Definition of Competency of Educational Objective Specification
IMS SS	IMS Simple Sequencing Specification
IPR	Intellectual Property Rights
JISC	Joint Information Systems Committee
LA	Learning Asset (small pedagogically decontextualised part(s) (piece(s)) LOs can be combined of)
LAMS	Learning Activity Management System

LDAP	Lightweight Directory Access Protocol
LIFE	the Learning Interoperability Framework for Europe (eLearning programme's project)
LO	Learning Object (any digital resource that can be reused to support learning)
LOR	Learning Object Repository (any collection of resources that are accessible via a network without prior knowledge of the structure of the collection)
LR	Digital Learning Resource (the term is used in the work in the broad sense, referring to all kinds of digital learning content and activities such as Learning Objects, Units of Learning etc.)
LRE	the EUN Learning Resource Exchange system for schools
LRE AP	Learning Resource Exchange Metadata Application Profile
MELT	Metadata Ecology for Learning and Teaching (eContent*plus* programme's project)
MoE	Ministry of Education
Moodle	Modular Object–Oriented Dynamic Learning Environment
OAI–PMH	Open Archives Initiative Protocol for Metadata Harvesting
OLCOS	Open eLearning Content Observatory Service
OARiNZ	Open Access Repositories in New Zealand project
P2V	Peer to Peer Networking for Valorisation (eLearning programme's project)
PAPI	IEEE LTSC Public and Private Information specification
Q4R	Quality for Reuse (Quality Assurance Strategies and Best Practices for LO Repositories project)
RELOAD	Reusable eLearning Object project
SCORM	Shareable Content Object Reference Model standard
SRU	Search and Retrieval via URL service
SRW	Search and Retrieve Web service
SQI	a Simple Query Interface Specification for Learning Repositories
ULF	Universal Language Format Technical Specification
UoL	Unit of Learning (Unit of Learning itself and all its components are considered here as embedded LOs, including learning objectives, prerequisites, learners' or trainers' roles, activity assignment, information objects, communication objects, tools and questionnaire objects)
VLE	Virtual Learning Environment (a single piece of software, accessed via standard Web browser, which provides an integrated online learning environment)
W3C–WCAG	World Wide Web Consortium Web Content Accessibility Guidelines

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Introduction

1.1. Topicality of the Work

The dissertation topic is high on the agenda of European Commission (e.g. 6FP, 7FP and eContent*plus* programmes), UNESCO, USA, Canada, and Australia.

"Content and Interoperability" is the largest strand in the work plan of European Schoolnet (EUN) [28] – consortium of 28 European Ministries of Education.

The new Strategy and Programme for the Introduction of ICT into Lithuanian General and Vocational Education for 2008–2012 [99] was approved by the Minister of Education and Science in December 2007, and they are currently under implementation by the Centre for Information Technologies in Education (ITC) [44] under the Ministry of Education and Science.

The vision of the Strategy is to create qualitative new and *flexible* students and teachers *learning environments* which would provide them *personalised (customised) learning possibilities* in electronic space and stimulate creation and implementation of modern ICT based teaching and learning methods.

There are four objectives emphasized in this Strategy:

1. *To create digital learning content and to develop modern teaching and learning services.*
2. To form digital teaching and learning infrastructure, to improve schools

provision with hardware and software, and increase access to ICT.
3. To educate schools communities competencies, to effectively apply ICT for education, to improve teaching and learning quality, and to develop digital teaching and learning culture.
4. To apply ICT in educational process organisation and schools management.

The following tasks are planned to achieve the 1st objective:

1. *To create convenient digital learning resources (objects) search system to integrate curriculum with resources (objects) and e-services.*
2. To prepare interactive teaching and learning content with the help of different institutions, active teachers and scientists.
3. To create open and safe teaching and learning space for storage of curriculum compliant learning content for different subjects which would provide possibilities to consult, discuss and exchange ideas.
4. *To implement international digital learning resources (objects) metadata standards, and to stimulate international cooperation to create learning content and e-services.*
5. To prepare and confirm legal acts (to protect authors, publishers and users rights) which would motivate pedagogues and publishers to create and disseminate digital learning content and services.

Implementation of the first and fourth tasks requires large scale dissertation topic–related research and development, and the dissertation could be the basic research work to successfully implement the main objective and the vision of the Strategy.

The work is relevant first of all for European national and regional agencies responsible for e-Learning content and services provision for primary, secondary and vocational schools as well as for schools themselves.

1.2. Problem Formulation

The main scientific problems investigated in this work deal with creation of flexible open source e-Learning content and services system (referred here as Digital Library of Educational resources and services – DLE) providing learning customisation possibilities for its users. DLEs are considered here to be the aggregates of “knowledge repositories, and services, organized as complex information systems” [20].

The principles of ultimate increase of reusability of Learning Objects (LOs) and adaptability of Virtual Learning Environments (VLEs) [108] are considered in the work as the main factors of DLE flexibility. It is investigated that flexible approach to DLE creation and development should be based on the idea of LOs partition to two main separate parts (small pedagogically decontextualised content objects, and pedagogical activities / scenarios / methods / designs), and such systems should consist mainly on ultimately reusable LOs, their (metadata) repositories and appropriate services such as modularised adaptable open source VLEs.

It is intended to present DLE scheme based on LOs ultimate reusability principle, flexible, modular architecture, as small as possible open source e-content and e-services components.

Standards and interoperability are key factors in the success of the introduction of such kind of DLEs, and therefore the main research object in the work is investigation and proposal of possible interoperability recommendations (guidelines) for DLE components.

A number standards and specifications are considered to be the most important for the educational sector in Europe. However, it is not sufficient just to identify these standards and specifications. More important is to understand at what stage of the adoption life cycle they are, and what should be done to improve adoption. While some specifications are only at the beginning stage of adoption, there are already a fair number of standards that have been well adopted, but too many islands exist. The analysis highlights the need for making old and new standards and specifications work together (i.e. interoperate).

The major issues here are: what standards, why, and clear guidelines aimed to improve e-Learning standards' application profiles and their adoption and application in e-Learning practices as well as recommendations how to combine existing standards and specifications into complete solutions that address the needs of the school sector in terms of LOs discovery, exchange and reuse.

The main problem is not identification of suitable standards and specifications, but the problem how to adopt these standards and specifications and apply / implement them in e-Learning practice. First of all, in order to make it easier for educators to discover and use learning content that addresses the needs of their students, to maximise reuse of content and minimise costs associated with its repurposing, good solutions are lacking for specific application profiles of IEEE LOM [33].

Approaches concerning LOM application profiles and curricula mapping (incl. controlled vocabularies) are the main topics while creating any metadata strategies, and therefore the author has paid serious consideration to these issues while preparing DLE interoperability guidelines. These approaches are the main topics created and investigated here because they could provide more quick and convenient LOs search possibilities in the repositories for the users.

Another key factor is quality of DLE systems, and therefore one more research object in the work is the effectiveness of methods of DLE components evaluation. Therefore a lot of attention is intended to pay to investigate and propose DLE components' complex evaluation tools suitable for systems based on flexible approach.

Practice of DLE creation and development for Lithuanian primary, secondary and vocational education based of flexible approach is intended to present in more detail.

1.3. Research Object

Dissertation research objects are:

- Flexible open source e-Learning system (DLE) creation principles.
- European Learning Resource Exchange (LRE) system for schools.
- Curriculum mapping and integration with LOs metadata on European and Lithuanian level.
- Improvement of IEEE LOM application profiles to provide users with more quick and convenient suitable LOs search possibilities in the repositories.
- Flexible DLE components connection and their interoperability.
- LOs technical evaluation tools.
- VLEs technical evaluation tools.
- VLEs experimental technical evaluation.
- Creation and development of experimental DLE software for Lithuanian education.

1.4. The Aims of the Work

The aims of the work are:

1. To create recommendations how to improve e-Learning standards and specifications adoption and application in e-Learning practices for flexible DLE working.
2. To create complex criteria and tools suitable for technical evaluation of the main components of flexible DLE, namely LOs and VLEs.

1.5. The Tasks of the Work

To realize the formulated aims the following tasks are to be solved:

1. To formulate and analyse the key principles of creation and development

of flexible DLE: ultimate reusability and interoperability of Learning Objects (namely Learning Assets – LAs and Units of Learning – UoLs) and VLEs adaptation capabilities.

2. After investigating the main interoperability standards and specifications for DLE, to formulate guidelines how to improve e-Learning standards and specifications, namely:
    a. To analyse, validate and provide recommendations for European Learning Resource Exchange (LRE) service for schools.
    b. To analyse and provide recommendations for curriculum mapping and integration with LOs metadata on European and Lithuanian level.
    c. To provide recommendations for improvement of existing IEEE LOM application profiles.
    d. To provide recommendations for flexible DLE components connection and their interoperability.
3. To formulate LOs complex technical evaluation criteria for flexible DLE (incl. Reusability / Interoperability criteria).
4. To formulate VLEs complex technical evaluation criteria for flexible DLE (incl. Adaptation and Interoperability criteria), and to evaluate popular open source VLEs against these criteria.
5. To partly create the practical example of implementation of flexible DLE – DLE for Lithuanian general and vocational education, and to prepare recommendations for its future development.

1.6. Research Methods

For the general analysis of proposed scientific approach to DLE creation and development and its components interoperability guidelines, methods of bibliographic research and comparative analysis have been used on Lithuanian and foreign scientific works published in periodicals and various Internet sources.

To formulate and analyse DLE interoperability guidelines, system analysis method has been used.

To analyse DLE components evaluation criteria, methods of comparative analysis have been used.

To validate European LRE system and LOM AP, and to evaluate VLEs, method of experimental research has been used.

The experimental method has been applied for DLE software creation, and to summarize the results – evaluative research method.

1.7. Scientific Novelty of the Work

While preparing the dissertation there were obtained the following new results for Informatics Engineering science:

1. There have been investigated and proposed the key principles of creation and development of flexible open source DLE – ultimate reusability and interoperability of LAs and UoLs and adaptation capabilities of VLEs.
2. There have been proposed recommendations for European Learning Resource Exchange system for schools.
3. There have been proposed recommendations for curriculum mapping tool and its integration with LOs metadata on European and Lithuanian level.
4. There have been proposed recommendations for improvement of existing IEEE Learning Object Metadata application profiles.
5. There have been proposed recommendations for flexible DLE components connection and their interoperability.
6. There has been proposed Learning Objects' complex technical evaluation tool for flexible DLE including reusability criteria.
7. There has been proposed Virtual Learning Environments' complex technical evaluation tool for flexible DLE including their adaptation capabilities criteria.
8. There have been obtained the results of practical technical evaluation of the most popular open source VLEs in conformity with this tool.
9. There have been created the practical example of implementation of flexible DLE – DLE software for Lithuanian general and vocational education, and have been proposed recommendations for its development.

1.8. Author's Participation in International Projects

There are several large scale international research and development dissertation topic–related ongoing projects where the author works as the leader of Lithuanian teams:

- *CALIBRATE.* EU FP6 IST CALIBRATE (Calibrating eLearning in Schools) project [10]. The CALIBRATE project aims to support the collaborative use and exchange of learning resources in schools. It brings together eight Ministries of Education including six from new member states and involves 17 partners in all. The project runs from October 2005 – March 2008.
- *EdReNe.* EU eContent*plus* programme's EdReNe (Educational Repositories Network) project [23]. EdReNe is a thematic network bringing together

members from web based repositories of learning resources with content owners and other stakeholders within education. The members share, develop and document strategies, experiences, practices, solutions, advice, procedures etc. on the organisation, structuring and functionality of repositories. The overall goal is to improve the provision of and access to learning resources.

- *P2V*. EU eLearning programme's P2V (Peer to Peer Networking for Valorisation) project [79]. The P2V project applies the methodologies in large–scale contexts, including a larger network of schools, ministries of education and inspectorates, to identify good practice, tools and results in the eLearning Programme related to three key areas of ICT in schools: digital resources, media literacy and new learning environments. It also further develops and refines an analytical framework to guide decision–makers at all levels for the effective use of ICT and e-learning in school environments.
- *eTwinning.* eTwinning action is part of the European Commission's Lifelong Learning (till 2007 – eLearning) Programme [27]. eTwinning is a framework for schools to collaborate on the Internet with partner schools in other European countries. It promotes school collaboration in Europe through the use of ICT by providing support, tools and services to make it easy for schools to form short or long term partnerships in any subject area. In eTwinning teachers (and pupils) are increasingly authoring their own learning resources, adapting and localising those of others and joining new social networks and content–related communities. In this environment, new frameworks, tools and approaches must be found to enable hard–pressed and time–poor teachers to apply specifications and standards to their content without having to understand anything of the underlying principles, technologies or alphabet soup of standards acronyms.
- *ASPECT.* The newest EUN initiative in the field is ASPECT project proposal to European Commission's eContent*plus* programme [3]. ASPECT is best practice network for educational content that involves 23 partners from 16 countries, including 10 Ministries of Education, four commercial content developers and leading technology providers. For the first time, experts from all international standardisation bodies and consortia active in e-learning (CEN/ISSS, IEEE, ISO, IMS, ADL [1]) work together in order to improve the adoption of learning technology standards and specifications. Most stakeholders will benefit from agreed profiles and established practices as projects like ASPECT help combine existing specifications into complete solutions that address the needs of the school sector in terms of LR discovery, exchange and reuse.

1.9. Submission for the Defence

Defended propositions:

- The principles of ultimate increase of LOs reusability (based on the idea of LOs partition to the two main separate parts – Learning Assets and Units of Learning) and VLEs adaptability are the main factors of DLE flexibility.
- Approaches concerning APs and curricula mapping are the main problems while increasing and improving LOs usability.
- Curricula mapping should make interoperability possible by making use of two smaller controlled vocabularies instead of a very large one on competencies.
- It would be purposeful to improve existing LOM APs to provide more quick and convenient search of ultimately reusable LOs possibilities by the means of changing (advancing) the status of following LOM AP elements: 1.7 General. Structure; 1.8 General. Aggregation Level; 5.2 Educational. Learning Resource Type; and 7.1 Relation. Kind.
- LOs and VLEs technical evaluation tools should include a number of criteria to evaluate LOs reusability level and VLEs adaptation capabilities and interoperability.

1.10. Work Results Approval

The results of the dissertation were presented in 10 scientific publications:

- 4 publications were printed in periodical reviewed scientific editions included into international databases [1A–4A].
- 3 publications were printed in international scientific conference proceedings included into international scientific databases [5A–7A].
- 3 publications were printed in the other scientific conferences proceedings [8A–10A].

The list of the author’s publications is presented on p. 193–194 of this work.

The results of the dissertation were presented at 10 conferences.

International conferences:

1. 7th School Informatics conference, KODI 2005, Klaipėda, Lithuania, September 15–17, 2005.
2. 2nd International conference “Informatics in Secondary Schools: Evolution and Perspectives”, ISSEP 2006. Vilnius, Lithuania, November 7–11, 2006.

3. International scientific practical conference “Information & Communication Technology in Natural Science Education”. Šiauliai University, Šiauliai, Lithuania, December 1–2, 2006.
4. International conference “Internet – the Present and Future”. Vilnius, Lithuania, March 1–2, 2007.
5. 8th School Informatics conference, KODI 2007, Panevėžys, Lithuania, September 13–15, 2007.
6. 13th Computer Science conference, KODI 2007, Panevėžys, Lithuania, September 13–15, 2007.
7. 1st Learning Object Discovery & Exchange (LODE 2007) workshop within the 2nd European Conference on Technology Enhanced Learning (EC–TEL07). Sissi, Crete, Greece, September 17–20, 2007.

National conferences:

8. Scientific technical conference “Information Technologies 2007”. Kaunas University of Technology, Kaunas, Lithuania, January 31 – February 1, 2007.
9. “Teaching of Information Technologies and Integration Possibilities with Other Subjects”. IV conference of Lithuanian Association of Teachers of Informatics (LInMA). Vilnius, Lithuania, March 17, 2007.
10. The 12th Intercollegiate conference “Information Society and University Studies” (IVUS’07). Vytautas Magnus University, Kaunas, 16 May, 2007.

The results of the dissertation were also presented and discussed in 4 international scientific practical e-content and e-services related workshops of EU funded projects:

1. e-Learning Programme’s P2V [79] project – policy visit to Vilnius, June 18–20, 2007.
2. 6th Framework Programme’s IST CALIBRATE [10] project – summer camp in Portorož, Slovenia, August 22–24, 2007.
3. eContent*plus* Programme’s EdReNe [23] project – kick–off meeting in Naples, Italy, June 11–13, 2007.
4. eContent*plus* Programme’s EdReNe [23] project – expert workshop WS 4.1 on standards and interoperability in London, Great Britain, January 8–9, 2008.

The results of the dissertation were also selected by EUN as an example of the best interoperability practice in Europe in 2007 and were published in EUN Insight Newsletter [28].

1.11. Dissertation Structure

The Scope of the Scientific Work

The scientific work consists of the 6 chapters, the 1st of which is Introduction, and the last – Generalization of results. There are also the list of references (literature), and the list of author's publications.

The total scope of the dissertation is 194 pages, 39 figures, and 19 tables.

The Structure of the Scientific Work

- In the 1st chapter (Introduction) the author presents topicality of the work, research problem and his scientific contribution.
- In the 2nd chapter (System Interoperability Problems Analysis) the author analyses the main existing and emerging interoperability standards and specifications for flexible open source DLE (section 2.1); and formulates the problem of standards and specifications adoption, application and implementation in e-Learning practice (section 2.2, literature analysis).
- In the 3rd chapter (System Interoperability Recommendations) the author:
  - Formulates and analyses the key principle of creation and development of flexible DLE: ultimate reusability and interoperability of LAs and UoLs (literature analysis and own research, section 3.1).
  - Analyses, validates and provides recommendations for European Learning Resource Exchange service for schools (literature analysis and own research, section 3.2).
  - Analyses and provides recommendations for curriculum mapping tool and curriculum integration with LOs metadata on European and Lithuanian level (literature analysis and own research, section 3.3).
  - Provides recommendations for improvement of existing IEEE Learning Object Metadata application profiles and their adoption and application in e-Learning practices (own research, section 3.4);
  - presents flexible DLE components connection and their interoperability schemes (own research, section 3.5).
- In the 4th chapter (DLE Components Technical Evaluation) the author analyses existing Los and VLEs technical evaluation tools (literature analysis, sections 4.1 and 4.3), formulates the own more complex tools for technical evaluation of LOs including their reusability criteria (own research, section 4.2) and VLEs including their adaptation capabilities criteria (own research, sections 4.4), as well as evaluates most popular open source VLEs against these criteria (own research, section 4.5).
- In the 5th chapter (System Experimental Implementation) the author presents the own experimental example of flexible DLE software for

Lithuanian general and vocational education (practice analysis and own developments, section 5.1), and formulates recommendations for its future development (own research, section 5.2).

- In the 6th chapter (Generalization of the Results) the author formulates general conclusions, recommendations and results of the work.

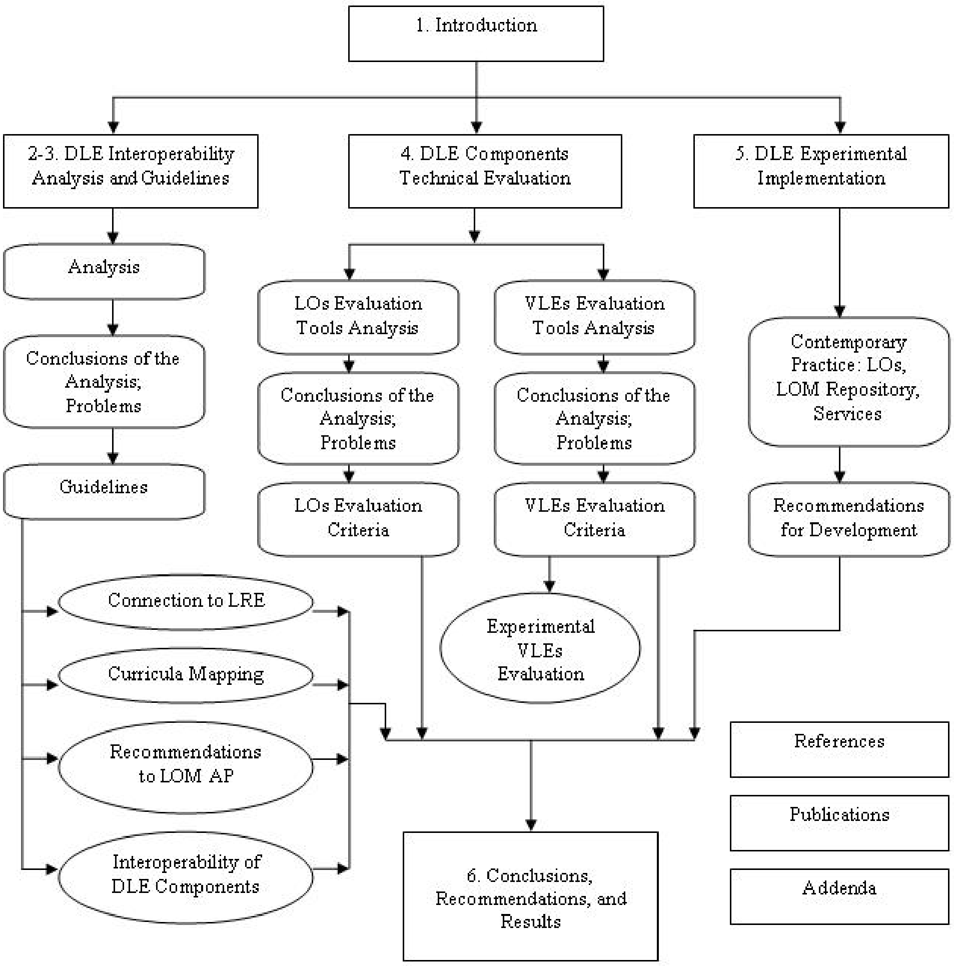

Figure 1. *Dissertation structure*

2

System Interoperability Problems Analysis

The aim of this chapter is to analyse the main existing and emerging interoperability standards and specifications for flexible open source DLE, and to formulate the problem of standards and specifications adoption, application and implementation in e-Learning practice.

2.1. Different Interoperability Aspects Analysis

2.1.1. Different Layers of Interoperability

ISO 2382–01.01.47 defines interoperability "the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units". Interoperability relies on agreements and the more these agreements are shared the greater the interoperability.

One of the requirements for a federated information system is interoperability, the ability of one computer system to access and use the resources of another system [47].

The reverse engineering community has recognized the importance of interoperability, the cooperation of two or more systems to enable the exchange and utilization of data, and has noted that the current lack of interoperability is a contributing factor to the lack of adoption of available infrastructures [53].

Where interoperability is concerned, standard development and implementation issues cannot be meaningfully separated [25].

Interoperability is the ability of two systems to interoperate. Whereas the term “system” is in this context often understood as a technical system, it applies to systems in the wider sense, i.e. including all actors in the educational system. Hence, interoperability can be examined in a semiotic framework that can help us to understand different aspects of interoperability:

- *Physical layer:* the physical appearance, the media and amount of contact available.
- *Empirical layer:* the entropy, variety and equivocation encountered.
- *Syntactical layer:* the language, the structure and the logic used.
- *Semantical layer:* the meaning and validity of what is expressed.
- *Pragmatic layer:* the intentions, responsibilities and consequences behind the expressed statements.
- *Social layer:* the interests, beliefs and commitments shared as a result.

These layers can be divided into two groups in order to reveal the technical versus the social aspect division. Physics, empirics and syntactics, taken together, constitute a domain where technical and formal methods are adequate. However, semantics plus pragmatics plus the social domain can hardly be explored if those methods are used exclusively and without modification.

The physical and empirical layers are today well covered by achievements in the ICT industry on which any educational system making use of ICT can build. At the syntactic layer we are concerned with the language, structure and logic used in order to have systems, subsystems and modules interoperate. The semantic layer addresses the interoperability of meaning (semantic interoperability); i.e. will information given by one actor in an educational system be understood correctly by another actor. This might involve terminology aspects (homonyms, synonyms, scope) as well as human language aspects. The pragmatic layer is concerned with common intentions such as a common pedagogical goal, and with responsibility aspects such as trust. For example, for any Digital Rights Management (DRM) system to work a certain amount of trust is always required. Likewise, when an educational institution is issuing a certificate then people will have to trust the validity of the certificate. Finally at the social layer, interoperability is concerned with the compatibility of beliefs and values of different educational systems. Whereas beliefs and values of education in Europe may vary from one country or region to another, in general we can say that they are compatible, grounded in a common European tradition.

Therefore this section focuses on the following layers:

- The syntactic layer which as part of the technical layers deals with technical interoperability.
- The semantic layer which deals with semantic interoperability [91].

Technical Interoperability of Services

Complex ICT systems are today often built following a service oriented architecture where each of the services knows technically how to interoperate with the other services by means of a well defined interface.

The major advantage is that system builders can make use of services from different service providers given that they obey the service interface specifications. Just like printers are interchangeable, given that they have a Centronics or USB plug, a learning object repository could be accessed easily if it has implemented for example the Simple Query Interface – SQI [13]. Service developers from their part can develop their service the way they want as long as they obey the interface specifications. Obviously, the more these interface specifications are shared among service developers, the greater the interoperability.

Semantic Interoperability

Semantic interoperability is achieved to the extent that users of interoperable services give the same or compatible meaning to information exchanged between the services. Semantic interoperability relates to information being exchanged between services and is achieved through several means. First, it requires a common conceptual model. Standards such as the IEEE LOM [33] and specifications such as various IMS specifications typically make use of a conceptual model or an information model and separate the what from the how; i.e. the conceptual model describes what information is exchanged in terms of concepts, their properties, and relationships between these concepts while a so–called binding expresses how this information is exchanged. Second, the concept properties may have values that require a common understanding. The values being exchanged are on the lexical level while semantics is at the conceptual level. Semantic interoperability is therefore also concerned with questions such as do different terms (possibly from different languages) express the same concept and does a specific term used by different users induce the same semantics? Therefore in order to achieve a higher degree of semantic interoperability, controlled vocabularies are often used. *The term vocabulary is used in this work in the broad sense, referring to value lists, classifications, taxonomies, glossaries, dictionaries, ontologies, and thesauri* [12].

Standards and Specifications for Interoperability

Interoperability relies on agreements and the more these agreements are shared the greater the interoperability. This is where standards and specifications come into play. *In this work the term "standard" is used for de jure standards, agreed by national bodies. For other written agreements concerning interoperability the term "specification" is used.*

An educational system consists of a set of interoperable services, standards and specifications in the field of learning technologies. The following elements can be distinguished:

- The request identifier; for example a string such as "Synchronous Query" identifies the requested service.
- The parameters sent with the request; for example a query statement.
- The result; for example a set of LO metadata.

Service interface specifications can be defined in abstract terms and can be bound to a specific expression format such as an application programming interface – API, or a web service description.

The parameters and results may consist of complex information structures which themselves are subject to standards and specifications. For example the result of a query to a LOM repository may be a result set of LOM instances following the IEEE LOM standard.

Standards for information structures typically consist of a set of assertion containers. For example the IEEE LOM standard v1.0 contains assertions concerning: (1) General Information; (2) Life Cycle; (3) Meta–metadata; (4) Technical; (5) Educational; (6) Rights; (7) Relation with other material; (8) Annotation; (9) Classification.

Learner information could have assertions about: (1) Competency; (2) Demographic Information; (3) Preferences; (4) Accessibility; (5) Performance and Achievements; (6) Plans/Goals/Reflections; (7) Activity; (8) Map of Relationships.

Typically a standard or specification will consist of rules on how to express such assertions; i.e. what assertions, by whom, when, etc. For example it will be important to know who made the claim about a performance or achievement.

A specification will have an information model (sometimes called conceptual model) and one or more expression formats called a binding. For example the IEEE LOM has several XML bindings. Sometimes the conceptual model and the expression format are integrated into a single specification; i.e. the conceptual model can be expressed only in a single way.

Each assertion will have an information structure. Dependent on what is asserted it might be more or less elaborated. For example data element 6.3 of the IEEE LOM "Rights.description" allows a free text while section 9 is fully elaborated in order to express taxonomies. Standards and specifications builders typically will have to choose between a relatively free way of expressing the assertion, or a prescribed format such as a formal language, or something in between where a prescribed top structure is provided but some details are in free format. In addition standards and specification builders will have to choose whether to allow more than one format or on a single one. For example the rights applicable to a LO might be described in more than one Digital Rights Expression Language. The major criterion of choice will be the extent to which agreement can be reached among stakeholders. Obviously, an agreement on the details and an agreement on a single information structure facilitate interoperability.

2.1.2. Government Policies and Strategies for Interoperability

Standards and interoperability are key factors in the success of the introduction of e-Learning. Attempts at rationalisation and improvement of online content require a high level of on–going interoperability. *The use of standards can result in lower costs, increased supply and access, higher quality and shorter delivery times.* Various bodies are doing a great deal of work in the field of standards but insufficient attention is being paid to transversal issues.

To develop concerted actions, EUN created the e-Learning Interoperability Framework for Europe – LIFE. LIFE seeks to provide a European framework in which actions concerning e-Learning interoperability can be organised in a concerted way bringing together actors from different educational sectors, from the private and public sectors and from the European Commission. Inside this framework, the European Commission funded this project [56], also called LIFE, in order to develop a Roadmap of Standards in Education for Europe.

Many of the different school networks around Europe use the word "standard" related with achievement in schools, and not exactly with the meaning used in this work. Here standard is "a technology, format or method ratified by a respected authority", though in many cases, we can consider to be a standard something that has not yet gone through the whole standardisation process, but is widely accepted and used.

And what are the main results we get by using standards? We can divide them into the following categories:

- Accessibility: we can access LRs from a remote location to where it is physically located and deliver them to other locations.
- *Interoperability*: use LRs developed in one location, with one set of tools or platform, in another location, with a different set of tools or platform.
- *Reusability*: incorporate LRs into multiple learning experiences.
- Durability: continue using LRs when technology changes, without redesign or recoding.
- Affordability: increase learning effectiveness and at the same time, reduce time and costs [91].

In many different environments, Interoperability is mainly used as a synonymous with the word standard, maybe because it is the first need for the educational community to achieve.

LIFE Survey

Questionnaires

LIFE questionnaire was distributed via the EUN Steering Committee and EUN Policy and Innovation Committee, and also through the participants in LIFE launching workshop.

Summarizing the information the following results were got:

- People dealing with standards in each country have good knowledge of what is going on around standards in the world, but some have no experience yet in implementation. In same cases, the people taking care of standards for the Ministry of Education do not belong to the Ministry itself as they work for an external agency or organization that takes care of coordinating these activities. This might be more effective as that is the case of the countries with a better level in the use and promotion of educational standards.
- From all the countries that provided information, only in Sweden, Norway and UK do educational organizations participate actively in standards organizations such as ISO.
- Content and LOs are the main area in which all the different countries start the use of standards, mainly metadata and mainly LOM (as Celebrate Application Profile – AP, which is also based in LOM).
- There is a great interest in using standards in the “Communities and Collaboration” and in the “Learning Objects” areas, where almost all the reasons to use standards are highly valued.
- Interoperability is the reason more considered across the different areas.
- IMS seems to be the better known and more followed organization concerning specifications. This makes IMS a study case to learn how they have become known in order to help other initiatives.
- Effectively implemented and used open standards are an essential pre–requisite to successful network supported learning, but they are certainly not a sufficient condition.
- There is a need to establish interoperable implementations of existing standards, then use them effectively, gather unmet requirements and put all these forward to develop new specs and new versions of existing specs.
- There is the idea (which can be considered hope in some cases) that the use of standards can, potentially, help to lower high costs of systems integration.
- Interoperability testing, where developers bring their systems together for multi–way testing, should be increased. Such testing should take

place at the national and European level to ensure cross border interoperability throughout Europe.

- Accelerating the process of adoption is another major challenge to achieve wider use of standards in education.

Interviews

Following the analysis of the questionnaires, the interviews took two different forms: mainly written but in some cases also spoken.

And the summary of the answers is the following:

Most of those who answered found the use of educational standards in schools essential, and the reasons given were as follows:

- It makes easy and quick searching and retrieval of content.
- Reusability of content improves.
- Interoperability.
- Possibilities to develop a mature educational content market increases.
- Better support of learning and teaching.
- It provides systems that support the creation, storage, security, and access to relevant, portable data.

Metadata

It is advisable to keep the metadata set as simple as possible, and compatible. This might ease the support to early adopters of metadata (publishers, authors, communities of practice) and the spread of good practice. Of course, the metadata system should be “user friendly” to ensure that its use optimises searches, and can be used easily by a teacher or a pupil.

There is a lack of standardized vocabularies and taxonomies in specific domains. When they do exist, they are often hard to find. As each country has its own educational infrastructure, with different terminologies, gradings, curriculum standards etc., this creates a problem of interoperability.

Given these difficulties, awareness about and competence in metadata is often insufficient in most schools and ministries.

So, when planning the work on entering metadata, the following could be a possible way forward:

- Learning about the surrounding world (or knowing what has been done already).
- Gather user requirements and use cases.
- Liaise with the library and information management community.
- Evaluate existing metadata creation and management strategies.
- Follow guidelines laid out in existing standards and specifications.

- Make the environment open and modular enough to adapt and change as the overall developments progresses.

As taxonomies and vocabularies are essential tools for metadata deployment, the use of a Thesaurus is very important for the future of metadata and the semantic web. The ELR Thesaurus is a very important milestone as it is the only one that is only focus on schools, but different thesaurus might be chosen. In any case, a thesaurus helps to enable exchange of information and resources. As such it should be continued and maintained both at European and country levels.

Interoperability

Interoperability and open interoperability standards are fundamental to ensuring that content is accessible, durable and reusable. If content is to be shared and reused then the importance of interoperability cannot be overstated. Therefore, this makes of “Open learning technology interoperability standards” a really good choice to create and package educational content.

It is also important to recognise that interoperability is of fundamental importance not only to content but to all data, including person data, metadata, course data, rights information, etc.

The problem with the answers to the questionnaire is that the word “interoperability” can have many meanings. In addition, one explanation why interoperability is not considered of upmost importance might be that countries, especially the smaller ones, have only one or a couple of different systems which means they do not need interoperability on a national level.

Why should we pay more attention to interoperability?

As most European countries are too small to have a sustainable domestic market, interoperability issues need to be solved if there is to be a real market across Europe for digital content. This applies not only to commercial distribution, but also to other alternatives such as free licenses for content like the Creative Commons. Interoperability should be central in any policy framework for e-Learning standards adoption. In addition, in seeking to avoid over dependence on dominant players, interoperability and open standards are key. It is important to stress this role of interoperability to schools when they are building their learning architectures and virtual learning environments. If they don’t use standards they will not be able to buy or download content in a satisfying way.

Exchange of LRs at a regional, national or European level could be extremely beneficial. To be able to exchange resources, whether data or content, at a regional, national or European level the applications that are used to manage and exchange these resources must implement open interoperability standards. Otherwise resource will become locked into the various applications used by different regions and communities and as a result exchanging these resources will be costly and difficult.

It is also important to recognise that some resources, in particular content, will require repurposing before they can be used in different social, cultural, linguistic and educational contexts. Developing content that complies with open standards will help to ensure that it can be effectively repurposed for use in different contexts.

The wider picture of interoperability

If we go beyond LRs, clearly interoperability between different administrative modules would also be highly beneficial but it appears hard to achieve. Such interoperability seems to be one of the emerging trends of the second generation web “Services Oriented Architectures”.

In the interest of efficiency and service quality, it is important that administrative data can be exchanged, between administrative systems within a school (financial administration and administration of marks and other academic achievements) and between systems in different schools (transfer of records from primary school to a secondary school). Both forms of interoperability of course operate on the same premises, you get the one for free if you establish the other. But obviously, all kinds of safeguards have to be built to ensure pupils’ and students’ privacies are maintained.

Achieving administrative interoperability will required coherent education and e-Learning strategies that encompass all sectors of the European educational community including K–12, further and higher educational, vocational training and adult and community learning.

Standards organisations

When thinking of adoption, discussing which standard or specification related organizations should be considered by Ministries of Education is a complex question. The answer can be divided in two parts. On the one hand there are the Learning Technology Standards and specifications where specifications from IMS, IEEE LTSC [34] and SCORM [92] are important. However, several of the specifications are afflicted with problems and need to be developed further to really be usable. There is also a problem with the usability of some specifications in schools, which differs from e-learning in other situations (such as trade and industry). The requirements and goals differ and some of the specifications are clearly not developed with the regular school system and their more constructivist view of learning in mind.

The other part of the answer concerns the general technology standardization. Here we find standards for interaction between different IT systems and architectures (common protocols and data structures), standards for modularisation (such as web service frameworks), catalogues (such as LDAP) etc. Those must also be taken into consideration for the IT architecture in schools.

If we make a list of those standards organisations which Ministries of Education mention they would consider when evaluating specifications for adoption it includes: CEN/ISSS WSLT; IEEE LTSC; ISO SC36; National standards bodies; IMS Global Learning Consortium; OASIS; W3C; Dublin Core [19]; SIF; ARIADNE [2]; AICC; SCORM; all open standards bodies [57].

At the same time, the use of standards in education should not be restricted to Europe. We should strive towards international standards. This makes the adaptability and flexibility of the specifications important.

Standards adoption

When starting to deal with educational standards adoption, the concept of application profiles will become important. Most open standards and specifications are designed to accommodate the generic requirements of many diverse educational communities. Implementations of these standards are usually based on application profiles that are designed to meet the specific requirements of a particular community or domain. Consequently, educational communities must be free to develop and implement their own application profiles based on their own user community’s needs. This means that application profiles should be created by whoever has a need for that, but they should try to reuse profiles created by others first.

But what will be a possible order or timeline for adoption of standards and specifications in schools sector? At school level, they should pay attention to standards that help them to run their business processes more efficiently (without the need of buying proprietary business software; open source can be more attractive). Then they should experiment on a small scale with learning objects, striving to be standards compliant to the extent that is currently doable. That could mean using the LOM, Content Packaging, the digital repositories spec, etc. Assuring that the applications they use are standards compliant should not be something for the schools to worry about, but rather for the application developers. Open source software might be the most promising way to go.

In general however, major issues will be: what standards, why, clear framework, awareness raising, inclusion in strategy documents.

Pedagogical issues in educational standards

Educational standards can be seen as a technological issue or linked to pedagogical improvement. There is no single answer here. While open standards help to facilitate technical interoperability and the exchange of data between applications their ultimate goal is to enhance teaching and learning. To be of relevance and benefit to the educational community, all standards and specifications must be based on sound pedagogy.

There is a chain from the choice of technology, architecture, information structure up to the classroom and the pedagogy. A flexible technology will allow for a flexible pedagogical approach. If standards are used to build the foundation of the IT environment this opens up freedom of choice when it comes to tools and content in the future. Combined with a modular approach to the Virtual Learning Environment and the overall learning architecture this will create a highly flexible environment that is designed for change and adaptation.

The impact of choices of standards

Strictly speaking, e-Learning standards are technological issues, but their adoption will have a strong pedagogical impact. Educational authorities should carefully identify and select which educational standards to promote. *ICT in education is not neutral (SCORM and QTI promote models of interaction with computers very different than IMS Learning Design).* Even though standards as such do not enhance pedagogy, if the technology being used in the classroom successfully incorporates standards so that the learner has ease–of–access to a wide range of resources, the teacher can customise learning by drawing data on an individual pupil, from multiple sources, seamlessly and effortlessly, and if the large administrative overhead in teaching can be minimised so that teachers can devote more time to the learners, then the pedagogical improvement will be self–evident.

Technology is then an essential investment in schools. However only through strategic planning and implementation will standards be likely to save money in the long run. Freedom of choice is also a question of future costs. If you can choose a less expensive alternative and combine it with a modular approach, this becomes more obvious as you may exchange or add as many components as you need instead of the whole system to adapt to changed conditions.

It might not be wise to promote standards as a way to save money. For some educational actors money is not the main issue in education, though decision–makers might not think exactly like that, and standards could be seen as means of improving quality without investing more money. We can divide standards in two: school management standards and pedagogical standards. Then, the main effect of the first will be to maintain or improve service levels for less or equal money, the effects of the second on improving learning and teaching quality – not on saving costs.

An economic return could be derived from having more motivated, more skilled and more competitive people.

Strategies

Teachers and schools

Thinking about a possible road–map for the adoption of educational standards in schools, the first thing is that standards should be kept out of sight of the teacher. Standards should help pedagogy and be invisible to the end user within any teaching and learning environment. Schools should not be involved in the standards discussion itself, and maybe only point out that proven standards compliance should be their overriding concern when buying software. The results of tests and recommendations based on them should be easily available to schools, as well as standards expertise and there is also a need to subsidise experiments in schools with standards–based software.

Overall Situation about Standards and Interoperability in Schools in Europe

What makes using standards more valued is interoperability. Interoperability is valued in different areas, as infrastructure (between equipment), content (between educational resources), e-learning authoring (between educators) and communities and collaboration (between students).

It is clear that "metadata" is the starting point for all countries as regards educational standards. IEEE LOM is the most popular as the base to create the particular sets, or application profiles.

IMS is the standards organisation that is most mentioned as the reference to follow in different areas (*IMS Content Packaging, IMS Learning Design and of course IEEE LOM are the specifications with a bigger interest for the Ministries*). ADL SCORM is also a well–regards reference to follow.

There is a clear accepted view that global standards and specifications are worth adopting, and not only Europe, though European needs should be represented in those global specifications and standards. Besides this, local and regional customisation should be done at that level. There is not enough interoperability and standards testing in Europe, and these tests will give end users more certainty that they are buying what they need, and that what they buy has the specifications and functionalities it claims to have.

Finally, standards are not perceived in the same way in all the countries. Countries with more centralised educational systems seem to be more worried about interoperability than those with a highly decentralized system where educational competences concern each municipality or region. This, of course, does not mean they are not interested in standards and interoperability.

2.1.3. Accessibility Interoperability

The recommendations of LIFE experts in this area are:

1. To develop application profiles and best practice guides for the LET domain of a number of established specifications and standards

As a start these should be prioritised:

- W3C – WCAG (Web Content Accessibility Guidelines) [109].

- W3C – ATAG (Authoring Tools Accessibility Guidelines).
- IMS – CP 1.2 (Content Packaging) [37].
- IMS – TI (Tools Interoperability).
- IMS – QTI (Question and Test Interoperability) [41].
- ISO 24751 (Individualised Adaptability in e-Learning) (this standard will supersede the IMS ACCMD and ACCLIP specifications).

2. To establish a guideline on how to provide alternative representations of LRs.
3. To establish a guideline on interaction capabilities of e-learning tools to ensure accessibility.
4. To harmonise the forthcoming ISO 24751 standard and IEEE LOM with respect to Digital Resource Descriptions. It should be easy for the user to search for specific accessibility capabilities of digital learning resources marked up with Learning Object Metadata.
5. To explore and demonstrate how the use of web services could enhance the accessibility capabilities of a technological infrastructure for learning.
6. To explore how accessibility technologies could be used to build more pedagogical adaptive software for teaching, learning and training supporting learning styles, learning preferences etc. Accessibility needs are not restricted to people with disabilities. This is the basic principle for Accessibility technologies. Accessibility solutions should work for all users of technology. Most of the work in Accessibility is not done with learning technologies in mind.
7. To include Accessibility Requirements when procuring learning technologies and LRs. Accessibility should be a requirement in all systems. To achieve this, the accessibility requirements need to be well defined and based on sound interpretations of specifications, standards and guidelines, and on best implemented practice.
8. To only refer to standards and specifications that are free of patents and IPR restrictions when procuring Learning Technology [57].

To improve accessibility to learning opportunities we should develop profiles and guides for the learning, education and training domain that would help us to gain more from a number of existing specifications, e.g. W3C's guidelines, a number of IMS specifications, etc. We should also develop guidelines how to provide alternative representations of learning resources and exploit the interactive capabilities of e-learning tools to ensure accessibility. Web services could enhance the accessibility capabilities of a number of technologies.

To ensure accessibility interoperability among different learning technologies, accessibility information should be embedded in all learning technologies.

2.1.4. Learning Assessment Interoperability

The recommendations of LIFE experts in this area are:

1. In the immediate future, further development of the IMS Question and Testing Interoperability specification (QTI) [41] should be limited. Development should be confined to areas of demonstrable need and user demand including; aggregation of qualitative and quantitative feedback on assessment items so as to enrich future usage, upgrade of QTI validation tool(s), the correction of errors or ambiguities that are identified by those implementing the specification, and greater harmonisation with other associated IMS specifications such as e-Portfolio [38], LIP [40], etc.
2. A high priority should be accorded to the provision of open source assessment related tools for developers and users. Such tools will facilitate their involvement and will lead to the availability of interoperable open source content, a key driver in market creation. There is a specific need to develop authorship tools that will assist (1) localisation of QTI implemented items and (2) the local interpretation or "calibration" of the results of any assessment task.
3. Consideration should be given by IMS to the construction of a QTI "Lite" Version 2 which is less complex, and easier to understand and implement. The existence of such a basic standard would facilitate interoperability at lower cost.
4. Specification and standard development aimed at supporting interoperability in the design of learning should recognize that assessment is a deeply embedded part of any learning process and that assessment functions should be included in the relevant specifications. Such issues are of particular relevance where assessment cannot be disaggregated easily from learning, e.g. game playing, simulated practice, and e-Portfolio construction [57].

2.1.5. Learning Content and Repository Interoperability

Digital learning content is increasingly used in education thanks to the variety of ways that they can be created, delivered, used and reused in different learning contexts. To better understand the complex question of interoperability of learning content it is beneficial to look at the different processes during its life; what are the interoperability aspects that are related to the creation of material, its discovery and eventually its use and reuse for learning purposes.

This section therefore looks at the different processes related to learning content in order to discuss the interoperability state of the art, issues, and recommendations. These processes are more and more delivered by separate services and systems that interoperate with each other such as a learning content management system, a service to describe and expose, learning content, federated repositories, discovery services, delivery services, digital rights management systems, and learning management systems.

State of the Art Concerning Learning Content and Repositories Interoperability

Learning content and learning content repositories is an area which is probably most developed from all areas in e-learning. Obviously many standards and specifications do exist for the content itself. However in order to exchange more complex multimedia content, the IMS Content Packaging (IMS CP) [37] specification was an important step for the exchange between VLE both for authoring and playing/using the content. This specification has had wide spread adoption within the e-learning and digital repositories sector. The specification allows for the storage, description, structure and transportation of content. The current public release of the specification in v1.1.4, with work on v1.2 ongoing and it is due to be publicly released in early 2008. This is likely to be the last major release of the specification from IMS as v1.2 is being put forward to IEEE for official standardization.

A more recent development is the work on IMS Common Cartridge (IMS CC) [36] specification which provides a common way of specifying the structure, authorization, and interoperability protocols of content and its assessment. The Common Cartridge is a constrained profile of IMS CP integrating QTI and LOM. It is hoped that this approach will overcome some of the remaining interoperability issues which exist between LMS's, even when they claim to be implementing the IMS CP specification. The Common Cartridge will define a commonly supported content format, able to run on any compliant LMS platform. It will enable content providers to achieve lower production costs whilst expanding the effective market by eliminating platform dependency. This will both stimulate production by larger content providers and open up the market to their smaller counterparts. The LMS providers in turn, will have a stronger business case to take to their customers, as schools, colleges, universities, training departments and certification programs will have available a broader catalogue of offerings reaching deeper into the curriculum.

The strength of the Common Cartridge Initiative is that it is being backed by a number of prominent educational publishers. If they produce content in this new format, then this will create a need for systems to be able to process content created in this format. The CC is expected to become available in the end of 2007.

The ADL SCORM [92] is now also widely adopted outside of its military origins into the educational sector, particularly in the US and Asia. In 2007 the ADL announced that it would like to transfer governance and stewardship of the SCORM into the wider learning community.

Learning content is usually described using (an application profile of) the IEEE LOM standard or the Dublin Core (DC) [19] specification and its application profile for education. Learning content as well as their metadata are usually stored in a repository.

A relevant standard for harvesting metadata is the Open Archives Initiative Protocol for Metadata Harvesting (OAI–PMH) [73]. Relevant in addition specifications for discovering learning resources are: the Search and Retrieve Web Service (SRW) [98], Search and Retrieve URL Service (SRU) [97], the Z39.50 client/server based service and protocol for Information Retrieval [114], and more recently the Simple Query Interface (SQI) [130] specification from CEN/ISSS WSLT. In order to get content, specifications for globally unique and persistent identification are important as well as specifications for actually obtaining the content. In this respect the Digital Object Identifier, Z39.88–2004, and the Handle System are relevant.

While resolving an identifier into a handle to obtain the learning resource licensing may come into play. Learning content may have multiple licenses described by Digital Rights Expression Languages such as Creative Commons [17], the Open Digital Rights Language, and MPEG 21.

Trends and Issues Concerning Learning Content and Repositories Interoperability

Open Content

One movement which has implications for the development of learning content is that of open content. There is no definitive description for open content it is general assumed to be content which is freely available, with liberal licensing to allow reuse and repurposing such as Creative Commons. The adoption of this type development process, which can appear at first glance as very attractive, particularly for the educational sector, does require a significant investment both in development process and also in shifting cultural attitudes towards the use of free content. Many teachers are happy to use others content but not share their own, or conversely do not want to use "free" content as it may not always have the same perceived value of bought content.

Recently the EC has funded a body to monitor and help foster the development of the open content movement, Open e-Learning Content Observatory Services (OLCOS) [76]. In early 2007 OLCOS produced a roadmap to "provide decision makers with an overview of current and likely future developments …and recommendations on how various challenges could be addressed." [77]. The roadmap provides a comprehensive overview of the state of open content development at the present time.

User generated content and Web 2.0

The advent of web 2.0 technologies has potentially many implications for the development, reuse and sharing of learning content. One of the biggest developments in the web 2.0 space is that of "user–generated content" and the proliferation of social spaces for sharing content such as Flickr [31], Youtube [113], MySpace [72] to name but a few. These sites have turned the notion of publishing on its head as users now can easily create and upload their own content and create new communities for sharing.

The potential for rich, interactive, highly collaborative content creation presents new paradigms for teaching and learning and the role of content delivery and creation. It also presents challenges for educational content standards and specifications as this new paradigm relies on the use and development of web services which are browser based, and do not require specialised systems such as VLE for access.

However commercial forces are at work in this arena with large corporations buying social spaces (such as Newscorp with MySpace) and increasingly closing down the number of services that can be used within these environments.

On the other hand, the notion of content mash ups (that is the ability to mix content from one source easily with multiple other sources) does offer educators increased flexibility over content and, it could be argued allows the development of a "push/pull content" model where services such as RSS allows content to be pushed out (or pulled in) to aggregators. Combine this with the recent development of visual editors such as Yahoo!pipesand customising feeds for particular curriculum areas becomes more in the realm of non developers. We are now in an era where people are producing connected as opposed to interactive content.

The use of web services needs monitoring as although at the moment many services are free, as noted, commercial forces are increasing in this area. All content developers need to be aware that the status of a free service could change literally overnight, and access to their content could change.

Mobile Learning

There is increasing demand for content to be able to be delivered in as wide a number of devices as possible; and particularly to mobile devices such as PDAs, telephones etc. This is often referred to as m–learning. In terms of interoperability, this trend presents a new set of challenges for content developers due to the sheer plethora of devices which are available on the market place. Studies have shown that the use of mobile technologies can have a positive impact on learning.

The JISC [45] "Innovative Practice with e-Learning" Guide showcases a number of case studies where mobile technologies have been successfully integrated within the educational settings. Producing content for m–learning usually still involves creating a different version that would be used in a VLE or digital repository. Software developers (notably Macromedia) are developing products which can produce content for a variety of devices but interoperability still needs much work in this area.

Interoperability Issues

While much content is produced by the e-learning user (teacher/learner) community, the sharing is still much less than it could be. This is mainly due to the fact that exposing learning content is still quite cumbersome and learning material which is well described is hidden in repositories most of the time not accessible. In addition finding the right LR can be improved by more effective ranking and precision enhancing mechanisms as well as harnessing social recommendation and community tagging. Furthermore the vast majority of teachers have a need to adapt and repurpose learning content. Current digital rights management techniques are insufficiently developed or adopted for doing this and easy to use modification, repurposing tools are lacking. This is particularly the case in a multi–lingual, multi–cultural environment where localization is key for the effective use and integration of learning resources in the classroom. Thus the interoperability issues are: (1) to find the right balance in ease of describing learning resources and semantic interoperability; (2) to develop interoperable solutions that improve the discovery and ranking in a heterogeneous environment, and that allow for easy adaptation and repurposing while respecting IPR.

Stakeholders Concerns and Issues on Learning Content and Repositories Interoperability

There are many stakeholders within the content arena including standards/specification bodies, publishers, repositories, VLE/LMS vendors, content developers, software developers, educational institutions, lecturers, educational technologist and learners.

Although there have been significant technical advances for the means of storing and transporting content with the development of specifications such as IMS CP, CC, QTI and Learning Design and the SCORM; there are still many barriers to interoperability due in part to the flexible nature of specifications which allow for degrees of flexibility in implementation.

In terms of semantics, there are a number of significant issues. The LOM still presents many challenges in actual implementation. Contextual metadata continues to be of increasing importance with the educational context – how someone used a piece of content is often more important than the description of it. This brings with it the added challenge of finding appropriate vocabularies to describe learning which are shared between the teaching and learning community and the system development community. The JISC Pedagogical Vocabularies Project produced three reports which explore the potential for identification, development and use of pedagogical vocabularies for the UK post–16 and HE communities. Despite being a UK based project, many of the issues it highlights have resonance within other countries; particularly the need to develop commonly understood and shared pedagogical vocabularies. In terms of user–generated content we are now in the era of the folksonomy, which Wikipedia describes as: “a user generated taxonomy used to categorize and retrieve Web pages, photographs, Web links and other web content using open ended labels called tags”. This user centred approach may well be a more successful way to provide meaningful metadata for users (particularly in an educational context) but it does perhaps present some other challenges for interoperability when compared to an internationally recognised standard such as the LOM [57].

Learning Object Repositories Interoperability

Recommendations

1. To promote organisational/social interoperability and to invest more in supporting sustainable communities. This is part of the pragmatic interoperability. Technical solutions should be more socially effective and therefore teachers should be more involved. For example, the judgement of users can be harnessed in order to find out what quality is and users may be able to provide metadata that connect better to their practice (cf folksonomies). Teachers should be given the tools for localising and adapting material more easily as well as tools for social and community based metadata tagging. The major challenge will be to find ways and provide tools and infrastructures for making the community generated outcomes interoperable. Furthermore, in order to empower users, trust is important, so that less control is needed. Systems fostering trust such as a federated identity management system are highly desirable.
2. To support communities in the agreement on use of LOM, vocabularies, application profiles, etc. This is directly related to the semantic interoperability. While recommendation 1 promotes diversity, recommendation 2 promotes harmonisation. Obviously there is a trade–off but to a certain extent they are complementary. Recommendation is intended to avoid unnecessary differences and to foster means to relate different approaches to each other. The use of the LOM by a community is described in a so–called application profile. In building an application

profile many degrees of freedom exist. If one is aware of other application profiles it is often possible to choose particular options that are compatible with the existing ones. For example, there might be reasons to develop a different vocabulary than what is provided in the LOM. If however one develops this as an extension or refinement of an existing vocabulary, interoperability is preserved to a certain extend. Similarly it is good practice to base the development of an application profile on an existing one. This recommendation is intended to improve the support for reaching agreements and building application profiles. This includes the establishment of registries for vocabularies and APs, provide the tools and guidelines for easily extend, refine, and map vocabularies and application profiles, and provide tools for certifying whether certain LOM instances are adhering to a particular application profiles.

3. To provide a framework of well factored out services and there relationships in an interoperability stack together with a registry of available services.
4. It is recommended that approaches for dealing with digital rights are further researched, tried out, and implemented. To this end the requirements of communities that share the same concern should be understood; requirements in terms of rights to be expressed and enforced, and workflow. For open content licensing schemes such as Creative Commons it will be necessary to identify how to deal with requirements of specific communities. For example it happens that Creative Commons is entirely suitable with the restriction that it only applies to users from a particular country or region. For commercial content it is recommended that models are developed for business to business situations as well as business to customer.
5. The vast majority of teachers (including professors) will want to do small modifications to learning objects in order to repurpose it or adapt it to specific local conditions. The community of teachers has primarily a need for simple repurposing/localisation tools and methods rather than complex authoring tools. In addition methods and tools should be developed to make LOs more adaptable. Furthermore, digital rights expression languages should be such that adaptation and localisation is made easy.
6. Related to querying other repositories the following recommendations are made:
   - The definition of a query exchange format: When searching a federation for resources, it is necessary to transport queries between heterogeneous systems. The exchange format should be rich enough to express meaningful queries and abstract enough to be easily

mapped into the concrete query languages supported by the target resource repositories.

- The specification of a query interface: This is necessary to transport queries to the federated repositories and get results. Such an interface must take into account the requirements of federated searches (e.g., asynchronous remote façade).
- The definition of a query result format: A common way to express query results is needed.
- The global identification of resources: Resources should be uniquely identified so that it is possible to unambiguously refer to them in metadata exchanged between systems.
- The global identification of systems and repositories: Similarly, it should be possible to unambiguously refer to the systems that host these resources.
- The description of learning content repositories or collections using so–called collection level description for LO collections. Metadata may include a subset of the LOM enriched with some new elements such as "Quality assurance procedures".
- The specification of a synchronization interface: A synchronization interface is necessary to mirror metadata. Ideally, push and pull scenarios must be supported.
- The definition of a user profile: Current specifications, such as IMS LIP, focus on the administrative data of learners. In order to provide more accurate search results it would be interesting to describe the "educational context" of a user (e.g., role: professor/teacher Vs student/pupils, topics of interest, etc.).
- Integration with federated identity management (single–sign on, user identity, access management): This is necessary (together with the integration with DRM systems) to make the rights associated with resources enforceable.
- Integration with digital rights management systems [57].

2.1.6. Learning Activity Interoperability

Throughout the brief but busy history of e-learning, the learning object has occupied a central role in the conception, design and production of electronically delivered courses. As the world of e-learning evolves, the primacy of the learning object is increasingly brought into question by advocates of a view which favours activity over objects. At the heart of this activity–centred view is the assertion that while the learning object has been a staple of e-learning since its inception, it has systematically failed to actively engage the learner in anything beyond electronic page–turning and the passive consumption (but not necessarily digestion) of knowledge. The activity–centred view on the other hand, places the performance of individual and group activities at the fore of the e-learning experience and makes use of the learning object as an auxiliary, intended to facilitate the various forms of interaction (negotiation of meaning, etc.) at various points throughout the learning activity. When some members of the e-learning community started to ask if the primacy of the learning object led to pedagogically sound learning technologies they started to explore Learning Activity Interoperability. They wanted to support an activity–centred view places the performance of individual and group activities at the fore of the interaction (negotiation of meaning, etc.). A move towards standardizing this activity–based approach to learning exists in the form of the IMS Learning Design Specification (IMS LD) [39]. The development of the was a direct response to a recognised need for a specification which would allow an interoperable way of representing and sharing pedagogically complex models of learning activities, which could include collaborative activities. The Open University of the Netherlands – OUNL – had been working towards creating a language to enable the sharing of learning activities and had developed the Educational Modelling Language – EML. This was used as the basis for the development of the IMS specification. The OUNL and the UK based Centre for Educational Technology Interoperability Standards (CETIS) [14] were the primary architects and driving forces behind the creation of the IMS specification. IMS LD does not define or recommend any particular pedagogical model, instead it provides a high level language, or meta–model, that can describe many different models and how people perform activities using resources (including materials and services), and how these three things are coordinated into a learning flow [18].

While the uptake of IMS LD is still in its infancy, it has caused wide spread interest from the e-Learning community due to its pedagogical underpinning. Initiatives such as the recent European Commission 6th Framework UNFOLD (Understanding New Frameworks of Learning Design) project [104], a partnership between the Universitat Pompeu Fabra, OUNL, CETIS and EUCEN, have helped to raise awareness of the specification. More generally, UNFOLD provided a European platform for the wider context of designing for learning, an umbrella term for any form of pedagogical planning that espouses the activity–centric point of view for which adherence to the specification is not strictly necessary. Designing for learning is part and parcel of everyday teaching practice. IMS LD provides a significant step towards rendering the design process more transparent to practitioners. This can help to facilitate the planning and execution of teaching and learning, in an e-learning context, with a shift in emphasis away from content delivery to one that promotes a greater understanding of the importance of learning activities.

State of the Art Concerning Learning Activity Interoperability

As the number of e-learning standards and specifications proliferate, the importance of the role of standardization in the field is growing. For an increasing number of designers, open standards are a sine qua non due to the degree of interoperability that they bring to e-learning. However, open standards notwithstanding, claims that interoperability is achieved at the cost of pedagogical ingenuity [49] have prompted the development of the IMS LD specification, an offshoot of the OUNL's EML. While space precludes an in–depth analysis of the workings of the IMS LD, a brief overview will serve to highlight the significance of this specification in the context of activity based learning.

Since its initial publication in 2003, IMS LD has distinguished itself by virtue of its high level language which, in theory, allows for the description of just about any conceivable pedagogical model for use with both individuals and groups. IMS LD is a language intended for use in modelling units of study. In effect the language affords designers the opportunity to describe the interaction and coordination of three key components in the learning process as conceived in LD, namely; the *learner* who interacts with *resources* during the course of a given *activity*. Through the use of the metaphor of a theatrical play, learning scenarios are described in terms of plays, acts and role–parts in such a way that both learning services and content can be organized into a user specified sequence before they are assigned to learners.

Another noteworthy characteristic of IMS LD includes its various levels: A, B and C, a design feature intended to facilitate the implementation process. Level A lies at the heart of LD and includes the means with which to add and coordinate people, activities and resources. Level B allows for more complex designs through the use of properties and conditions. The former are used to collect learner data including preferences, test results etc. while the latter serve to constrain the learning flow in accordance with predetermined criteria designed to accommodate a specific set of circumstances or preferences. Level C adds ever increasing sophistication to learning designs through the use of notifications which serve to automatically trigger new activities upon the completion of tasks.

From an interoperability perspective, the interest in IMS LD lies in its ability to afford learners the opportunity to work on the same activities using the same services and resources across a variety of IMS LD compliant learning platforms. Compliancy can be achieved by any system through the adoption of an IMS LD import and export format and is not dependent on the use of any particular infrastructure or methodology. The advantages of such a high level of interoperability include the ability for designers and teachers alike to export learning activities created in one VLE for use in another. Work is being undertaken to develop IMS LD import and export capability in a number of VLEs including Moodle and LAMS.

Despite the innovative nature of IMS LD, the specification itself is designed in such a way that it is able to support and make use of a number of existing specifications necessary to model interoperable learning activities and assessments. These include IMS Content Packaging (IMS CP), IMS Question and Testing Interoperability (IMS QTI), IMS Simple Sequencing (IMS SS) [43] to name but a few.

No comparative overview of LD would be complete without mention of ADL's [1] Shareable Content Object Reference Model (SCORM) and SCORM 2004 which also has a number of points in common with IMS LD including the use of CP and LOM. But in spite of these surface similarities, their respective differences underline their variance in purpose. Such differences include SCORM 2004's limited description of runtime behaviour for the single user only which, while resulting in limited pedagogical use, makes less demands of the server than IMS LD. On the other hand, SCORM profiles a large set of specifications which render it highly specific and, for this reason, easier to implement than IMS LD.

In terms of expressivity however, SCORM is severely restricted in contrast to IMS LD, which allows for the extraction of pedagogy from content such that it is able to offer the kind of functionality that characterizes structured activity–based learning (e.g. peer collaboration, formative assessment, tracking and sequencing of individual and group work etc.). There has been some discussion on the possible integration of SCORM and IMS LD [51], although, no concrete action has been taken in this regard.

While IMS LD has been shown to have the potential to bring the learning activity to the fore of e-learning, there has been some concern at the relative lack of standards related activity since the first release of IMS LD in 2003. Recent developments with IMS QTI 2.0 however look set to expand IMS LD.

IMS LD was intended to put pedagogy before technology by providing ways to create, run and share any number and kind of complex learning activities. It was also an attempt to address the gap between the, instructional design led specifications and profiles such as IMS Simple Sequencing and SCORM and the more constructivist approaches desired particularly from the education sector.

This approach brought about a considerable level of interest from educational practitioners. However at the time of the release of the specification there was little, if anything in the way of tools and concrete examples of compliant learning designs.

This lack of implementation can probably be attributed to two main factors: firstly the specification was arguably ahead of its time – the formal orchestration of people, activities and services was not commonplace within an e-Learning context; secondly, the lack of tools to initially create learning designs and then run them in a web–based teaching and learning environment. Any tools that were available required a high level of XML programming capability, which was not (and still is not) a skill held by mainstream educators or indeed many learning technologists.

One system that did emerge fairly soon after the release of the IMS LD specification was Learning Activity Management System (LAMS) [54]. Developed at Macquarie University in Australia, LAMS provided a "learning design inspired" authoring and runtime environment. The simple, drag and drop user interface provided an easily understood, teacher centric, introduction to the general principles of designing collaborative learning sequences. However, despite its apparent user friendliness, the LAMS system did not provide an interoperable solution as it did not adhere to the IMS specification. Nevertheless, it did provide a route for the less technically focused to join the wider design for learning debate. It should also be noted that LAMS can now export LAMS sequences as IMS LD, Level A packages.

There is still relatively little in the way of implementation of IMS LD compliant tools, but that is changing. Key stakeholders are providing commitment to IMS LD and providing funding for further developments including the development of authoring and runtime tools.

We are now approaching a period where there are a number of IMS LD tools available and this coupled with projects funded by for example the Joint Information Systems Committee (JISC) [45] in the UK should provide a basis for developing more implementation practice.

Relationships with the Adoption Life Cycle of IMS LD

We are now at a stage where we have the first iteration of a specification with at least one open source reference implementation. On the technical side, we are beginning to see the implementation of runtime systems and developers are working towards establishing interoperability. On the pedagogical side, we are now developing a small (but growing) group of practitioners who are creating the learning designs which can be run by these systems and accessed by teachers and learners. In conclusion, in terms of tools, systems and actual learning content that could be used in a real teaching scenario, we are very much at the stages of first generation tools, activity development and services. Critical mass of interoperable systems, services, content exchange and delivery has not been achieved yet.

Recommendations

- It is recommended that further research be undertaken into mapping learning activities and pedagogic patterns in order to develop exemplars of learning designs in whatever format practitioners express them.

- It is further recommended that additional tools be developed with "user friendly interfaces" allowing practitioners, tutors and teachers to author and create access and repurpose IMS Learning Designs.
- Additional work is required to investigate the existing practice around the creation, sharing, housing, discovery and repurposing of learning designs.
- Guidance and clarity is required for practitioners, tutors and teachers in respect of DRM) and intellectual property rights (IPR) issues.
- Research is required into the complex issues surrounding the vocabularies of learning activity; formal expressions Vs the use by practitioners of folksonomies in order to establish a common vocabulary.
- Practitioners, tutors and teachers require guidance in the translation of "inspirational" learning designs into workable "run time" applications.
- Additional support to practitioners, tutors and teachers is required in respect of existing tools used in the creation of IMS Learning Designs and other expressions of learning designs [57].

2.1.7. Learner Information Interoperability

Learner Information is likely to be the type of learning related information digitally stored for the longest time. Current approaches to learner information take an institution–centric view of the learner, and are primarily concerned with the management of official records – a combination of operational data and progression data – and this information is being looked at in terms of standardisation for exchange amongst institutions and official bodies. The importance of standards is gradually increasing as Learner Information is needed in an increasing number of systems for e-Learning. In order to avoid redundancy and corruption of information it is essential to enhance the interoperability and transferability of Learner Information between different systems in order to reuse data in new contexts, in combination with fragments of other types of Learner Information from other sources.

The e-Portfolio is a web–based information management system that uses electronic media and services to provide a lifelong learning device for users, a monitoring tool for training institutions, an improved access to employment opportunities. Learner information is used for various purposes: reporting and administration, accountability, assessment and last but not least, social organisation. The e-Portfolio can provide an opportunity for the European Union to have a stronger implication in improving European employability through its promotion, provided there is a coordinated action regarding competencies certification and validation across Europe, using the same format, protecting personal data and finally ensuring system interoperability.

However currently available systems, known to the IMS e-Portfolios Development Committee, store e-Portfolios in formats that have no facilities for importing and exporting e-Portfolio information conformant with accepted standards. There are two main reasons for the inaccessibility of Learner Information. Some of the information about the learner is not permitted to be used outside administrative systems and there are no mechanisms to exchange the information (or parts of it). Secondly the information is often locked into proprietary data formats. This, in combination with a market with only a few suppliers of administrative system, has a checking effect on the use of standards. This makes it difficult or impossible to move e-Portfolios data between systems, and leads to inefficiency and redundancy when integrating e-Portfolio tools with other enterprise systems.

Moreover, to be portable e-Portfolios need to ensure educational continuity between programs within an educational institution that use e-Portfolios, integration of evidence about learning over time, and smooth transfer of verifiable information about learning and evaluation between institutions, levels of education, and employers. From an individual perspective, information about and artefacts of a person's performance and achievement, as recorded in an e-Portfolio, need to operate across institutions and countries throughout their lifetime.

In order to develop advanced systems and services that help improve European citizen employability, through the promotion of e-Portfolio, there is a need to have common references for:

- e-Portfolio format: the scenario online template has to include general information (language, description, creator, audience, source, other contributors, scenario flow diagram from different perspectives, a list of stakeholders and other actors, information about resource's format and contribution's rights management, information about the person who enters the object/resource (role of the creator/publisher of the scenario).
- Competency definitions through the model of learner competency IMS LIP [40], based on RDCEO [42] and to be applied all over Europe.
- Europass Diploma Supplement.
- Data protection and privacy procedures.
- Interoperability of e-Portfolio on different platforms and environments.

State of the Art Concerning Learner Information Standards and Interoperability

There are various standards for storing, processing and exchanging information about users. Apart from the Lightweight Directory Access Protocol (LDAP) [55] specifications for catalogues and the vCard specifications for digital "business cards", the IMS LIP [40] and the specifications IEEE LTSC Personal and Private Information (PAPI) [80] differ slightly. While IMS LIP tends to take on a classical CV–structured approach to Learner Information, PAPI has a stronger focus on performance information and interpersonal relationships. In addition to the differences mentioned above, there are some important technical divergences regarding their respective data models. While IMS LIP is XML–centric, PAPI has a number of different bindings to programming languages APIs, protocols and data representation formats (including XML). PAPI uses a registry–based approach which means that it becomes less sensitive to changes and a bit more susceptible to additions. PAPI has a focus of separating different types of Learner Information – such as contact and performance information. While IMS LIP categories the data into 11 different categories (and PAPI into 6), IMS LIP has no technical mechanisms for separating the data. This might be a weakness when combining information from different sources: such as LDAP data for contact and LMS data for performance or when there is a need to separate different types of information for integrity and security reasons.

Besides IMS LIP and PAPI, there are some limited efforts that address specific parts of the Learner Information. EduPerson [24] is an example of a LDAP schema–class for Learner Information. EduPerson can be used in combination with other standards to store catalogue data in an LDAP catalogue. Universal Learning Format (ULF) [103] is another effort. ULF is based on different standards such as vCard and RDF but, in spite of that it is a proprietary format.

e-Portfolio data

The main Learner Information categories are related to competency, demographic information, preferences, accessibility, performance and achievements, plans/goals/reflections, activity, map of relationships.

Each Life–long Learner creates, manages, and owns their individual Portfolio and the data it contains. This data is categorized as follows:

- Static Biographical – describes invariant characteristics of the Life–long Learner such as date of birth.
- Dynamic Biographical – describes variant characteristics of the individual such as current address or email information.
- Self–Reported – information under the direct control of the Life–long Learner and modifiable by them regardless of source such as a writing sample, a computer aided design work product, or a transcript furnished to the Life–long Learner by a third party and entered into their Portfolio by the Life–long Learner.
- Third Party Validated – information placed in the LLL Portfolio with the permission of the Life–long Learner but under the control of a validating third party such as a certifying training provider or degree granting

educational institution. The obvious example is a transcript but also includes test and evaluation scores and may be extended to include performance reviews and personnel evaluations and health certifications as well.

Portfolio's access is under a strong public key infrastructure and requires full digital certification. Key fields in each record in the Portfolio are separately encrypted to prevent direct identification of individuals from non–specific information. For example, access to a single transcript will not yield and individual information and therefore cannot be linked back to an individual.

Stakeholders Concerns and Issues Concerning Learner Information Standards and Interoperability

Technical issues

Currently available systems, known to the IMS e-Portfolios Development Committee, store e-Portfolios in formats that have no facilities for importing and exporting e-Portfolio information conformant with accepted standards. This makes it difficult or impossible to move e-Portfolios data between systems, and leads to inefficiency and redundancy when integrating e-Portfolio tools with other enterprise systems. IMS Learning Information Package and IMS e-Portfolio [51] specifications have been found inadequate when documenting collaborative team–based learning activities. Alongside team–based projects, sometimes a group of people studying or working collaboratively and who jointly contribute their efforts build a portfolio based on group–constructed artefacts. To support collaborative learning and data exchanging between personal and group profiles, specifications for multi–learner profiles seems to be necessary.

Recommendations: Competency common definition

Competency common definition at the European level is a first step before proceeding to any standardization effort. An immediate objective for Europe should be to have developed a set of shared vocabularies for relationships and competencies that are in actual use in high stakes exchanges of learner information, across national lines, across levels of formal education, and between the public and private sectors. Vocabularies should be developed for exchange of learner information both within Europe and beyond.

Schemes for learner information and resources should increasingly use the terms from the same sets of controlled vocabularies. For elements that use controlled vocabularies, such as for a competence or learning outcome, all schemes for learner or resource information should ensure that they contain a place for a unique identifier, as well as a person readable name or term. It would be advantageous to have a globally unique way of identifying the conceptual domain of the elements in learner and resource information and to use the terms from the same sets of controlled vocabularies.

It is recommended:

- To reuse existing vocabularies from available repositories.
- To promote interoperability among repositories of vocabularies.
- To develop guidelines for the creation, maintenance and control of vocabularies.
- To develop sample projects exemplifying good practice.
- To support and document the process by which shared meaning is negotiated across multiple vocabularies.
- To develop a set of explicit business cases.
- To support multilinguality [57].

2.1.8. Education Institution Interoperability

It is recommended:

(1) To support the development of plug and play software that can be glued with the already existing Education institution (enterprise) environment. Modularised learning environments, with clearly defined interfaces with the Enterprise world, must be produced in order to ease the development of a holistic approach based upon the combination of, as small as possible, software components.

(2) To develop reference models and frameworks for the Education Enterprise. These must be as technology neutral and general (e.g. flexible) as possible. Avoiding too detailed prescriptions of what (types of) services and components to be included in the basic layers.

(3) To discourage any proposals for monolithic system architecture; adopt a distributed model made up of distinct, stand–alone components that communicate over open protocols/interfaces.

(4) To build or find applications that map between different languages and ontologies using:

- Communication protocols (HTTP, SOAP, XML–RPC, Peer–to–peer, etc.).
- Communication languages (OAI, ECL, eduSplash, etc.).
- Metadata (IEEE LOM, Dublin core).
- Ontologies made up of vocabularies for metadata.

(5) To develop an appropriate system for unique identifiers. The EU should support and possibly fund the process to agree on a universal unique identifiers model as well as the research towards and eventual deployment of a suitable system to manage it.

(6) To support the development of standards and technology that allow any Web–enabled application to send and control learning–related information to learning–supporting systems and standards that enable a learning–supporting system to listen for and compile such information. Many standards are needed to support this. A learning–supporting system must have a way to identify which application is sending what information about which learners and standards must be in place to enable the information to be collated and analyzed [57].

2.2. Problems of Standards Implementation in e-Learning Practice

Why do we need standards and specifications?

With the recent explosion of Web 2.0 user–generated content and the increasing availability of federated educational repositories, ongoing work on standards and specifications that support the greater interoperability of school sector educational resources remains key:

- Both at national level and Europe–wide, in initiatives such as the European Commission's eTwinning action, teachers (and pupils) are increasingly authoring their own learning resources, adapting and localising those of others and joining new social networks and content–related communities. In this environment, new frameworks, tools and approaches must be found to enable hard–pressed and time–poor teachers to apply specifications and standards to their content without having to understand anything of the underlying principles, technologies or alphabet soup of standards acronyms.
- The EUN [28] and its supporting 28 Ministries of Education and other partners have launched a publicly available Learning Resource Exchange service for schools building on the CALIBRATE and MELT projects. Initially, this include a federation of up to 20 major content repositories offering approximately 40,000 learning resources and 125,000 learning assets (with Creative Commons licenses and tagged according to a LOM–based application profile) from both public and private sector partners. Additional content from Associate Partners is also available via the LRE federation. Application of open standards and specifications has already been key to the current development of the LRE architecture and content. The implementation of existing and emerging specifications that will improve the cross–border exchange of content is vital for the ongoing success of this initiative.

- In the private sector, commercial developers (such as those taking part in ASPECT [3]) are conscious that their investment in, and the promise offered by, some of the earlier content specifications have not been wholly successful. Portability of resources and the ability to play content seamlessly within standards compliant VLEs still remains problematic. Projects like ASPECT have an important role to play here in helping these providers to understand the pros and cons of different combinations of existing standards. For example, while the new draft IMS Common Cartridge specification promises to harness a number of these earlier specifications and provide a better level of integration with third–party tools, implementation of Common Cartridge is still at a very early stage and many questions remain unanswered.
- Most stakeholders will benefit from agreed profiles and established practices as projects like ASPECT help combine existing specifications into complete solutions that address the needs of the school sector in terms of learning resource discovery, exchange and reuse. For example:
  - Educators will find it easier to discover and use learning content that addresses the needs of their students; it will also be easier to maximise reuse of content and minimise costs associated with repurposing of materials.
  - Students will benefit from having access to the highest quality learning resources available, making a significant impact on learning outcomes and the quality of their learning experience.
  - Content providers will be able to advertise their products by making them easily identifiable, discoverable and usable.
  - System vendors will have a limited set of specifications to support in order to make their systems compliant with major federations of learning resources.
  - Finally, federation builders will secure their investment by developing infrastructures based on standard specifications [3].

Why raising awareness of standards and specifications is not enough

For both policy makers and end users, educational content standards and specifications remain largely impenetrable. Part of the difficulty is the nature of the topic itself and the technical complexity of the issues under consideration. However, there is a growing awareness that part of the problem also stems from its failure to really connect with the educational community and to fully appreciate the needs of end–users. As highlighted by the EUN LIFE project in 2006: “There is an awareness gap between the overwhelming majority of end–users and the standards community. This reflects a similar, though perhaps not quite so wide, gap between the pedagogical perceptions of learning technologists and subject experts. We suggest that there has been a failure to recognise fully the priorities of end–users and that this might explain in part the limited adoption of standards and specifications in education."

Even more recently, there is a growing realisation by several commentators in the standards community that raising awareness concerning the need for standards falls short of what is required.

However, this perceived lack of mapping of standards to best practice is precisely something that the current eContent*plus* call is designed to address through the new instrument of a Best Practice Network (BPN).

Partners in the ASPECT [3] project are convinced that, if properly structured and managed, new BPN frameworks can help redress the "disconnect" between standards organisations and the educational community by: focussing on implementing standards as well as raising awareness; and supporting emerging standards and specifications that map to and are influenced by best practice related to the use of ICT in schools.

Current State of the Art Concerning Standards and Specifications Adoption and Implementation in e-Learning Practice

Prior to the development of the ASPECT proposal, European Schoolnet consulted a number of its supporting Ministries of Education (MoEs) in order to better understand what emerging content–related standards and specifications are deemed critical, particularly by some of those countries that already have well developed educational content strategies and that have already made significant investments in the development of standards compliant learning resources and application profiles. Similar enquiries were also made to key providers of open educational resources such as the ARIADNE [2] Foundation and commercial developers that had participated in EUN content–related projects such as CELEBRATE [11], eCOLOURS, CALIBRATE [10] and MELT [68].

Furthermore, the recommendations of the LIFE project have been taken into account as these address the adoption of standards and specification for e-Learning.

As a result of this exercise, a number standards and specifications (see Table 1) are considered to be the most important for the educational sector in Europe and will be the focus of activities in ASPECT [3].

The analysis results of the Learning Technology experts in the ASPECT consortium is given in Table 1 which follows the adoption life cycle stages as developed by B. Olivier/CETIS (see Figure 2).

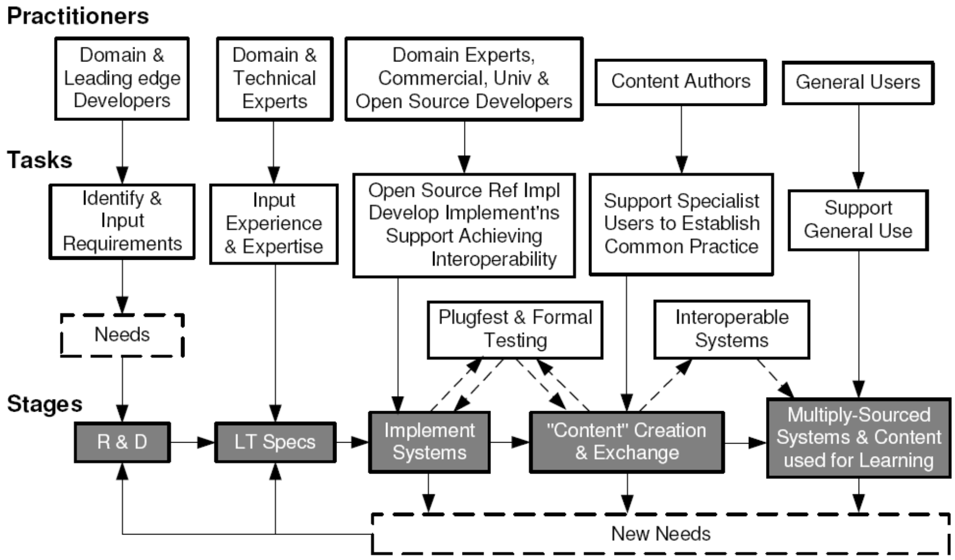

Figure 2. *Standards and specifications adoption life cycle stages [3]*

Table 1. *Standards and Specifications[3]*

Standards and Specifications	
IEEE LOM Dublin Core	IEEE LOM and DC are well adopted. DC is for content in general while LOM is designed for educational content. The major need is to be able to transform metadata instances from one format into another. While solutions for mapping the default specifications exist, good solutions are lacking for specific application profiles of IEEE LOM and DC.
XVD, VDEX, ZTHES, SKOS	ZThes has a wide adoption and the latest version has improved features for internationalisation. VDEX has a wide adoption as well. XVD is the most advanced specification supporting mappings between vocabularies and alternative structures but it has very little adoption at this stage. SKOS has currently the best approach to the mapping of vocabularies. Hence transformers between the formats should be offered to the wider audience of vocabulary developers. However, this is not sufficient. All too often it is the case that Application Profile developers invent vocabularies again and again. Apart from being inefficient, it harms the semantic interoperability of different application profiles. Given this situation, adoption can be best supported by providing a registry for vocabularies and mappings between vocabularies that allows for uploading and downloading in different formats.
SQI, SPI, SRU,	SRU/SRW are well adopted in the library world. SQI has a good adoption in the European Learning Technology world and many MoEs

Standards and Specifications	
SRW OAI–PMH	have adopted it for exchanging LOM instances in the LRE. SQI has been developed in order to support more advanced features such as asynchronous communication and different query languages in federated LO repositories networks. SQI could be profiled to support RSU/SRW such that both specifications could be used in a federated search scenario. OAI–PMH is well adopted also in the European LT world. As it is dealing with a different scenario (harvesting), it can co–exist with the other specifications. SPI is at the specification stage. It is work planned under CEN/ISSS contract. It is expected to become available in 2008 and hence ASPECT will co–operate with this effort and provide demonstrator implementations.
CQL, PLQL, LRE–QL	These are all abstract query languages that operate on a conceptual model instead of, for instance, relational tables. They have been developed by different parties involved in federating LO repositories and are used to interrogate metadata following the IEEE LOM. In the end it would be better to have a single well thought through query language. ASPECT will thus first investigate this route and, if this is not possible, try to establish translation mechanisms. LRE–QL is already an application profile of PLQL.
SCORM	SCORM is in Europe well adopted in the military world in a NATO context, and to a large extent by commercial publishers, especially for training purposes. However, the adoption in the school sector is limited. Cited barriers include the limited pedagogical models (primarily instructional design) SCORM supports, as well as the steep learning curve demanded if one would like to repurpose a SCO, a situation that occurs much more frequently in the school sector. The first issue is not retained within ASPECT, as it will involve a long–term effort within the LT research and pedagogical communities. The second issue will indeed be investigated. i.e. how can the practice of adaptation & repurposing of SCORM objects be improved.
IMS Common Cartridge	IMS Common Cartridge is a specification under development. Content Packaging, Question/Test Interoperability (QTI) and Metadata, with the IMS Tools Interoperability Protocol. Partners in the consortium being part of IMS, will release the first player in Q2 2008. As such, it is at the beginning of the adoption life cycle and adoption support measures will therefore be in terms of awareness raising, and demonstrators. The ASPECT project will also use Common Cartridge compliant content by different providers.
IMS Content Packaging and IMS Simple Sequencing	The same conclusions as for SCORM can be drawn and ASPECT will follow the same approach. In addition, practice should be re–evaluated given that IMS content packaging is part of the IMS Common Cartridge specification.
IMS–QTI	IMS–QTI is reasonably well adopted and works well for what it is

Standards and Specifications	
	supposed to do. While the consortium recognizes that the educational world needs more advanced specifications to fully support assessment, this is not retained as an objective. The ASPECT project will, however, seek to make the current practice easier, especially in light of IMS–QTI being part of the new IMS Common Cartridge specification.
IMS LD	IMS Learning Design is already an older specification but a really wide adoption is missing. However, since the prime focus of IMS LD is an activity, and not content, it is not retained in the ASPECT project. However the practice of IMS LD will be very much influenced by the work done in ASPECT as learning resources is part of the IMS LD specifications.
CORDRA	CORDRA is a model that is not really adopted in Europe. One of the barriers is the confusion between the general model and its specific implementation and deployment within the US DoD in the ADL–Registry. Nevertheless it is an important specification. Specific elements, such as the Handle System for identifiers, are of particular interest. Hence, ASPECT will analyse and compare the technological options offered and set–up a demonstrator implementation to be used by content and metadata providers.
Creative Commons	Creative Commons is by now well adopted. There are however some problems that hamper its adoption. First, as content providers are creating variants, interoperability of those variants becomes a problem. In addition there is a usability problem. EUN's two and a half year experience with the implementation is that, although Creative Commons is very simple, end–users such as teachers and learners make regular mistakes (about 30%) when uploading material. Therefore, the ASPECT project will investigate these usability issues in order to improve the adoption and practice of Creative Commons.

It is not sufficient just to identify these standards and specifications. More important is to understand at what stage of the adoption life cycle they are, and what should be done to improve adoption.

2.3. Chapter 2 Generalization. Tasks Formulation

Conclusions of Literature Analysis and Problems to Solve

The main conclusions based on analysis of existing and emerging interoperability standards and specifications are:

1. The majority of standards and specifications are not adopted and do not conform with educational practice.

2. There exists a problem of complex solutions for application of standards and specifications in education.
3. Standards and specifications often do not cooperate.

While some specifications are only at the beginning stage of adoption, there are already a fair number of standards that have been well adopted, but too many islands exist. The analysis highlights the need for making old and new standards and specifications work together (i.e. interoperate).

So the main problem is not identification of suitable standards and specifications, but the problem how to adopt these standards and specifications and apply and implement them in e-Learning practice.

First of all, in order to make it easier for educators to discover and use learning content that addresses the needs of their students, to maximise reuse of content and minimise costs associated with its repurposing, good solutions are lacking for specific application profiles of IEEE LOM.

3

System Interoperability Recommendations

The aims of this chapter are:

- To formulate and analyse the key principle of creation and development of flexible DLE: ultimate reusability and interoperability of LAs and UoLs (section 3.1).
- To analyse, validate and provide recommendations for European Learning Resource Exchange service for schools (section 3.2).
- To analyse curriculum mapping problem and provide recommendations for its integration with LOs metadata on European and Lithuanian level (section 3.3).
- To formulate guidelines for improvement of existing IEEE Learning Object Metadata application profiles and their adoption and application in e-Learning practices (section 3.4).
- To present flexible DLE components connection and their interoperability schemes (section 3.5).

The keyword here is “flexible”. The presented approach for flexible DLE is based on the proposition that it should consist mainly on ultimately reusable LOs and their metadata repositories as well as appropriate services to create, modify and manage LOs, e.g. modularised open source adaptable VLEs.

The need for reusability of LOs has at least three elements:

1. *Interoperability:* LO is interoperable and can be used in different platforms.
2. *Flexibility in terms of pedagogic situations:* LO can fit into a variety of pedagogic situations.
3. *Modifiability to suit a particular teacher's or student's needs:* LO can be made more appropriate to a pedagogic situation by modifying it to suit a particular teacher's or student's needs [66].

The author's approach is that ultimate reusability of LOs should be ensured by their partition to two main separate parts (Learning assets – LAs and Units of Learning – UoLs) which should work independently and should have clear different functions:

- LAs are considered not to be directly interconnected with particular pedagogical activities / designs, and therefore it should be possible to reuse the same LAs to implement different learning designs.
- UoLs are conversely considered to be LOs containing learning activities / designs reusable for different subjects and different LOs / LAs.

This approach needs the investigation of reusability and interoperability of these two separate parts of DLE within the system and DLE as a whole on European level.

The main research topic here is investigation and proposal of possible interoperability guidelines for LAs and UoLs. The major issues here are: what standards, why, and clear guidelines aimed to improve e-Learning standards application profiles and their adoption and application in e-Learning practices as well as recommendations how to combine existing standards and specifications into complete solutions that address the needs of the school sector in terms of LOs discovery, exchange and reuse.

The author has published 7 articles on the topic of the chapter [1A–2A, 5A, 7A–10A].

3.1. Learning Content and Activity Reusability

3.1.1. Learning Content Reusability

The three elements of LOs reusability, namely, interoperability, flexibility in terms of pedagogic situations, and modifiability to suit a particular teacher's or student's needs, will be discussed in this section as well as LOs reusability issues on European level (LR exchange and LOs relation with the curricula).

The Notion of Learning Object

Learning Objects are elements of a new type of computer–based instruction grounded in the object–oriented paradigm of computer science. Object–orientation highly values the creation of components (called “objects”) that can be reused in multiple contexts. This is the fundamental idea behind LOs: instructional designers can build small (relative to the size of an entire course) instructional components that can be reused a number of times in different learning contexts. Additionally, LOs are generally understood to be digital entities deliverable over the Internet, meaning that any number of people can access and use them simultaneously. Moreover, those who incorporate LOs can collaborate on and benefit immediately from new versions.

Supporting the notion of small, reusable chunks of instructional media, Reigeluth and Nelson [88] suggest that when teachers first gain access to instructional materials, they often break the materials down into their constituent parts. They then reassemble these parts in ways that support their individual instructional goals. This suggests one reason why reusable instructional components, or LOs, may provide instructional benefits: if instructors received instructional resources as individual components, this initial step of decomposition could be bypassed, potentially increasing the speed and efficiency of instructional development.

To facilitate the widespread adoption of the LOs approach, the Learning Technology Standards Committee of the Institute of Electrical and Electronics Engineers (IEEE LTSC) [34] formed in 1996 to develop and promote instructional technology standards. Without such standards, universities, corporations, and other organizations around the world would have no way of assuring the interoperability of their instructional technologies, specifically their LOs.

A similar project called the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE) [2] had already started with the financial support of the European Union Commission. At the same time, another venture called the Instructional Management Systems (IMS) Project was just beginning in the United States, with funding from Educom. Each of these and other organizations (e.g., ADL [1]) began developing technical standards to support the broad deployment of learning objects. Many of these local standards efforts have representatives on the LTSC group.

LTSC chose the term “learning objects” to describe these small instructional components, established a working group, and provided a working definition: “*Learning Objects are defined here as any entity, digital or non–digital, which can be used, reused or referenced during technology supported learning* … Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations or events referenced during technology supported learning”. This is a very wide definition that can be interpreted to include just about anything, which makes the definition somewhat hard to use [83].

This definition is extremely broad, and upon examination fails to exclude any person, place, thing, or idea that has existed at anytime in the history of the universe, since any of these could be “referenced during technology supported learning.” Therefore, Wiley had defined a learning object as “*any digital resource that can be reused to support learning*” [110].

This definition of LO, “any digital resource that can be reused to support learning,” is proposed for two reasons. First, the definition is sufficiently narrow to define a reasonably homogeneous set of things: reusable digital resources. Second, the proposed definition is based on the LTSC definition (and defines a proper subset of learning objects as defined by the LTSC), making issues of compatibility of learning object as defined within Wiley [110] and learning object as defined by the LTSC explicit. The proposed definition captures what the author feels to be the critical attributes of a learning object, “reusable,” “digital,” “resource,” and “learning,” as does the LTSC definition. With that compatibility made explicit, the proposed definition differs from the LTSC definition in two important ways.

First, the definition explicitly rejects non–digital and non–reusable resources. The definition also drops the phrase “technology supported” which is now implicit, because all learning objects are digital.

Second, the phrase “to support” has been substituted in place of “during” in the LTSC definition. Use of an object “during” learning doesn’t connect its use to learning. The LTSC definition implies that nothing more than contiguity of an object’s use and the occurrence of learning is sufficient, meaning that a banner advertisement atop an online course web page would be a legitimate LO. The definition emphasizes the purposeful use (by either an instructional designer, an instructor, or a student) of these objects to support learning [110].

The idea of LOs is now a widely accepted concept for the delivery of modularized e-learning content. Originating from Object Oriented programming, the concept has evolved to embrace almost everything that is digital. The concept needs to be more clearly defined in order to deliver what it promises. Most implementations are not technology– and pedagogy–neutral and do not support sophisticated reuse [83].

The concept of LOs has gained wide spread acceptance in the world of e-learning. The main purpose of LOs is to provide a modularized model based on standards, that enhance flexibility, platform independence, and reuse of learning content – as well as providing a higher degree of control for teachers and learners. The definition and meaning of the term Learning Object varies considerably between different actors and communities as well as over time. Much of the changes are due to the fact that standards have matured, that implementation has shown that everything didn't work as expected or depending on focus and theoretical perspective. Independent of this, the idea of LOs is – and has always been – to organize Digital Learning Content into small, fairly context–independent chunks that can be assembled, disassembled and combined in different ways and in different learning contexts. LOs from different vendors can be combined with each other to form a module that can be used in a specific learning context. Ideas that are much inspired by experience from system development which shows that component–based approaches are favourable for quality and significantly reduce time to market [7]. Depending on the approach, the management and composition of LOs into larger modules is managed by the teacher, the learner or someone outside the educational institution – for example by a content provider or someone distributing a learning "package". However, much of this is still just a vision and there is an impending risk that the potential multi–billion Euro market for LOs will not develop as anticipated if interoperability and common concepts cannot be guaranteed [83].

The lack of common definitions and models for LOs is a threat to interoperability and technical quality – as well as a threat to the concept itself. McGreal points out, after a review of the LO terminology, that a LO may ranges "from anything to everything". Much of the vision surrounding the LOs concept has yet to be fulfilled [67].

The movement towards a modularised model and standards for learning content was started in the early nineties by the Learning Architecture– and Learning Objects task force (LALO), formed as a part of the Computer Education Management Association (CEdMA). Inspired by object– and component technology in Computer Science, parts of the e-learning community started to realize the considerable benefits that could be obtained using a modular approach to learning content. The objective of the LALO Task Force is best reflected in the formulation by CEdMA: The vision of the LALO task force has been to enable new and existing learning content to be created as independent Learning Objects, such that they can be assembled in any combination to meet an individual's learning needs, resulting in increased personal productivity.

An important condition in order to realize Learning Objects is the use of Standards for Learning Technology, such as IMS, IEEE/LTSC, SCORM and others. This is an important reason why the Learning Object community to a large extent has set the Learning Technology standardization agenda. Much of the standardization work focuses on descriptive information (metadata), structure and packaging of learning content and not so much on the learning architecture and VLE. However, since many of the content–centred standards have matured, the focus is slowly changing and the VLE is receiving more attention.

International standards (preferably open) is an absolute condition for interoperability and that the kind interoperability that is needed to meet the LOs vision primarily comes from the use of standards [83].

The metaphor of Lego is commonly used to characterise LOs. Spokesmen for the Lego metaphor claim that *anyone should be able to assemble a Learning Module for a specific pedagogical context – simply by assembling Learning Objects of their choice*. The Lego metaphor is often criticized for being over simplified, which has lead to the development of more sophisticated metaphors. One commonly used metaphor is the "atomic" Learning Object, refined by Whiley in [111]. *The atomic Learning Object is subjected too much stricter rules and not anyone can assemble LOs, and every LO cannot be assembled with any other LO. They must have certain attributes and properties in order to function together. The atomic view (and similar) makes the e-learning life more complicated, but at the same time more realistic. Wiley describes a model based on the complexity of the logic contained, combined with the granularity of a LO. This is regarded at five levels ranging from the "Fundamental Learning Object" consisting of just a "raw asset", to the "Generative–Instructional Learning Object", which is basically an interactive module for learning. Wiley claims that the atomic model is "instructional design theory–neutral"* [111].

Sosteric and Hesemeier define Learning Objects as digital objects that have a formal educational purpose within a predestined pedagogical context [95]. They take on a rather traditional view on learning. It could be argued that there is a risk that such view can limit the pedagogical choices as well as the innovative aspects of using ICT and digital learning content.

McGreal means that the definition should be limited down to units that practitioners already prefer to work with and suggests a definition where LOs are "…any reusable digital resource that is encapsulated in a lesson or assemblage of lessons grouped in units, modules, courses and even programmes" [67].

Song and Andersson take a slightly different approach to LOs as they mean that LOs should be regarded as decomposable, and that there must be a separation between data, operations and the carrier of the data [94]. They also argue that an object should be described using a set of attributes and relationships to other objects. Song and Andersson focus mainly on the internal structure of LOs and their relations to other objects. The Song and Andersson approach rests heavily on experience and concepts from Object Oriented Programming.

In [82] Paulsson and Naeve suggest a model and a taxonomy (the VWE taxonomy) that is compatible with the taxonomy suggested by Wiley [111] and in some ways (architecturally) similar to the model suggested by Song and Andersson [94]. The basic idea of the VWE taxonomy is to separate the data, application logics and presentation of a Learning Object. This is accomplished by the introduction of three different types of components: data–objects (referred to as "Fundamental Learning Objects" by Wiley [111], "raw assets" by Koppi and Lavitt in [50] and Information Objects by McGreal [67] and resource objects. Resource objects are of two types: Helper Resource Objects and Creator Resource Objects. The first type is used to add application logics and/or presentation to a data–object (similar to a viewer or a plug–in) and the second is used to add application logics, that adds to the learning environment, without necessary being tied to specific content.

The problems described above were also evident from the study [83] of LOs from three LO Repositories (LOR). The LRs in the repositories where mainly of two types: Fundamental LOs (e.g. pictures, video, and texts), described in the left part of Wiley's taxonomy or Generative–Presentation/Generative–Instructional LOs (according the Wiley taxonomy). The second type of LOs also includes web pages, which could be argued to be Combined–Open LOs according to Wiley's taxonomy. The first type of LO has a high level of context independence, pedagogically as well as technically and is to be regarded as data objects that can be used as building blocks for larger modules. Technically, those LOs are not limited to learning, but they are described using metadata that loosely puts them in a pedagogical context. This first type of LO is fairly uncomplicated to handle they are mainly used as "raw" building blocks in larger units or "as is", as they are non–decomposable media objects [83]. The second type is much more complex to handle as they are a result of someone's authoring efforts, where several elements are aggregated into a larger unit (sometimes referred to as a module) – often handled as an instructional unit, based on an intended pedagogical use and sequencing. In our study, these aggregated LOs were commonly constructed using one or many components such as Flash animations, Java Applets, PDF files or web pages. In most cases LOs were not decomposable and the only factors that distinguished them from arbitrary digital resources was that they where produced for learning, i.e. implemented elements of instructional design and/or a pedagogical model, and that learning domain metadata had been added to describe them; generally according to application profiles of IEEE LOM or IMS Metadata. The metadata provided was in general mainly bibliographic and rather limited. The Application Profiles where only used to a very limited extent. Interestingly, the elements of instructional design were in most cases implemented using application logics – or in cases of web page, using hyperlinks, and not using existing standards such as simple sequencing or IMS Learning Design [83].

Specifications such as IMS Content Packaging were only used at the next level to combine LOs from the LOR. The effect of this is that such LOs are only decomposable to a minor extent defiance of that many LOs were complex with a high level of aggregation, containing several levels of granularity. The potential for inter–contextual reuse is limited to sequencing and packaging of LOs that are already assembled and stored within the LOR.

There are two main problems with LOs: That the variety of definitions leads to a variety of different types of LOs that are not compatible. The fact that LO (according to several definitions) by definition can be almost any digital resource makes the concept relatively pointless.

Another problem is that, currently, “reuse” of LOs is often limited to packaging and sequencing of pre–packaged units, which have nothing else in common other than that hey are called LOs, are described using educational metadata, and are packaged and sequenced together. They can however not function together in terms of interacting, exchanging data and messages, being subordinate to the same look and feel, or share application logics. None of the studied LOs used any standard interfaces for interaction [83].

A resource truly becomes a LO (a resource, reusable within another learning context) when it is associated with self–describing information – metadata. Metadata is used to implement LO repositories, to search for LOs in the repository, to share LOs, to import LOs into or export them from VLEs, to combine them with other LOs (using them as building blocks to build lessons, courses and other learning materials) [7A].

The various approaches to LOs attempt to meet two common objectives:

- To reduce the overall costs of LOs.
- To obtain better LOs.

The provision of LOs provides better access to quality resources and supports enhanced learning outcomes [7A].

Defining Learning Objects' Reusability

Reusability is the extent to which an LO can operate effectively for a variety of users in a variety of digital environments and a variety of educational contexts over time. LO reusability is affected by technical, pedagogic and social factors applying to both initial development and subsequent reuse [85].

This definition corresponds to our views and permits us to differentiate three main areas where reusability takes on different values, which in turn helps us understand what type of quality is wanted and needed in order to assure high quality. We propose to look at reusability from these three different aspects, which are further detailed below.

Technological Reusability

Essentially technical reusability is a synonym to technical interoperability and refers to the capacity of the LOR to import and export metadata and standardized protocols holding resources.

It also refers the way the LOR manages resources and metadata records and the type of metadata that is used. It involves storing, searching (federated and harvesting) and accessing LO's in the LOR.

Three quality dimensions can be distinguished, each pointing at quality criteria that must be specified:

- Metadata schema accuracy and appropriateness.

- Technical quality of the LO itself; does it conform to educational standards such as SCORM or IMS Learning Design?
- Technical quality of the LOR: does the LOR allow harvesting, federating according to international standard protocols?

Pedagogical Reusability

Pedagogical reusability here refers to pedagogical aspects of the resource, such as its capacity to be adaptable to different contexts and target audiences as well as its size. Granularity of a resource is a much discussed subject and how small or big should it be to be easily reused or adapted? A commonly found idea is that the smaller the unit, the easier it is to adapt and reuse.

Three distinct but common ways of pedagogical reuse are proposed, namely to:

- Use LO as an example or inspiration.
- Use the learning object as is.
- Use a LO by:
    - Recompose a new LO by putting several together.
    - Use the instructional strategy or structure of a LO.
    - Decompose an existing LO to make a new one.

Pedagogical reusability then demands instruments that can ensure the quality for each type of reuse and the possibility to adapt content, learning and teaching strategies used within the LO to other contexts. This is further explored in the Q4R Instrument section under pedagogical factors.

Socio–cultural Reusability

This is a concept that derives from instructional design and eLearning initiatives that essentially points at four important categories to take into account when designing high quality LO. These are:

- General cultural and social expectations.
- Teaching and learning expectation.
- Differences in the use of language and symbols.
- Technological infrastructure and familiarity [85].

Decontextualization of Learning Objects

The instructional design behind LOs is increasingly moving toward decontextualization. This is true because of an inversely proportional relationship between the size of a LO and its potential for reuse. LO “use” is better described as “contextualization”. That is, when an instructional designer or automated system “uses” a LO, they are actually placing the object into an instructional context. The relationship between internal context of the LO itself and the external context into which it is being placed determines whether or not the object "fits" into that context. The less specific the internal context of the LO, the more instructional contexts into which it will "fit". Conversely, the more specific the internal context of the object, the fewer instructional contexts into which it will "fit".

While the primary design criterion of LOs–based approaches is generally reusability, considerations of granularity (i.e., how "big" the LO should be) and architecture (i.e., the structure according to which the objects should be assembled) frequently require designers to reformat all existing content before it can be "reused" in a given LOs system [112].

It is possible to conclude, e.g. on the basis of FP5 IST CELEBRATE project [11] evaluation evidence, that it is possible to support a constructivist or advanced pedagogy through the use of LOs, but that this is more likely to be a feature of a teacher's classroom than the LO. Clearly the LO type may have some impact on this (i.e. it has affordances), but it is evident that even the most apparently "non–constructivist" or "non–advanced" LO (e.g. Drill and practice) could be used as part of advanced pedagogy, if the teacher has the skill of use and the repertoire of approaches in her teaching.

We have examples of where LOs can be similar or even the same, which are used with quite different pedagogy. Evidence from CELEBRATE survey indicated that almost three–quarters of teachers thought LOs could be used for both individual and collaborative work; on the face of it these are two quite different requirements. Evidence from classroom observations also supports this multiple view of pedagogy of LO [66].

LOs have many characteristics attributed to them either through the way they are formally defined or the discussion about them. The CELEBRATE project proposal indicated some of these categories by talking of them as "reusable chunks delivered across multiple platforms" and indicating the size of these chunks: "small, reusable "learning objects" … supportive of more constructivist learning models". The literature on LOs also attributes characteristics to LOs, most notably the fact that they have some identifiable pedagogy. The size of the "chunks" referred to above has become known as an issue of granularity: how large or small should LOs be?

An accepted part of the definition of an LO is that it has some identifiable pedagogy, which in a sense gives it the curriculum focus talked about above. A number of elements of the evidence indicate that this is not straightforward. First, the classroom environment was where the control of the nature of the pedagogy resided, not the LO. This is most graphically illustrated by the fact that the same LO can be used in pedagogically different ways by the teacher in his / her classroom and can be related in different ways to other activities. So, although the LO can "contain" pedagogy, this does not necessarily determine the way it is experienced by students. The argument presented in CELEBRATE was that there is an interplay between the affordances of the LO and the teacher's pedagogical practices. This element of the evidence is helpful in the context of the project's desire to create a new generation of LOs that reflect constructivist pedagogy and that would support the likes of collaboration. Most of the LOs did not reflect many characteristics of advanced (constructivist) pedagogy as we called it; indeed a large proportion were "Drill and practice" not generally supportive of such pedagogy. Nevertheless, teachers were able to create elements of advanced pedagogy in their classrooms where LOs were used. The issue would still exist as to quite where the pedagogy resided, as any linking of LOs to reflect a particular pedagogy would not be within an LO, but be in the VLE [66].

The basic idea behind the LO concept is suitable for many teachers as it supports a commonly preferred way of working. In [87] Reigeluth outlines a methodology where teachers locates a couple of resources (often books, articles etc. in the non–digital world) in order to make a selection of the parts they want to use in a specific context and reassembling them to a package – often using a Xerox machine or by simple reading instructions (i.e. sequencing). It has however turned out to be hard to make LOs support such methodology in a reasonably context independent way, supporting different pedagogical approaches and still being interoperable and technology neutral at the same time [86]. To start with, LOs need to be decomposable as well as being "ready–to–use" building blocks for composition of modules [94]. In [111] Wiley introduces LOs as "an instructional technology concept". The strong relation to the field of instructional design theory, individual instructions and the idea of "sequencing" learning activities is also one of the reasons for much of the criticism [67, 86]. Partly this relates to the idea of LOs as being "instructional theory neutral", which they in most cases aren't. This is in turn related to the idea of pedagogical context independence, which is a quite important attribute. Besides being a problem that originates from LO definitions and the theories behind them, it is a problem caused by some of the used standards and frameworks. For example, Rehak says in an interview [52] that SCORM is "…essentially about a single–learner, self–paced and self–directed. It has a limited pedagogical model unsuited for some environments". Further on in the interview he says: "SCORM has nothing in it about collaboration. This makes it inappropriate for use in HE and K–12". This clearly illustrates problems caused by the way that LOs are implemented and used – often claiming a constructivist approach and without considering the shortcomings of the used definitions, model and standards, nor it's origin from learning design theory which in turn originates from the 70th ideas on "individual instructions". In [65] McCormick argues that even though many LO advocates claim to support a constructivist and socially interactive approach to learning, it is not very well connected to the mainstream pedagogical literature. McCormick argues that one way to address this problem is to keep the pedagogy outside the LO.

3.1.2. Learning Activities Reusability

Units of Learning and IMS Learning Design

A lot of learning does not come from knowledge resources at all, but stems from the activities of learners solving problems, interacting with real devices, interacting in their social and work situation. A lot of research about learning processes provides evidence for this stance that learning doesn't come form the provision of knowledge solely, but that it is the activities of the learners into the learning environment which are accountable for the learning. The emphasis on learning designs is also justified from a reusability perspective [81].

The rather novel approach is that the teachers should be able to reuse pedagogical methods as well. This recurring issue has been present in the research field of educational technology for the last couple of years [48] and what remains to be resolved is whether teachers are actually able to export a particular pedagogical "approach" (e.g. how the course module or online event has been organised) and reuse it in course modules, which might be in a different subject domain with different content material. The way of abstracting the pedagogy from an online course is still something that is challenging. Pedagogy includes the notion of structuring learning / teaching activities (processes) in a in a course. Today's VLEs do not attempt to support such features, as they are more oriented towards content and user management, rather than activities' or processes' workflow.

An important contribution, which could address this limitation, is the development of IMS LD. One of the basic aims of IMS LD is to enable the abstraction of different learning design approaches into a meta–language that will represent and allow the interchange of practically any learning scenario. The meta–language when designing LRs is an important point, because it strongly affects the usefulness, interoperability and reusability of a LR and its assets. In short, IMS LD can be described as an XML–based description of requirements for e-Learning based on the conceptual model of "people doing activities with resources". The emphasis on activities is important, both from a pedagogical perspective as well as from an educational technology perspective, as the XML describes how the different activities should be organised. This includes which roles the different users in the learning scenario have, how the activities will flow during the learning scenario and when and how the users will use the different resources available to them.

This subsection's main purpose is to provide the ideas on how to create a framework and architecture for the reuse of content and pedagogical methods. This will be based on exploration of IMS LD and its ability to model collaborative learning processes and how it is possible to extract such processes from the LR.

IMS LD

IMS LD is not a tool or environment, but a specification that provides a model for developing LOs and VLEs [2A]. IMS LD describes tasks and activities, their assignment to roles, and the flow of activities that constitute a course module or lesson known as “Unit of Learning” (UoL). The specification consists of three documents:

- The XML Binding Document.
- The Information Model.
- The Best Practice Guide.

The XML Binding Document is a technical document detailing how IMS LD elements are represented in XML. The Information Model presents the vocabulary of and the functional relationships between the concepts, the different IMS LD elements and the set of runtime behaviours that delivery systems must implement. The Best Practice Guide presents some use cases that represent various types of learning scenarios as a way of informing teachers that want to create course modules and lessons with tools based on IMS LD.

IMS LD grew out from work done at the Open University of the Netherlands (OUNL) that began to develop the Educational Modelling Language (EML) in 1998. The origin of EML was to develop a semantic notation for complete units of study to be used in net–based learning. The concept of “unit of study” is the smallest unit that provides a learning situation for students. It cannot be decomposed into smaller parts without losing its educational meaning. A whole study program, a course, course module or a lesson; they are all examples of units of study. This implies that content material such as videos, images and exercises cannot be isolated from the educational context in which they are used. Based on educational research in the fields of learning psychology and instructional design, the EML team created a meta–model that could express commonalities between different types of learning.

The meta–model contains four packages:

1. The learning model.
2. The unit of study model.
3. The domain model.
4. Theories of learning and instruction.

The learning model describes how learners learn based on commonalities between learning theories. Based on axioms on how learners learn and act, the learning model raises questions concerning the kinds of activities learners carry out when learning, and aspects of motivation and results.

The unit of study model represents aspects that a learning designer has to take into account when designing a unit of study. Roles, learning objectives, prerequisites, learner characteristics, learning domain, learning context and assessment are all considered important aspects.

The domain model represents the characteristics of the subject domain (e.g. mathematics, history etc.). Different domains embody different cultures for learning and have their own way of dealing with knowledge and skills.

Together, these four packages form a meta–model (Figure 3). Important aspects identified are learning objectives, roles (both learners and staff), activities and environments (containing services and content material).

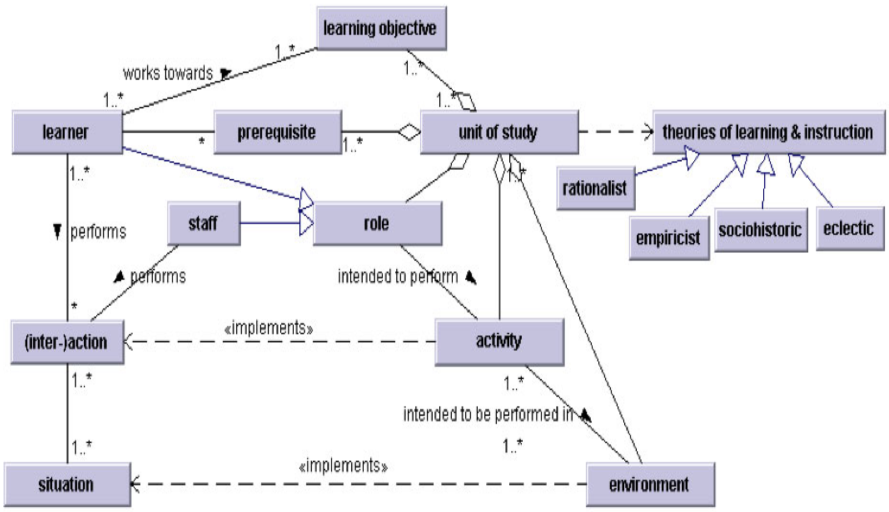

Figure 3. *EML pedagogical meta–model [26]*

The work on Educational Modelling Languages (EMLs), and their subsequent integration in the IMS Learning Design Specification, is the most important initiative to date, to integrate Instructional Design preoccupations in the international e-learning Standards movement. The EML concept challenges the over importance devoted to LOs seen solely as information packages [88].

At the same time as EML was being developed, IMS worked on a number of e-learning specifications, mainly targeting support processes for learning rather than the learning process itself. By early 2001, IMS had reached the point where it recognised the need for a specification that addressed the description of learning processes and set up the Learning Design Working Group. It had an ambitious scope that could only be met in a reasonable timescale if it was based on existing work. EML was submitted to the Working Group in the second quarter of 2001. EML was a very complete and mature specification, focused on the entire learning process and was thus complementary to the specifications developed by IMS [78]. The IMS LD working group dropped the content specification for marking up materials used in the learning process, and extensions for multimedia, assessments and learner interaction with the runtime system, but the meta–model was kept and is currently the data model of education in IMS LD.

IMS LD's concept of a learning module, lesson or course is called "Unit of Learning" (UoL). A UoL is basically an IMS Content Package where the Organizations element (that defines the structure of the overall learning experience) is IMS LD specific (see Figure 4).

One of the basic aims of IMS LD specification is to enable the abstraction of different learning design approaches into a meta–language that will represent and allow the interchange of practically any learning scenario. The meta–language when designing LOs is an important point, because it strongly affects the usefulness, interoperability and reusability of a LO and its assets.

UoL itself and all its components are embedded LOs, including learning objectives, prerequisites, learners' or trainers' roles, activity assignment, information objects, communication objects, tools and questionnaire objects [81].

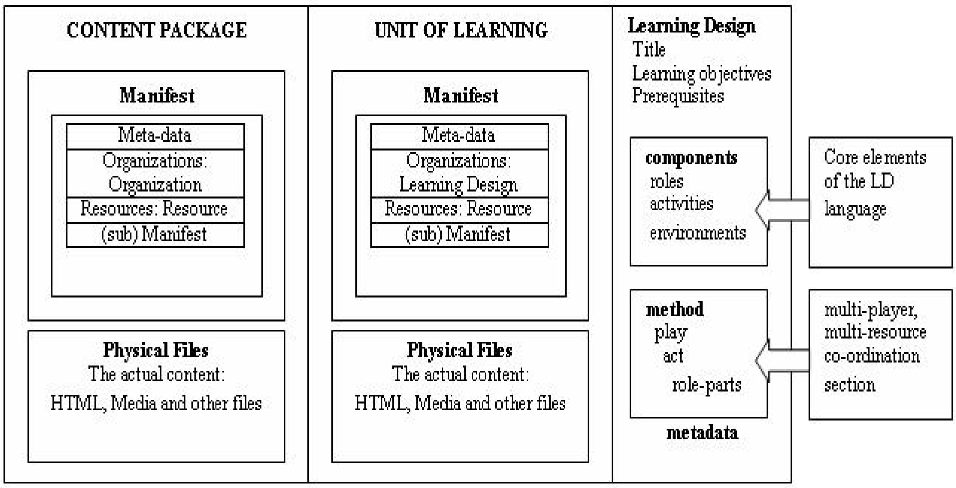

Figure 4. *IMS LD's location in IMS Content Package and structure of IMS LD elements [78]*

Identifying the LOs associated to a UoL and the interrelations between them is not sufficient from a technical perspective. The IMS LD information model needs to be expressed in a standard XML binding enabling computer processing by any compliant e-learning system. It should then be possible for any VLE to interpret and use the unit of study, reuse the LOs composing the unit in new contexts, as well as adapt, distribute and archive UoLs and all the LOs they contain.

A UoL refers to any delimited piece of education or training, such as a course, a module, a lesson.

When activating a UoL, the method element is central. It is located within the UoL set of XML files. This central element and its sub–elements control the behaviour of the UoL at runtime, coordinating the activities of the actors in the various roles they play and in their use of LOs. A method is composed of plays that provide alternative scenarios for the same unit of study, to adapt to different target populations or to different delivery models such as distance or classroom learning. Each play unfolds in a series of one or more acts which are always run in sequence. An act brings together one or more role–parts, each role–part associating exactly one role (learner, trainer, tutor, manager, etc.) with exactly one activity, associated or not to a set of LOs. At every level within a method, it is possible to specify rules when a role–part, act, play or UoL is completed [81].

IMS LD consists of a set of components that plays together during a method. Key components in IMS LD are roles, activities, activity structures, environments, properties and conditions.

Roles: In IMS LD there are two predefined roles, a learner role and a staff role. Each one of these roles can be further specialised into sub–roles. For example, in a learning scenario students can have different roles. Each role can then be assigned to different activities.

Activities: in IMS LD, activities are associated with a role and they contain the actual instruction for a person in that role. There are two types of activities; learning activities that are directed at a student and aim to achieve a specific competence and support activities where students support peer–students or a teacher supports the students.

Activity Structures are basically aggregated activities that can reference other activity structures, environments and UoLs.

Environments are URLs to learning objects and services that can be inside or outside the UoL. Students typically use learning objects when performing an activity, but these objects are not a part of the activity description itself. Services are used to provide facilities that are helpful for completing activities like discussion forums and e–mail systems.

Properties are containers that can store information such as the progression of a student in a course module such as completed activities and results of tests.

Conditions enable designers to define rules that govern the behaviour of a UoL as a whole and what gets presented to individual roles.

The components express a pedagogical method when they are configured in the method section of IMS LD (see Figure 4). Here the role–parts are linked to the different activities and the flow of the activities is created. Metaphorically, IMS LD considers a learning scenario to consist of one or more plays in which there can be one or more acts. The play can be considered a course, a course module or a lesson while the acts specifies which are the activities or activity structures that will be performed and by whom (e.g. a student). During the performance of activities, if learning objects or services are needed, then they will be placed in the environment supporting the activity. Another important part of the method section of IMS LD is conditions that have the form of "If–Then–Else" rules. The "If" part of the condition uses Boolean expressions on properties defined in the component section. Conditions are used to tune the path a student can take through a course module or to personalise a course module against some predefined characteristics.

Besides conditions, IMS LD also contains a notifications mechanism for making new activities available. Notifications can be triggered by a change to a property value, the completion of an activity, or a condition that evaluates to true. The notification can make a new activity for a role or it can send a message to a student on behalf of another student. Notifications can be useful if the input for an activity depends on the outcome of another activity [78].

These component and method sections of IMS LD have been divided into three parts:

- Level A where the core components such as roles, activities and environments are defined as well as the core method parts of play, acts and role–parts.
- Level B where properties and conditions are introduced.
- Level C where notifications are included.

This division of IMS LD into three parts has been created to make it easier for tool developers to conform to the specification when they develop their authoring tool or VLE.

Currently there are only a few tools that are able to reach level C of IMS LD and one of them comes from the RELOAD project that has developed both an editor and a player for editing and running level C compatible UoLs. RELOAD is a JISC funded project developing tools to facilitate the use of emerging Learning Technology Interoperability specifications such as those produced by ADL and IMS. The editor has been developed at the University of Bolton. It approaches editing from a "bottom–up" approach. When developing a course module using a "bottom–up" approach, the designers have to do preparation beforehand (e.g. modelling user interaction using UML). Then the designers can fill in the forms provided by RELOAD editor.

All the physical files that will be included in the UoL have to be created in advance. Then these files can be linked to activities and, when this is done, the designers are able to edit the physical files using RELOAD's built–in text editor. It supports editing conditions in such a way that the representation structure of expressions and actions exactly reflects the element structure of IMS LD specification.

The RELOAD editor is an example of tree–based authoring tools where the elements of IMS LD are presented as a tree structure. An interface is provided for users to navigate through the tree and to enter values for the elements.

There are also graphical oriented tools that use nodes and arrows to represent IMS LD. An example is MOT+ [81, 71], which is developed at Tele–university in Montreal. It enables users to navigate in and construct hypertext documents that make up a learning design. A learning design represented as hypertext documents can be exported as IMS LD XML files.

Reusability of Units of Learning

How can we extract pedagogical methods from a learning design based on IMS LD?

Creating ready–made templates for teachers is a new area of focus within the field of educational technology and was also demonstrated in the CELEBRATE project [11] where teachers used templates [66].

This question is closely connected to work on the reuse of LOs [111] and the more recent work on pedagogical patterns [6].

In IMS LD the idea has been to reuse the elements representing learning processes in different ways. As Colin Tattersall points out in a comment to Stephen Downes critic of reusable LOs [22]: “Using IMS LD it is possible both to take an existing learning design and use it with new content resources (for example applying a learning design for Problem–Based Learning to the areas of medicine, sociology, computer science etc.) or have existing content resources be used with different learning designs (for example having resources on the history of Canada be used in both programmed instruction and competency–based learning approaches)”.

This statement reflects much of the current work done on reuse of IMS LD’s UoL:

- Ready made templates where the teacher fills in desired elements of an “empty” UoL.
- Reusable UoL’s where the whole unit can be exchanged between repositories and modified on a detailed level.
- Reusable elements of a UoL where specific components (like an act or activity structure) are exchanged between repositories and modified [26].

Reusable UoL

When reusing whole UoL’s like LO’s there would be problems regarding metadata for exchange and how a system could give a teacher access to modify the UoL. It is out of our scope here to discuss exchange of UoLs.

Modifying an existing UoL is dependent on the editor's ability to read IMS LD level A, B and C. The editor must also have a proper interface so that the components in the different levels can be modified. At level A the editor should be able to alter the method section as well as all the files referenced in activities and environment section. At level B the editor should allow the editing of properties and conditions that are assigned to the different files and at level C the editor should allow modification of notification.

In LAMS the modification of an existing LAMS course is an easy task. When one imports a LAMS course (one xml file) into the authoring tool, he can instantly start editing each activity component within the design, rearrange the activity components in a new sequence, remove parts of the design or add new activity components. It is ideal for repositories that do not provide readymade "best practice" templates, but rather let the teachers themselves create a community with UoLs. Then the teachers themselves would find the best examples of different pedagogical methods especially designed for their school or community [26].

Reusable Elements within a UoL

A UoL consists of an IMS manifest xml file and corresponding resource files. If one wants to reuse only parts of a learning design he would have to look into the manifest file to identify structures that could be extracted.

Looking only at the activity element would not make any sense because, to this element, one only gives it a title and assign resource files that describe that activity, the learning objectives of that activity and the prerequisites. One can also describe what will happen when the user ends the activity. This could be reused as a possible LO (content), but is unlikely to represent a teacher's pedagogical method.

The activity–structure element does not give any meaning as a pedagogical method either because, in this element, you only group together activity elements, which still have not been connected to role–parts. As Brouns et al. [9] notes: "We expect patterns to occur in the learning design method of a learning design, because the method specifies the teaching–learning process. In order to be as flexible as possible, we need to identify small reusable components in the method section. Acts are the smallest, independent sections within a method."

We should, therefore, look at the elements in the method section where the design actually play as learning activities coupled with support activities and role–parts. We could reuse the whole method element, but that would basically be the same as reusing the whole LD. However, if we go down to a reasonable granularity level, where there is a sequence of activities connected to role–parts, we can focus us on plays and acts. Both these elements have a granularity level that makes them reusable. In [26] example of case the authors have only one play and two acts. As they demonstrated in the template example they would be able to reuse the whole play.

And in a "big" learning design, where there are many concurrent plays, this could make sense.

We could also go down to the level of acts where many activities play together with role–parts and reuse these containers of meaningful learning processes. In [26] case they had two acts: one individual and one collaborative. To reuse the individual act, they would have to extract the act–element where the different role–parts are embedded and also have to be extracted. These role–parts are connected to activity structures that consist of activities and their referenced resources. Elements for activity structures, activities and resources would then have to be extracted as well. Every connection between these elements is done through an "id" property of the element itself and a "ref" property to the element it is connected to. The elements of plays, acts, activity structures, activities and resources are all at level A of IMS LD.

However, if they were to reuse these elements in a learning design on level B, they would have to be able to extract all the conditions (if–then–else elements) where the activities we extracted played a part. This should be possible because all the activities that belong together in an act also have their "if–then–else" condition elements logically grouped together. These "if–then–else" condition elements also refer to their corresponding activities through their "ref" property defined in the manifest file and a "class" property referred in corresponding activities' resource file. The "class" property is typically used to show/hide parts of a page [26].

Reusing Whole or Parts of a Learning Design

Reusing a whole UoL in tools like RELOAD is obvious as it supports all three levels of IMS LD. Most tools that are close to the specification should be able to represent a learning design, although there could be interface problems.

Reusing parts of a learning design is, however, a greater issue. Currently there is only one tool that supports the reuse of parts of a learning design.

MOT+ [81] is a tool that uses a specialized type of diagram that attempts to represent knowledge in a wide variety of domains, including learning design, as a collection of meta–knowledge objects linked together by concepts such as instantiation, composition, specialization, precedence and regulation. Essentially a rich UML diagram, initially developed for an instructional engineering system,

Paquette's [81] LICEF group has added enhancements to enable MOT+ to serve as an IMS LD editor.

The MOT+ editor provides a hypertext based user interface for creating Meta–Knowledge Model Diagrams with different modes for different domains. In the IMS LD mode, they support level A constructs, including play and act. If already familiar with Meta–knowledge representation, this tool reduces the time to create learning design diagrams and the learning curve for using the tool is very short. However, if users are not already familiar with this way of representing knowledge, it could be difficult to choose the correct link type from the wide variety of available links.

To reuse parts of an IMS LD structure, a designer could simply cut an act from one learning design document and paste it into another learning design document thus reusing that specific act. That act would still keep its internal model intact.

3.2. Recommendations for European Learning Resource Exchange System

European LRs implementation in education policy is based on the EUN Learning Resource Exchange (LRE). Here are the main principles of this policy:

- Learning resources are described using open learning object metadata standard LOM for expressing metadata about learning resources.
- Federated search engine to search for learning resources is implemented (to run search in all LO repositories, connected to each other).

The term "learning resources" here includes learning objects and smaller parts (pieces) they can be combined of – learning assets [10A].

The LRE is a service that provides the means to unlock the educational content hidden in digital repositories across Europe and share it among all partners of the LRE and their users. The service is offered to actors providing digital content: Ministries of Education (MoEs), regional educational authorities, commercial publishers, broadcasters, cultural institutions and other non–profit organisations who are offering extensive but heterogeneous catalogues and repositories of online content to schools. Exchange system is implemented by connecting national LO repositories of various countries to the federation system – an infrastructure for discovering and exchanging LOs, where each partner remains in control of LOs and their metadata.

Core services provided by the LRE system are:

- LR discovery.
- LR exchange (including DRM).
- LR semantic interoperability [7A].

The quality of the former two services depends on implementation of the latter service – semantic interoperability of the resources. Therefore a lot of attention is channelled to research and practical solutions forming in this domain.

Semantic interoperability problems appear when users can't find a relevant resource, find irrelevant resource, misinterpret or don't understand the learning resource itself, or don't understand the metadata (e.g. purpose, copyright, technical requirements, intended audience) and/or evaluate the learning resource wrongly. It is being looked for the best solutions of the semantic interoperability problems. For example, some of proposed solutions might be: development of controlled multilingual vocabularies (terms and their meanings, as well as context), multilingual thesauri (currently 14 languages and about 1200 terms are included into European thesaurus), terminology and curriculum mappings, tracking of end user tagging, using of machine translation, developing resources with future localisation in mind, localisation of the resources, resources metadata automatic production from observation of user behaviour.

One of LRs semantic interoperability issues is design of truly multilingual service. This includes all possible solutions mentioned above concerning learning content, and properly internationalised and then localised interface of service implementation, e.g. portal [7A].

A new content service for schools

The LRE is a new service that will enable schools to find educational content from many different countries and providers. It initially includes content from MoEs and other partners that are working with EUN in the EC–funded CALIBRATE [10] and MELT [68] projects.

Approximately 40,000 learning resources and over 100,000 learning assets will be available when the full service is launched at the start of 2008. Additional resources from LRE Associate Partners in both Europe and the USA are already starting to be included in the LRE and the amount of content that schools can access will grow rapidly.

Providing open educational content

LRE content comes in all different sizes, shapes and languages. It includes both larger or more complex LRs as well as smaller learning assets (which might just be an individual photo, a short piece of text or an small audio file). Teachers are also encouraged to submit lesson plans related to LRE content and, later on, will be able to upload resources they have developed themselves.

The LRE has resources on virtually every curriculum subject and includes those directly produced by or for MoEs and other public bodies, as well as resources developed by teachers themselves. Some private sector organisations are also contributing content that can be freely used in schools. All LRE content can be thought of as “open educational resources” or educational materials and resources that are offered freely and openly for anyone to use and in some cases they can also be adapted and redistributed.

Transparent to the teacher

Teachers do not need to understand anything about the LRE architecture or how it works. They simply carry out a search on the LRE portal itself or, if their national or local repository is part of the LRE federation, they can search for LRE content without going to the LRE portal at all.

Technical Description of LRE

From a technical standpoint, the LRE consists of an infrastructure based on a "brokerage system" to which independent systems (e.g., learning resource repositories, educational portals, learning (content) management systems) connect to share learning resources in a federated way.

This architecture has been adopted because it offers maximum flexibility: it is decentralised enough to allow content providers to manage their collections autonomously, and is secure enough to ensure the trust needed when dealing with content for school pupils.

Figure 5 shows the LRE architecture. The backbone of the federation is a brokerage system, named "Limbs Is My Brokerage System" (LIMBS), to which repositories of learning resources and educational portals connect thanks to a client java library (depicted as a grey bar) that encapsulates the different networking protocols behind standard application programming interfaces (APIs).

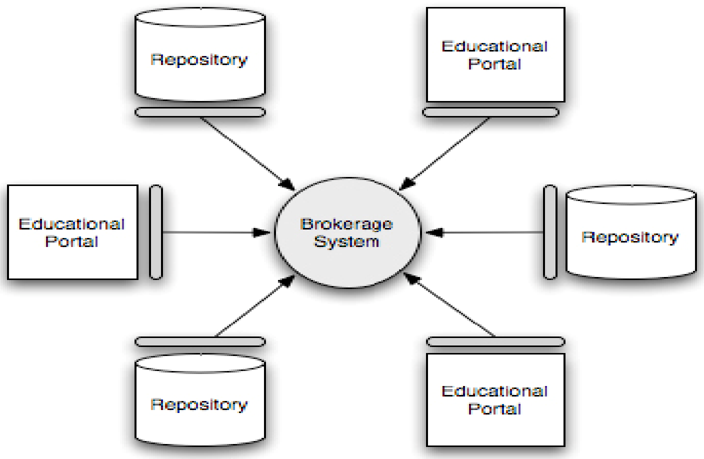

Figure 5. *The LRE technical architecture [64]*

LIMBS and its client are released under the Lesser GNU Public License (LGPL). The decision to open up the code of the brokerage system was motivated by the desire to:

- Foster adoption: An open source brokerage system provides a guarantee to the members of the federation that their integration efforts will not be lost. It gives them the possibility to influence the solution that they adopt and enough control over it to ensure its continuation.

- Foster development: The involvement of a larger community of developers and public scrutiny of the source code shortens development time and improves the quality of the code and documentation produced. Moreover, the community helps to make sure the developments are in line with users' requirements.
- Promote the federated model outside the e-learning community, by encouraging the adoption of LIMBS by other communities (e.g., digital libraries).

A variety of open source licences were considered for the release of the LIMBS code. LGPL was chosen because it allows both commercial systems and pure open source systems to use the client and join the federation.

The LRE is organised as a set of independent services (e.g., metadata exposition, resource discovery, resource exchange, digital rights management) that can be combined arbitrarily. At the client side, each service corresponds to a pluggable module with a simplified (and, when possible, standard) interface. When connecting a new system to the federation, one selects the services needed and integrates the corresponding modules. This makes the integration effort proportional to the number of services being integrated. Since the brokerage system is able to automatically discover the services supported by a client, it is possible to transparently add or remove services to any system connected to the federation.

Federated Searching: Metadata Exposition & Resource Discovery with SQI

A federated search consists of an educational portal end–user (e.g., a teacher or a pupil) querying all the metadata repositories available on the LRE for references of learning resources matching the search criteria. The LRE service module that enables federated searches is based on the Simple Query Interface (SQI). SQI is a standard API used to query repositories of learning resources. It is characterised by its independence in terms of query language and result format.

The methods that compose the API are separated into two groups: the source methods that a system (for example an educational portal) must support to be able to send queries and receive results and the target methods that a repository must support to expose its metadata by allowing another system to send it queries. In Figure 6, SQI client modules are depicted as red bars (solid for the source, blended for the targets).

During a federated search, an educational system uses its source SQI client module to send a query from its user to the brokerage system. As a result of SQI flexibility, queries may specify any query language and result format. The brokerage system then propagates the query to all the repositories of the federation that implement a target SQI client module (Figure 6A). The repositories that support the language of the query and the requested result format (i.e., metadata format) process the query and return the results to the brokerage system that then forwards the results to the source SQI client module of the system that originally sent the query (Figure 6B).

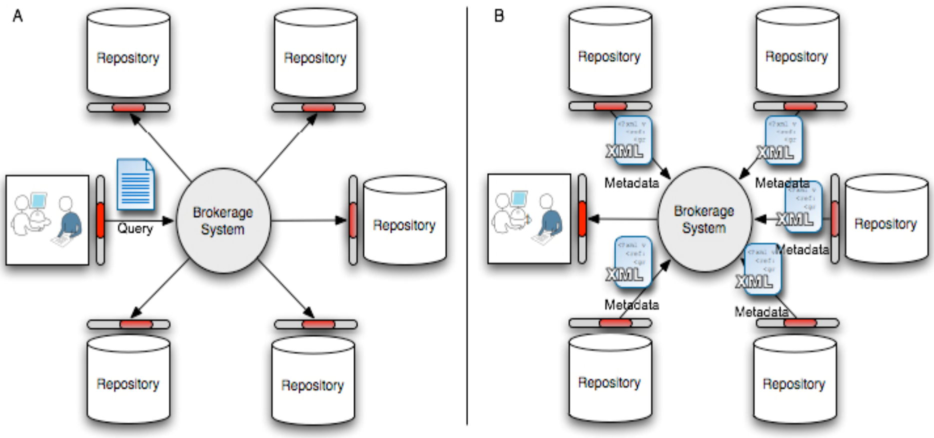

Figure 6. *Federated searching [64]*

Although, thanks to SQI, the LRE provides support for multiple metadata formats and query languages, it proposes its own application profile based on the Learning Object Metadata standard (LOM), known as the LRE Application Profile v3.0 and has its own abstract query language (LRE–QL) derived from the CQL and PLQL query languages. The LRE application profile and query language are adapted to the context of schools in Europe, which permits to the LRE to offer good performances in terms of semantic interoperability in addition to the technical interoperability provided by its infrastructure.

Metadata Harvesting with OAI–PMH

Harvesting metadata consists of allowing repositories to expose their content by having their metadata harvested (i.e., mirrored) by a third party (the harvester). Depending on the harvesting service specification, the mirroring of metadata can be total or limited (selective harvesting) according to various criteria (e.g. collections, time periods).

The LRE proposes metadata harvesting as an alternative to SQI for exposing the metadata of a repository. The harvesting of metadata itself relies on HTTP requests as defined by the Open Archive Initiative Protocol for Metadata Harvesting version 2.0 (OAI–PMH). The latter is complemented by an OAI client module that allows repositories:

- To be registered by the brokerage system so that they can be found by harvesters and
- To ensure that only authorized harvesters get access to their metadata.

In Figure 7, a harvester and 3 repositories negotiate the harvesting of the repository collections with the brokerage system (black arrows). Then, the harvester uses OAI–PMH to harvest the metadata contained in the repositories (blue arrows and bars). Harvested metadata are stored in a harvester repository that implements a target SQI client module. Thanks to the latter, the harvested metadata can be discovered during federated searches as described in the previous Section.

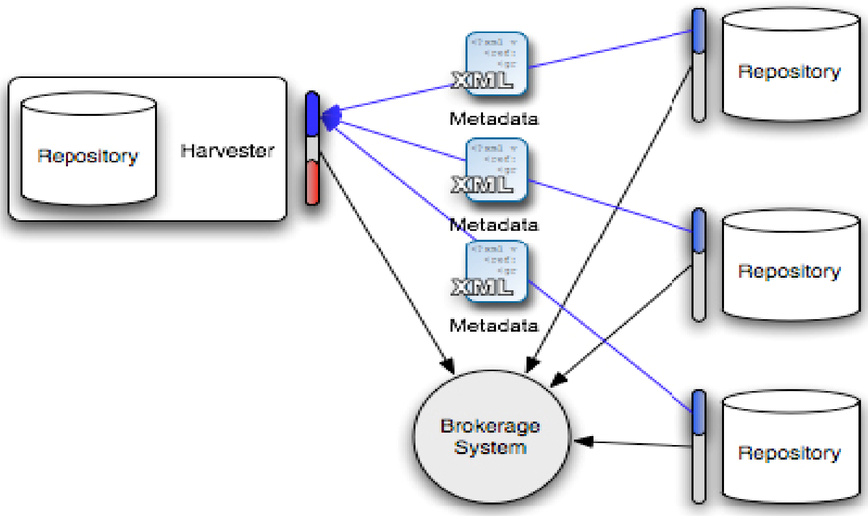

Figure 7. *Metadata harvesting [64]*

Federated Search versus Metadata Harvesting

When choosing whether to support "live" searching, harvesting or both, repository owners should bear in mind that these are not equivalent and each has its pros and cons. During a federated search, the repository is queried in real time, whereas, with harvesting, exposed metadata is gathered into a central cache and it is this cache that is queried. On the one hand, the former means that, during a search operation, a repository can take advantage of unexposed information to process queries more efficiently (unexposed information is information about resources that a repository stores but does not make directly available either because it is not part of the selected metadata standard or because its access is restricted for some reason). On the other hand, it means that, during a federated search, each repository needs to be powerful enough to support the load of processing queries, which, in a federation can be a significant overhead, particularly if the default option for a federated search service is to search all repositories.

Real time searching of repositories will always produce up–to–date results. This is an advantage when collections are volatile with frequent updates. The drawback of live searching is that repositories that are temporarily unavailable at query time, for whatever reason, are ignored. In contrast, when searching cached (i.e. harvested) metadata, complete results are always returned (even if some repositories are unavailable at the time of the query). But the results might be outdated.

The four criteria for selecting which method of exposing content to use are summarised in the table below:

Table 2. *Criteria for searching / harvesting method selecting [64]*

Criteria	Harvesting	Searching
Up–to–date results		+
Completeness of results	+	
Usage of unexposed metadata		+
Minimise load on repository	+	

Making a repository interoperable requires some degree of effort and the result is frequently better, in terms of performance and efficiency, when the repository was initially designed to be interoperable rather than when one tries to make interoperable an existing repository that was not designed with interoperability in mind.

For example, specifications for exposing content (such as OAI–PMH and SQI) allow their clients to select the metadata format to be used to answer a request. This requires the efficient export of metadata in a standard format that is generally different from the internal format of a repository.

For a repository not designed for this purpose, this is generally not an easy task. Similarly, to be fully supported, OAI–PMH requires a repository to keep track of deleted metadata records. Generally, repositories that have not been explicitly designed to support OAI–PMH do not support this feature. These issues need to be taken into account when choosing a repository.

Digital Rights Management (DRM)

The main objective of the Digital Rights Management mechanisms supported by the LRE consists in providing all the necessary components to support as many business and distribution models as possible. A second objective consists in making possible their progressive adoption: although the protocol supports many possible use cases, it is really up to the LRE members to decide up to what point they want to implement DRM.

The basic principles behind the LRE Digital Rights Management protocol are the following:

- No Digital Rights Expression Language (DREL) is required.
- Content providers have full control on the distribution of their assets.
- The DRM access protocol is built around a simple message exchange made of a “Use Request” and “Use Response” message.
    - In a “Use Request”, the requestor has to provide information about himself, called “context”; this context is meant to carry all necessary information to the content provider to allow him to take an access decision. For instance, this context could contain the affiliation of the requestor, his country, his identity, or his role.
    - In a “Use Response”, the provider provides his response to the use requestor. If access to the content is denied, the reason should be included in the response. If access to content is granted, the provider must provide all necessary information for the requestor to access the content. This access information is packaged in a piece of data called the “handle”.

All the complexity of the DRM protocol is hidden in the context and the handle:

- For a very simple open distribution model, the context can be empty, while the handle would contain a simple URL where the content is accessible.
- For institutional licensing, the context would contain the institution of the requestor, so that the provider knows where the request comes from and can thus make a proper authorisation decision.
- More complex models can be built, requiring different levels of information from the requestor.
- Complex content protection schemes can also be put in place; for instance, the handle could point to encrypted content and include a cryptographic key that allows that encrypted content to be read.

The DRM protocol is illustrated on Figure 8. Thanks to DRM client modules (depicted as yellow bars) resource requestors and providers can communicate under the supervision of the brokerage system that acts as a trusted third party. Requestors send use request messages to the brokerage system. Each of these messages contains a reference to the resource that a requestor wants to access and a description of the context of this requestor. The brokerage system checks the authenticity of requests and forwards them to providers. Based on the information contained in requestors’ contexts, providers can decide to authorise requestors to get access to resources by returning handles to the brokerage system that forwards them to the appropriate requestors.

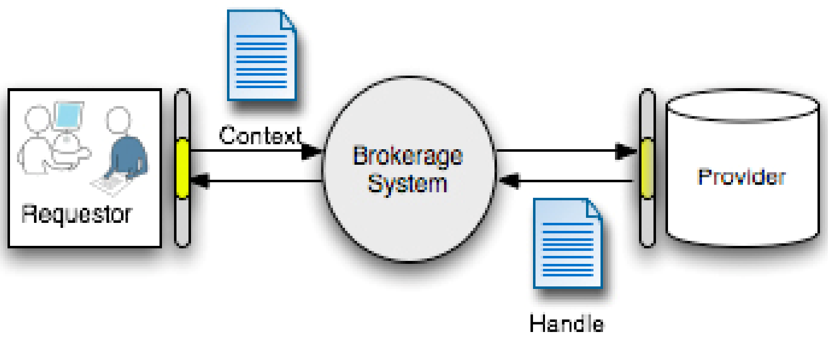

Figure 8. *Digital Rights Management [64]*

The LRE as a Federation of Federations

The LRE is not a closed world. It can be interconnected to other federations. Figure 9 shows examples of such interconnections.

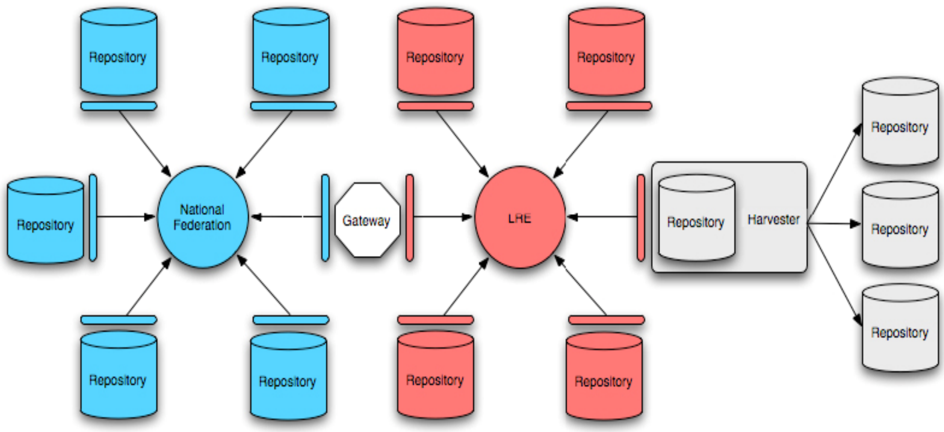

Figure 9. *The LRE as a federation of federations [64]*

The LRE, depicted in red, is connected to another federation, depicted in blue, thanks to a gateway that is connected to both federations through their respective client modules. In this case, the gateway is responsible for turning one federation's requests and responses into the format supported by the other one and the inverse. The LRE is also connected to another federation, depicted in grey, by connecting to the repository that contains all the metadata harvested in that federation.

The LRE Today

The LRE is being primarily developed within the CALIBRATE and MELT projects with support from the European Commission's IST and eContent*plus* programmes. By the end of 2007, it is anticipated that up to 20 repositories will be connected or making available a critical mass of open educational resources via a publicly available LRE service for schools.

Partners that will initially contribute content to the LRE are:

- 16 Ministries of Education and/or ICT agencies acting on their behalf in: Austria, Belgium (Flemish community), Region of Catalonia (Spain), Estonia, Finland, Germany, Hungary, Iceland, Ireland, Israel, Italy, *Lithuania*, Poland, Spain, Sweden, Slovenia.
- The ARIADNE Foundation.
- Commercial providers such as Cambridge–Hitachi (UK) and Skolavefurinn (IS).

By the end of 2007, both projects will also start to make available additional learning resources and assets from a diverse group of LRE Associate Partners.

The LRE Application Profile

The Learning Resource Exchange uses a LOM–based Application Profile that has been specifically designed for schools and tested in large–scale validations in several countries. As part of the application profile, a number of multilingual vocabularies may be used. The most extended one is the vocabulary to describe the subject of a learning resource. Here we can offer the LRE Thesaurus that helps automate part of the translation work for learning resources that have been indexed in one language.

LRE LOM Application Profile v3.0:

- Defines mandatory, recommended, and optional LOM elements.
- Is based on Controlled vocabularies:
    - Token form + translation.
    - European school sector specific (e.g., age range).
- LRE Thesaurus (discipline).
- Curriculum mapping (competency).
- Information model = federated schema.
- XML binding = exchange format [59].

Building a Learning Resource Exchange for Schools

The vision for a European LRE for schools has emerged directly out of EUN's work with its supporting Ministries in CELEBRATE [11], FIRE [30], CALIBRATE [10] and MELT [68].

The active participation of a large number of MoE in these projects seems to indicate that EUN work related to interoperability and content exchange is of strategic importance.
EUN has also gained international recognition for its activities; the recent OLCOS report even goes so far to suggest that: “The most important Europe–wide (and potential global) player in e-learning content may become the European SchoolNet (EUN) through their European Learning Resource Exchange which is currently under development” [77].

The essential point for MoE is that the LRE represents a framework that supports semantic and technical interoperability of content repositories and adds value to national content strategies by providing:

- Federated search from within national portals.
- Access to high quality content from other MoE and international partners.
- An open architecture that MoE can implement locally with support from the EUN Office.
- Open source tools (e.g. for collaborative authoring, social tagging and curriculum mapping).
- Opportunities for MoE to monitor/apply new interoperability standards and specifications.

The LRE vision also does not assume that all learning resources from national repositories will “travel well” and can be used in different national contexts. But, there appears to be a growing appreciation by Ministries participating in CALIBRATE and MELT that some learning resources developed in one country have the potential to be reused elsewhere.

Validation of LRE Service in Lithuania

Two CALIBRATE project tools validation days were held in Lithuania: (1) October 24, 2007, Druskininkai – 30 participants; (2) November 30, 2007, Vilnius – 11 participants. Totally 41 teachers participated from 21 schools from all over Lithuania.

The following subjects’ teachers have participated mostly: Mathematics – 14 teachers, Information Technologies – 11, and Physics – 6.

One of the validated tools was CALIBRATE portal. Portal’s usability and different LOs search strategies implementation level were evaluated mostly. The main results of CALIBRATE portal validation are following.

Question 3: Please rate your level of experience with different ICT–related activities below

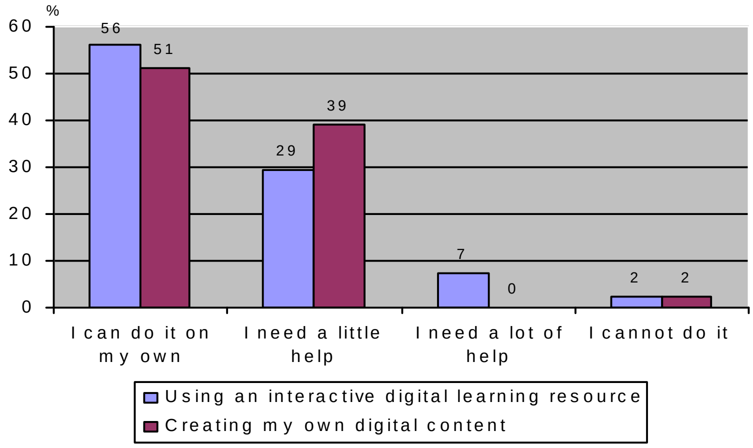

Figure 10. *Teachers level of experience with LOs*

85 % teachers can (re–)use LOs, and 80 % can create LOs by themselves with no or little help.

Question A.2: Advanced search: Rate what kind of sorting is the most useful for you

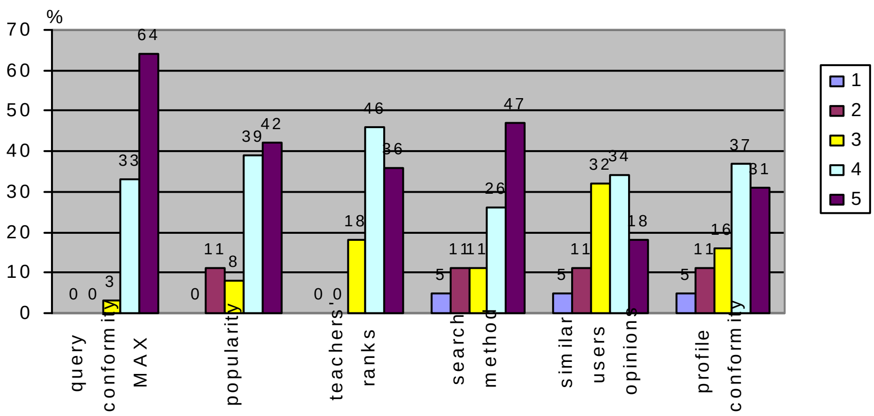

Figure 11. *Kind of LOs sorting most useful for teachers*

Here and below the teachers were asked to put the number in the appropriate box: from 1 (not useful at all) to 5 (very useful).

We see that 97 % teachers prefer (i.e. find it useful and very useful) full query conformity, 82 % would take into account other teachers ranks, 81 % prefer LOs sorting adequate to search method, 42 % would take into account LOs popularity, 68 % prefer LOs sorted accordingly with their profile, and 52 % would take into account similar users opinion (tagging).

Question B.2: How will you use the resource?

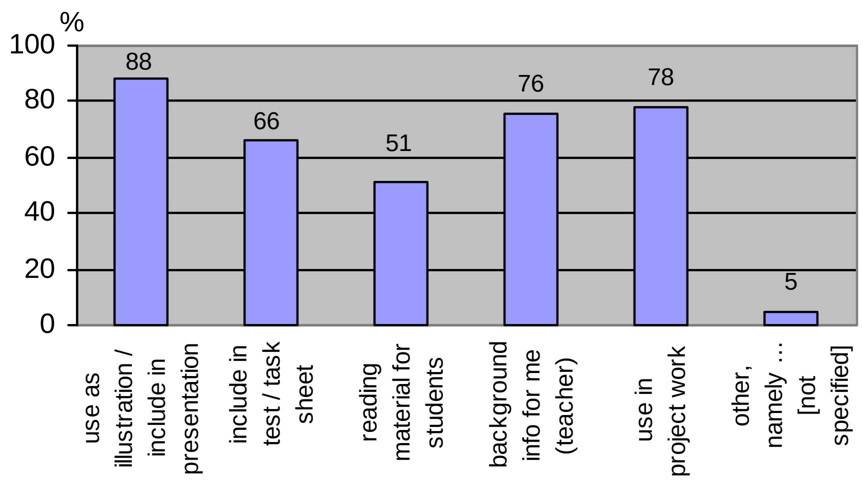

Figure 12. *How the teachers will use LOs*

Most of the teachers would use the found LO as illustration or include it in presentation (i.e. as Learning Asset), in project work, as background information, or include LO in test / task sheet.

It is obvious that the majority of teachers prefer to reuse "small" Learning Assets, and they intend to reuse the majority of LAs in another way and in another learning context than it was primarily designed by LAs authors.

From the analysis of Figures 11 and 12, we could suppose that the majority of teachers prefer to have the mechanism of advance search of ultimately reusable resources. Therefore it is extremely important to identify LOs metadata standard's elements suitable to describe LOs reusability level, and to develop software for such kind of advanced search in the repositories. It is clear that these elements are extremely important to fill in while creating LOs metadata.

Question B.4: Were you satisfied with the material(s) you found?

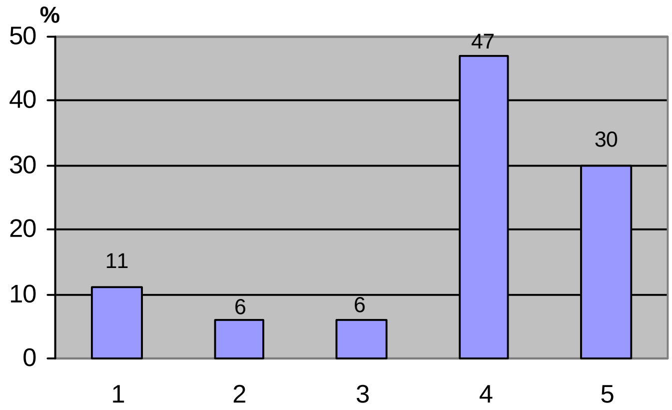

Figure 13. *Level of teachers satisfaction with LOs they found in LRE*

We see that 77 % teachers were satisfied or very satisfied with LOs they found in LRE portal.

Question B.5: Would you find this material(s) again?

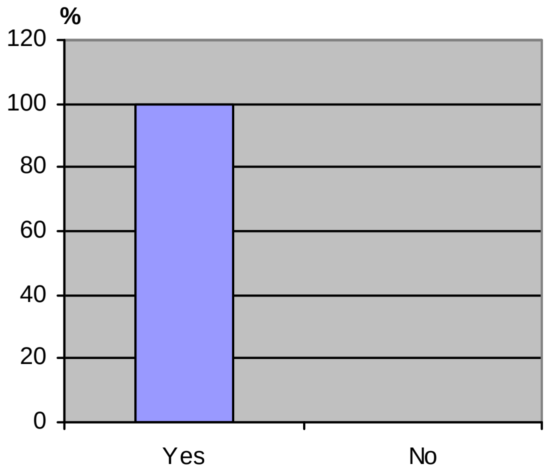

Figure 14. *Teachers capability to find the LOs again*

We see that all teachers would find the LOs again in LRE portal.

Question B.6: Would you use this system again?

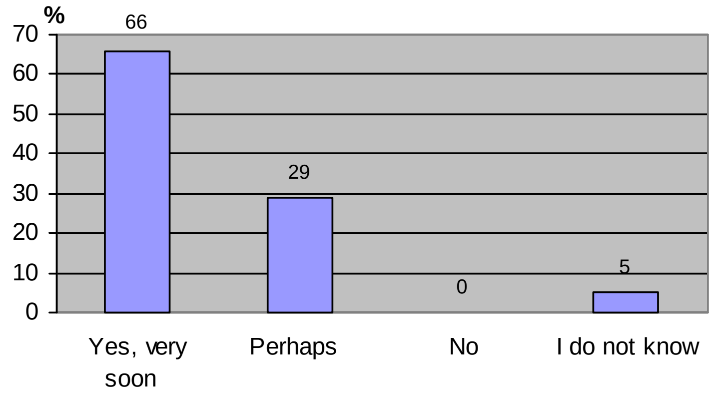

Figure 15. *Teachers capability to use LRE system again*

We see that 95 % teachers would use LRE very soon or perhaps, only 5 % do not know.

LRE validation in Lithuania has shown that the teachers prefer LOs from national repositories which have the potential to "travel well" and can be used in different national contexts. These reusable LOs preferred by the teachers are mainly "small" decontextualised Learning Assets. Therefore in order to maximise LOs reusability in Europe LRE should consist mainly of decontextualised Learning Assets.

There are two main conditions for LOs reusability elsewhere:

- LOs have to fit different countries' national curricula.
- Different countries' LOM application profiles have to be oriented towards quick and convenient search of reusable LRs.

The main tools for this (curricula mapping and guidelines for LOM AP) will be presented in the next sections. Approaches concerning application profiles and curricula mapping (incl. controlled vocabularies) are the main while creating any metadata guidelines or strategies [88]. Indeed, LRE at the moment contains about 140.000 high quality LOs, and the main problem is to provide more quick and convenient suitable LOs search possibilities in the repositories for the users.

Therefore the recommendations to curricula mapping and LOM AP are the main in the author's DLE interoperability guidelines.

LRE validation in Lithuania has shown that the majority of teachers prefer to have the mechanism of advance search of ultimately reusable resources. Therefore it is extremely important to identify LOs metadata standard's elements suitable to describe LOs reusability level, and to develop software for such kind of advances search in the repositories. It is clear that these elements are extremely important to fill in while creating LOs metadata.

3.3. Recommendations for Curricula Mapping

Semantic interoperability and reusability in comprehensive curricula–based education could be ensured if we could provide mechanisms where a meaningful entity in a country's curricula can be mapped to a meaningful entity in the other countries' curricula [1A, 2A].

CALIBRATE approach is an ontology covering a common set of features for LOs and curricula. This is a three aspect classification model describing topic, goal and activity features (TGA). For curriculum analysis:

- The "T" refers to the topic of a part of the curriculum.
- The "G" refers to the desired level or competence that learners should obtain.
- The "A" refers to intended and prescribed learning activities by the pupils as part of the competence descriptions [1A].

The descriptions of pupils' learning activities, "A", are integrated parts of the goal/competence statements in the curricula. In general the "A's" are described by nouns expressions, e.g. to measure, to construct, to illustrate etc.

To capture the semantic of curricula cross Europe we need to classify them according to at least T, G and A. Other contextual factors to avoid ambiguity have to be presented in LOM profile. It is suggested to use topic and its sub– and related topics (e.g. mathematics, algebra, geometry) to conceptually map a national curriculum.

However, this is not enough. While analysing the different national curricula CALIBRATE researchers have discovered that they also have competencies embedded and these are connected to certain learning activities. For the knowledge organisation system to represent a precise meaning of a curricula it must take into consideration both competencies and their implicit learning activities (e.g., *four main concepts for describing goals in Mathematics curricula were identified: Acquire, Apply, Create and Participate (revised Bloom taxonomy)*; for each of the main concepts there are 4–9 concepts that are narrower in definition).

We could use TopicMap as a tool for navigating in the document structure, based on the semantic information contained in the document. Based on the tagging the systems could perform different types of queries based on the classification, and/or based on the different tagged information elements within a part of the document.

We choose to represent the curricula document in XML, which also gives us the possibility to use a vast amount of tools and applications for navigating and processing this information, there is a number of XML standards that would be useful. Since all the XML tools and the different formats for processing the curricula, and the curricula are in XML format, it will give us an advantage of reuse of tools and methodologies between the different "systems", since both Topic Map, RDF, SKOS and the curriculum have the same format. When you browse the curriculum using Topic Map, and select a node, based on the semantic tagging of that part of the document, you should get a list of "Goal oriented words" and a list of "Topic oriented words" – based on the combination of this information and the TGA classification a set of LOs should be provided.

Identification of Goal oriented words could facilitate:

- semantic enrichment, gives possibility for automatic searches in keyword, classification and description of LOs;
- communities to annotate directly to Competency / Goal placeholders in the curriculum.

Identification of topic related words could facilitate:

- communities to annotate relevant learning resources directly to the curriculum;
- more advanced searches;
- more advanced browsing [96].

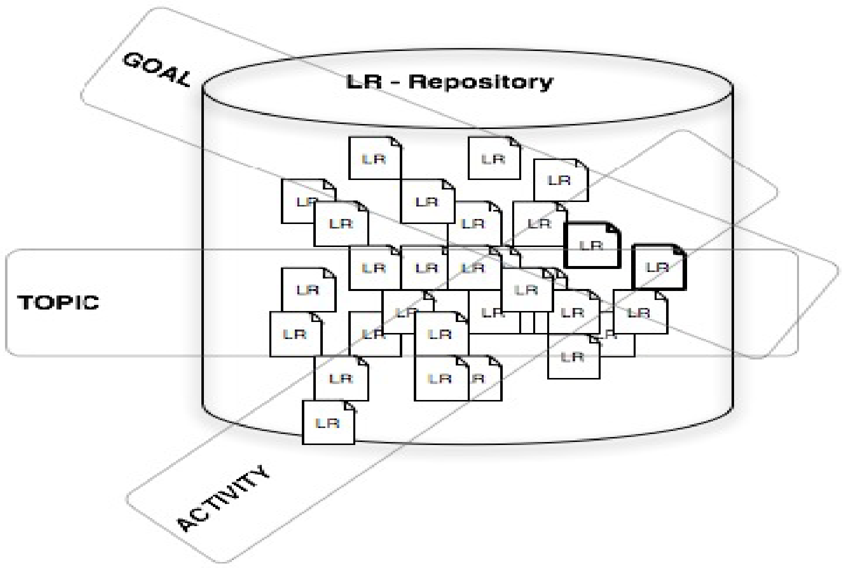

Figure 16. *Search in LO repository using TGA ontology [96]*

Lithuanian Mathematics curriculum for elementary and basic levels was chosen as a pilot for mapping in CALIBRATE, and it was mapped against learning goals in conformity with revised Bloom taxonomy in October 2006 during the project workshop in Prague.

Curricula Mapping: Problem Statement

While much progress has been made in improving semantic interoperability in order to discover, evaluate, and use learning resources, teachers in primary and secondary schools have constantly and consistently pointed to the requirement of being able to do this in terms of their national/regional curriculum.

More in particular, given that a LR is properly metadata tagged using one national/regional curriculum, can the LR be discovered and can the metadata be shown to another teacher in terms of her own national curriculum, such that it eventually can be used in order to meet the goals of the teacher's national/regional curriculum?

We consider mapping approach to be the most suitable for solving the problem [106]. A mapping is provided between the different curricula such that if a LR is metadata tagged according to one curriculum (e.g. the Austrian curriculum), it can be discovered and shown in terms on another curriculum (e.g. the Lithuanian curriculum).

A curriculum mapping means that a component of one curriculum can be mapped to a boolean expression of components of another curriculum. This mapping can be done in two ways: relating all curricula pair wise to each other or relate all curricula to a common spine.

Apart from the mapping challenge there is the question of relating curricula to educational content both for metadata tagging and for discovery.

So essentially the challenge covered in section is threefold:

- *How can we map curricula to each other. This deals with the semantic interoperability of curricula in order to avoid the tagging of LRs according to all existing curricula.*
- *How can we relate curricula to LRs. This in order to offer teachers to discover, evaluate and use LRs in terms of their familiar curriculum.*
- *How can we find LRs based on curricula and competencies.*

Interoperability of Curricula

Curricula may contain a number of elements but *the most important element is the set of educational goals.* The best way to establish interoperability is to translate these goals into a common language. Obviously, *if a goal can be broken* *down in smaller parts, the likelihood of finding common ground is higher than when using more complex goal expressions.*

In our approach we favour competencies as the basic building block and this for two reasons:

- it is easier to understand the targeted competencies behind an activity than the other way around; which indicates that competencies are more elementary, and
- eventually learners will be assessed and this will usually be done by testing whether learners can solve problems requiring certain competencies [106].

While many *definitions of competencies* exist, this section follows more closely the definition as used in the Learning Technology standardization world, i.e. as *any form of knowledge, skill, attitude, ability or learning outcome that can be described in a context of learning, education or training.*

Interoperability of Competencies

Thus, the principle part of a curriculum is what students should learn expressed as targeted competencies.

The basic building blocks for targeted competencies are: an action verb expression and one or more topics. The topic might for example be “adding fractions” and the action verb expression might be “understanding” or “applying”.

As such competencies can be expressed as a tuple of the form

$$c = \langle v, \{t1, \ldots, tn\} \rangle$$

where “c” stands for competency, “v” for an action verb expression and “t1, …, tn” are topics [106].

Usually there would be only one topic, but occasionally there will be more than one. For example: “to understand the relative size of the number and effect of arithmetic actions on the number” (from Lithuanian Mathematics curriculum for elementary and basic education translated into English while implementing CALIBRATE project).

The elements of the tuple come from two taxonomies: a topic taxonomy and an action verb expression taxonomy. Hence the problem of interoperability of curricula is reduced to the interoperability of these topic and action verb expression taxonomies and this is the key to the solution as it avoids a too complex spine to which curricula should be mapped.

So the first step is to translate the goals of curricula into competencies. The relationship between the different taxonomies is given in Figure 17.

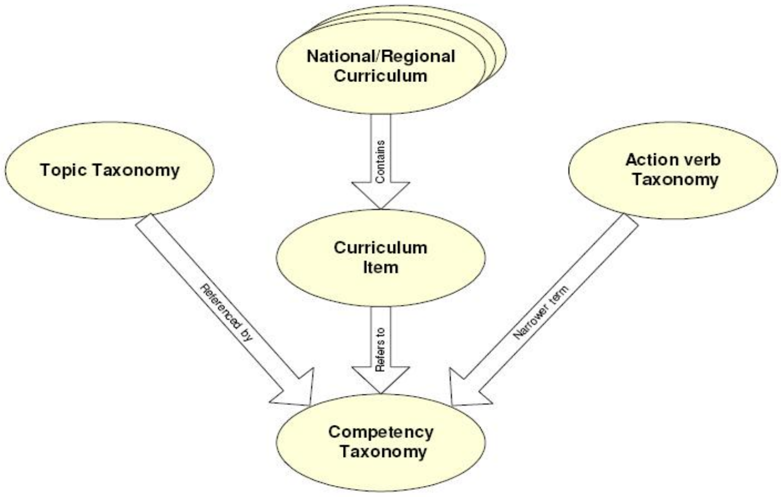

Figure 17. *Relationships of curriculum items and taxonomies [106]*

Lithuanian example

Further the author uses the example from Lithuanian Mathematics curriculum for elementary education:

- Field (topic): Positive numbers and actions therewith.
- Essential abilities (goals): To understand the relative size of the number and effect of arithmetic actions on the number.
- Achievements (2^{nd} grade): Understands the sequence of natural numbers up to 100.

As one can see the expression “understand” has narrower terms “understand the relative size” and “understand the effect of arithmetic actions”. Further refinements are possible by taking different action verb expressions for different topic categories. For example the action verb expressions for mathematics could be different from the action verb expressions for languages. The second part of the solution is that competencies are referenced by terms in the Topic Taxonomy. For example “understand the relative size of the number and effect of arithmetic actions on the number” references the terms “numbers” and “arithmetic actions”.

Semantic interoperability is thus achieved by first expressing curriculum items in terms of targeted competencies, and second by expressing these competencies as tuples of action verb expressions and topics which both can be drawn from a controlled vocabulary.

The fact that two simple controlled vocabularies are used for expressing competencies allows for translation in other languages as well as automatic relaxing search criteria. For example if no LR could be found matching the competency "understands the sequence of natural numbers up to 100" then it could be relaxed to "understand the relative size of the number" climbing up the Topic taxonomy. Similarly it could be relaxed by climbing up the Action verb expression taxonomy. This relaxing mechanism also allows to map curricula even if there is no perfect match.

The example of Lithuanian Mathematics for elementary education curriculum mapping and its relation with LOM AP is presented in Figure 18.

Here two main concepts for describing goals in Mathematics curricula are identified as "Acquire" (yellow colour) and "Apply" (blue colour).

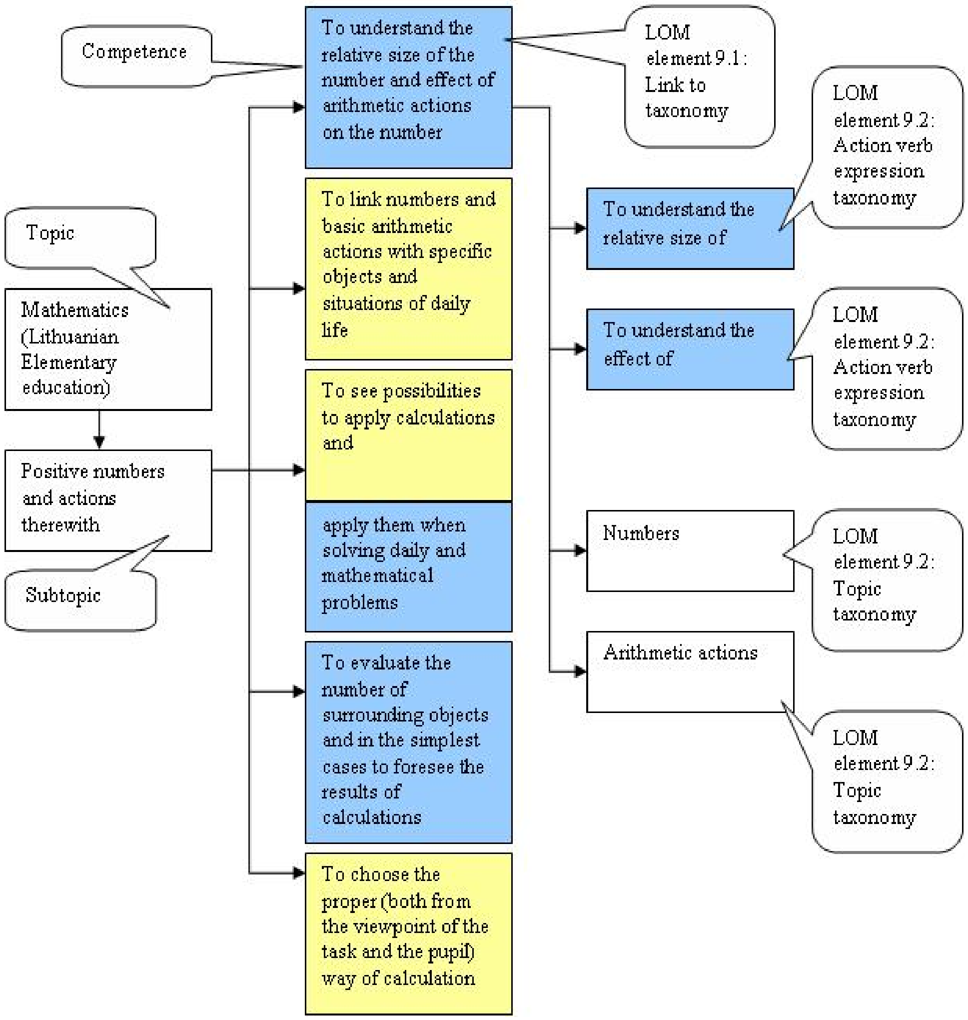

Figure 18. *Example of curriculum mapping and relation with LOM AP*

Linking Curricula to Content

Linking curricula to content can be done in two ways:

(1) An explicit relationship is established between a LR resource and a curriculum item. For example LO 72564 is said to be relevant for the curriculum item “the pupils are able to understand the relative size of the number and effect of arithmetic actions on the number”. More in particular – using concepts from set theory: the relationship is defined between a resource and the extension of a set of related curriculum elements. The extension of a set comprises the members of a set. Alternatively, the relationship is defined between a curriculum element and the extension of a set of related LRs. This can be done as metadata tagging of a LR or the curriculum element. For example a librarian or teacher indicates for which curriculum element the LR under consideration could be used. This may happen before or after discovery/evaluation, or use.

(2) The relationship between a curriculum element and a LR is defined by intension. I.e. the relationship is defined between a LR and the intension of a set of related curriculum elements. The intension of a set is its description of defining properties, i.e. what is true about the members of the set. The set of related curriculum elements could for example be described in terms of targeted competencies assuming that a curriculum element is suitable for the development of one or more competencies. A second way of establishing the relationship between a curriculum element and a LR by intension is that for a given curriculum element the properties of possible related resources are given. For example age, language, subject, targeted competencies of the resource. The properties that can be used for the describing a set of LRs and that are possible related to a curriculum element are: Keyword, Coverage, Structure, Aggregation Level, Interactivity Type, Learning Resource Type, Interactivity Level, Semantic Density, Intended End User Role, Context, Typical Age Range, Difficulty, Typical Learning Time, Language, Classification (purpose being discipline, competence, or activity). Again, establishing the relationship may happen before or after discovery/evaluation, or use.

In the CALIBRATE project the experiment set up is linking a LR in an extensional way to a curriculum item or a competency. The way this is done is by giving the users the opportunity to browse the curriculum and indicate where a LR – e.g. identified through search or browsing – can be used. The CALIBRATE project provides this opportunity to both curriculum experts as well as casual users such as teachers. By doing the latter, social tagging is introduced where the tagging process is guided through controlled vocabularies related to competencies. Hence teachers can indeed browse their own national/regional curriculum and find LRs that are useful in attaining the educational goals and to develop the underlying competencies.

The IEEE standard for Learning Object Metadata (LOM) is used for storing the metadata concerning competencies related to the curriculum. The competencies are stored in section 9.1 of the LOM where it is indicated that the classification concerns a competency and in section 9.2 where terms from an action verb multilingual thesaurus, and from a topic multilingual thesaurus are stored.

Within the project these two thesauri were developed. The action verb thesaurus according to Bloom's revised taxonomy and a topic thesaurus for the subjects Mathematics and Natural Sciences. The thesauri are multilingual thesauri and the competencies can be recorded also in a multilingual way.

Curricula Mapping: Conclusion

The approach makes interoperability possible by making use of two smaller controlled vocabularies instead of a very large one on competencies which would be more volatile. We exchange information on competencies in a multi–lingual and multi–cultural environment by: (1) breaking down competencies, and (2) relating these competency components to multilingual controlled vocabularies. The approach builds on proven technologies, i.e. thesauri, and well–known vocabularies for the action verb expressions and allows for relaxing the search criteria building upon the hierarchical structure of the two vocabularies. The approach can be used for tagging by experts indexers as well as for social guided tagging where the guidance comes from the multilingual thesauri provided. The approach is resilient to change in curricula and to the addition of new curricula. Even a teacher could determine her year plan and be automatically interoperable as long as the year plan is specified in terms of tuples (indicating competencies) of action verb expression and topic(s) which are a subset of the Cartesian product of the terms in the two vocabularies: topic and action verb expression. The approach fits very well with the current practice of describing LOs. Indeed section 9 of the IEEE LOM standard can be used without alteration. For LOM data element 9.1, indicating the purpose, the value "competence" should be used.

One condition to be fulfilled is that curricula are expressed as competencies, which is not always the case. Sometimes they are expressed as activities to be undertaken or simply as subjects to be taught. In that case the targeted competencies should be researched or interoperability can be restricted to the topic vocabulary [106].

The distinct features of the approach as described in this section, makes it very promising and therefore it was no surprise that the first tests in practice held with CALIBRATE curriculum experts in the spring of 2007 were indeed successful. Curriculum experts were indeed able to express curricula in terms of competency tuples and teachers confirmed the usefulness of finding resources on the basis of curriculum items and/or competencies. The evaluation recommendations and results: (1) not one big competency taxonomy but two smaller vocabularies, (2) more resilient to change; (3) using proven technologies – thesauri (subject, revised Bloom); (4) possibility for relaxing the search: the results of the proposed method are substantially better in comparison with the method of trying to find LOs suitable for developing the same competencies with Google (approx 1.5 minutes Vs approx. 1.5 hours).

3.4. Recommendations for LOM Application Profile

The aim of this section is to examine the main international LOs metadata standard EUN Learning Resource Exchange Metadata Application Profile v3.0 [58] necessary for working of flexible DLE, and to formulate the suggestions how to improve this AP to fit flexible DLE requirements.

The improved AP could be approved as Lithuanian LOM AP.

Experimental Survey

LRE AP validation research was implemented by the author during CALIBRATE summer camp in Portorož, Slovenia, in August 2007.

8 Lithuanian teachers–experts have participated in the research. They have created 26 lesson plans for their students using foreign LRs found in CALIBRATE portal:

- 3 teachers of Physics (have created 11 lesson plans).
- 2 teachers of Mathematics (have created 7 lesson plans).
- 3 teachers of English (have created 8 lesson plans).

After that the experts were asked to qualify the used LRs concerning their:

- Pedagogical “decontextualization” level.
- General structure.
- Granularity level.
- LR type.
- LR relation kind.

The results of the survey are the following:

- Lesson plans’ pedagogical “decontextualization” level (are there any pedagogical methods / scenarios / activities included):
  - Physics – demonstration (decontextualized, flexible).
  - Math – decontextualized, flexible.
  - English: – decontextualized, flexible.

It is obvious that the teachers reuse the majority of LOs in another way and in another learning context than it was primarily designed by LOs authors.

- Used LRs general structure (LRE AP v3.0 element 1.7):
  - Physics – atomic.
  - Math – atomic, linear.
  - English – atomic
- Used LRs general aggregation (granularity) level (LRE AP v3.0 element 1.8):
  - Physics – 1 (the smallest level of aggregation).
  - Math – 1 (the smallest level of aggregation).
  - English – 1 (the smallest level of aggregation).
- Used LRs type (LRE AP v3.0 element 5.2):
  - Physics – demonstration, educational game;
  - Math – demonstration, drill and practice;
  - English – demonstration, assessment, drill and practice, project, presentation, reference.
- Used LRs relation kind (LRE AP v3.0 element 7.1):
  - Physics – hasmetadata.
  - Math – hasmetadata; ispartof, isbasisfor.
  - English – hasmetadata.

The results of the research show that *the teachers would mostly like to find pedagogically decontextualised ultimately reusable LOs and therefore to have a service for quick and convenient search of such LOs*.

While searching for LRs in CALIBRATE portal the experts have used browsing by subject and advance search services. These advance search services have not contained any services to ease the search of reusable LRs in the portal. The LRs in the portal are described in conformity with partners LOM Application Profiles, and these Application Profiles have not contained any services to simplify the search of reusable LRs. Therefore it took very much time for the experts to find and choose suitable reusable LRs for their lesson plans.

Proposals for LOM Application Profile

Proposals for LOM AP Concerning Learning Content

These results and other more profound examination of LRE Metadata AP v3.0 [58] based on flexibility requirement for DLE (sections 2.2.2 and 2.2.3) have shown that it would be purposeful to improve LRE AP v3.0 to provide more quick and convenient search possibilities for those searching ultimately reusable e-content and activities components by the means of changing (advancing) the status of a number of LRE AP elements [1A, 5A, 8A].

This principle could be the basic one for preparation of Lithuanian LOM AP.

The examination of LRE AP v3.0 [58] has shown that it is fully suitable for interoperable working of learning content. These “content” LOs could be LAs and other pedagogically decontextualised LOs with more complex structure and aggregation level.

LAs are considered here the main “content” components of pedagogically and organizationally flexible cost effective DLE model providing learning customisation possibilities for its users.

In the terms of LRE AP v3.0 [58] LAs are:

- Mainly “atomic” LOs according to structure (element 1.7).
- LOs with granularity level 1 (the smallest) according to aggregation level (element 1.8).
- “Learning asset” according to educational type (element 5.2).
- LOs having metadata, and having been a part of, or a basis for more complex LOs according to kinds of relations with other LOs (element 7.1) [5A].

In the terms of LRE AP v3.0 [58] other more complex LOs are:

- Collection, networked, hierarchical and linear LOs according to structure.
- LOs with 2, 3 and 4 granularity level according to aggregation level.
- LOs other than “learning asset” according to educational type.
- LOs having more complex kinds of relations with other LOs [5A].

These more complex LOs could be later on combined of LAs in various ways by searching for suitable LAs in various repositories and VLEs and combining them together for different pedagogical processes / scenarios / activities / designs. Creation of such LOs could be suitable for end users in educational institutions, for different projects and problems solving, etc.

The main LRE Metadata AP v3.0 elements which vocabulary values could reflect LOs ultimate reusability deal with structure of LO, its functional granularity (aggregation) level, educational type and difficulty for use as well as kind of relation of this LO with the others [1A].

Therefore it would be purposeful to improve LRE AP v3.0 in order to provide more quick and convenient search possibilities for those searching or browsing for ultimately reusable “content” components by the means of changing (advancing) the status of LRE AP elements listed in Figure 19 and in more detail in Table 3 below.

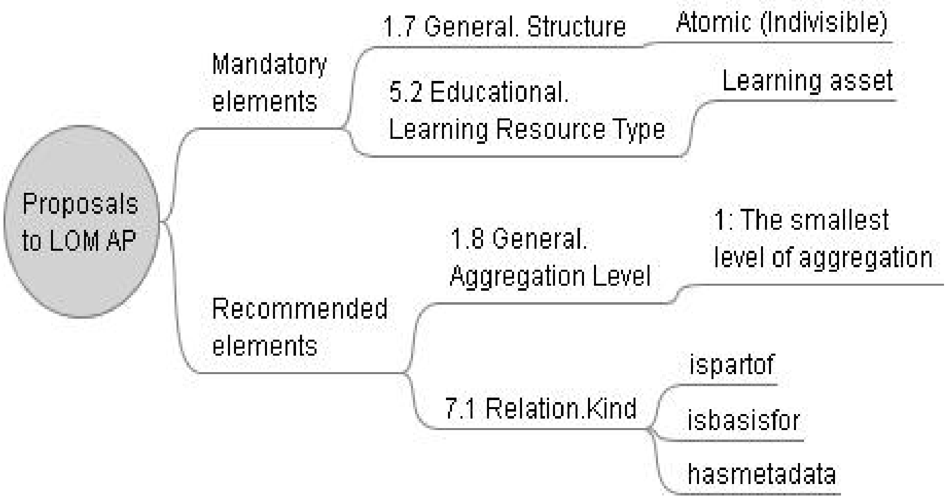

Figure 19: *Proposals to Lithuanian LOM Application Profile*

While searching for ultimately reusable LOs the user has to search for LOs metadata containing suitable vocabulary values:

- "Atomic" for element 1.7 (General.Structure).
- "1" for element 1.8 (General.Aggregation Level).
- "Learning asset" for element 5.2 (Educational.Learning Resource Type).
- "ispartof", "isbasisfor" and / or "hasmetadata" for element 7.1 (Relation.Kind).

Table 3: *LRE elements which status is proposed to change*

Nr	Element	Suitable vocabulary value	Explanation	New status	Other vocabulary values
1.7	General. Structure	Atomic	A LO that is indivisible (in this context). Assets such as individual picture, sound etc. files are considered always "Atomic".	Manda-tory	• Collection. A set of LOs with no specified (navigational) relationship between them • Networked. A set of LOs that are linked together with no clearly definable path

Nr	Element	Suitable vocabulary value	Explanation	New status	Other vocabulary values
			Using this element with other elements (e.g. 4.1 Technical. Format and 5.2 Educational. Learning Resource Type), it is possible to describe LOs in even greater detail		• Hierarchical. A set of LOs that are linked together with tree structure path • Linear. A set of LOs that are linked together with a clearly defined single sequence path
1.8	General. Aggre-gation Level	1	The smallest level of aggregation, e.g., raw media data or fragments	Recom-mended	• 2: A collection of level 1 LOs, e.g., a lesson • 3: A collection of level 2 LOs, e.g., a course • 4: The largest level of granularity, e.g., a set of courses that lead to a certificate
5.2	Educatio nal. Learning Resour-ce Type	Learning asset (not an authorised value)	A single, multimedia asset or component that is used to create learning resources including learning objects – text, audio, photographs, graphics, short video clips. On their own, or grouped in collections, assets can be	Manda-tory	• Application • Assessment • Broadcast • Case study • Course • Demonstration • Drill and practice • Educational game • Enquiry–oriented activity • Experiment • Exploration • Glossary

Nr	Element	Suitable vocabulary value	Explanation	New status	Other vocabulary values
			used to support learning in a wide variety of contexts. “Learning asset” is not a resource type but a category of resource types. The resource types belonging to this category are audio, data, image, model, text and video		• Guide (advice sheets) • Lesson plan • Open activity • Presentation • Project • Reference • Role play • Simulation • Tool • Web resource (weblog, web page, wiki, other web resource) • Other
7.1	Relation. Kind	• ispartof • isbasisfor • hasmeta-data		Recom-mended	• haspart • isversionof • hasversion • isformatof • hasformat • references • isreferencedby • isbasedon • requires • isrequiredby • haspreview • ispreviewof • istranslationof • hastranslation

Proposals for LOM AP Concerning Learning Activity

The examination of LRE AP v3.0 [58] has also shown that standards like LRE AP v3.0 are not fully suitable to describe LOs directly interconnected with particular pedagogical processes / scenarios / designs reusable for different subjects and different LOs / LAs (i.e. UoLs).

There are several LRE AP elements suitable to be used while describing pedagogical processes / scenarios / designs like UoLs.

They are:

- *General.Description – 1.4.*
- *General.Keyword – 1.5.*
- *Educational.Learning Resource Type – 5.2.*

Vocabulary values most suitable for describing UoLs types could be:

  - Lesson plan.
  - Open activity.
  - Project.
  - Role play (material for an activity that implies the active participation of a learner in a concrete situation).
  - Simulation.
  - Tool.
  - Other.

- *Educational.Description – 5.10.*
- *Relation (Element 7).* This category defines the relationship between this learning object and other learning objects, if any.
- *Classification (Element 9).* This category describes where this learning object falls within a particular classification system.

Proposed Elements of Lithuanian LOM AP

The metadata described in this application profile supports a variety of LO uses including:

- Management.
- Searching and finding.
- Technical interoperability.

Description of properties of individual LOs including:

- Educational attributes.
- Digital rights.
- Technical features.

The full element set establishes the information model for the Lithuanian Learning Object Metadata AP. The information model groups metadata elements into nine categories:

1. General.
2. Life Cycle.
3. Meta–Metadata.
4. Technical.
5. Educational.
6. Rights.
7. Relation.

8. Annotation.
9. Classification.

The set of mandatory and recommended elements proposed for Lithuanian LOM AP based on LRE AP v3.0 [58] and the authors' research results (see Table 6) are presented in Table 4:

Table 4. *Mandatory and recommended elements of proposed Lithuanian AP Data Model*

Mandatory elements		
1.1	General. Identifier	Element is intended to give the LO a unique label in order to identify the LO and its origin. This element is for administrative purposes only and should not be exposed to common users.
1.3	General. Language	Element is intended to identify languages used within the LO. Every language used to communicate with a user in a LO should be described. Languages are not exposed to users as codes and tokens used by machines but in human readable form. The applications, e.g. search engines and metadata tagging tools, are mapping codes to words which are then shown to users by their respective user interfaces.
1.7	General. Structure	Element is intended to provide information about the structure of the LO. Vocabulary values: • Atomic: A LO that is indivisible (in this context). Assets such as individual picture, sound etc. files are considered always "Atomic". • Collection: A set of LOs with no specified (navigational) relationship between them. An HTML page containing assorted picture files can be considered "Collection" type LO. • Networked: A set of LOs that are linked together with no clearly definable path. Because only one value is permitted to this element, LOs containing multiple features from this vocabulary should be defined as "Networked". • Hierarchical: A set of LOs that are linked together with tree structure path. • Linear: A set of LOs that are linked together with a clearly defined single sequence path. Only one value from the vocabulary is permitted.
5.2	Educational. Learning	Element is intended to indicate the potential educational use(s) or type(s) of the LO. Many LOs have features from

Mandatory elements		
	Resource Type	more than one of the following categories. One or more values from the LRE Vocabulary should be selected for this element. Elements are ordered so the first value is the most dominant kind.
6.2	Rights. Copyright and Other Restrictions	Element is intended to indicate if any copyright or other restrictions apply to the LO. If the value of this element is "yes", then element "6.3 Rights. Description" becomes a mandatory element. Vocabulary values: • Yes: Copyright and/or other restrictions apply to a LO. • No: No copyright or other restrictions apply to a LO.

Recommended elements		
1.2	General. Title	Element is intended to give the LO a human readable name.
1.4	General. Description	Element is intended to provide summarizing description of the LO.
1.5	General. Keyword	Element is intended to provide free text keywords describing the LO's content. Recommended element "9.2 Taxon Path" is to be used in place of "1.5 General. Keyword" when values are derived from LRE Thesaurus. The most specific terms descriptive of the LO's content should be used. Each term or phrase should use a separate keyword element and lengthy phrases should be avoided.
1.8	General. Aggregation Level	The functional granularity of this learning object. Vocabulary values: 1: the smallest level of aggregation, e.g., raw media data or fragments. 2: a collection of level 1 learning objects, e.g., a lesson. 3: a collection of level 2 learning objects, e.g., a course. 4: the largest level of granularity, e.g., a set of courses that lead to a certificate. Level 4 objects can contain level 3 objects, or can recursively contain other level 4 objects.
2.3	Life Cycle. Contribute	Element is intended to describe who has contributed to the LO.
2.3.1	Life Cycle. Contribute. Role	Element is intended to describe the role of the contributor. Vocabulary values: • Author: An entity primarily responsible for making the content of the LO. An author can be a person, institution, group or other entity. • Publisher: The individual or organization responsible for making the LO available in its present form, such as a publishing house, a university department, or a corporate entity. • Unknown: The individual or organization whose role of

Recommended elements		
		contribution is not known. • Initiator: The person, institution, or funding agency responsible for originally causing the development process. • Terminator: The person or entity responsible for intentionally removing access to the LO. • Validator: The person or entity responsible for confirming the overall integrity of the LO. • Editor: The person or entity responsible for the revision of the LO for the purposes of publication or public presentation. • Graphical designer: The specialist or entity responsible for the construction of the visual elements of a LO. • Technical implementer: The specialist or entity responsible for the construction of the technical elements of a LO (usually software programmer). • Content provider: The person or entity that is supplying content for the LO. • Technical validator: The person or entity responsible for confirming the technical integrity of the LO. • Educational validator: The person or entity responsible for confirming the educational integrity of the LO. • Script writer: The person or entity responsible for the creation of a text read or performed in an audio, video, and/or interactive learning resource. • Instructional designer: The specialist or entity responsible for applying research–based principles to the design of the LO. • Subject matter expert: The person or entity that is expert in the domain pertaining to the LO.
2.3.2	Life Cycle.Contribute.Entity	Element is intended for identification of and information about entities (i.e., people, organizations) contributing to the LO. Minimum information about a person: name (first and last) and affiliation. Minimum information about organization: name and web page address.
2.3.3	Life Cycle. Contribute. Date	Element is intended for the date of contribution.
3.4	Meta–Metadata. Language	Element is intended to describe the language of the metadata instance.
4.1	Technical. Format	Element is intended to provide information about software needed to access the LO.
4.2	Technical.	Element is intended to provide information about the actual

Recommended elements		
	Size	file size of the LO. Although the actual value is in bytes, user interfaces should give users a more friendly view of this data. If the LO is compressed, then this element should refer to the uncompressed size.
4.3	Technical. Location	Element is intended to provide information where the LO is physically located.
5.5	Educational. Intended End User Role	Element is intended to indicate the typical user of the LO. One or more (up to seven) values from a LRE Vocabulary should be selected for this element. Elements are ordered such that the first value is the most frequently used. Vocabulary values: • Author: An author creates or publishes a LO (LOM). An author is defined as the person who originates or gives existence to anything. An authoring tool that produces pedagogical material is a typical example of a learning object whose intended end user is an author. • Counsellor: One who counsels or advises; an adviser. • Learner: A learner works with a LO in order to learn something. One who learns or receives instruction. • Manager: A manager manages the delivery of a LO. A person who organizes, directs, or plots something; a person who regulates or deploys resources. • Parent: A person who holds the position or exercises the functions of a parent; a protector or guardian. • Teacher: One who or that which teaches or instructs; an instructor. • Other: Role that is not one of the above.
5.6	Educational. Learning Context	Element is intended to indicate the institutional environment or the level of education appropriate for use of the LO. One or more (up to 12) values from a LRE Vocabulary should be selected for this element. Vocabulary values: • Pre–school: A kindergarten or nursery school for children of preschool age. • Compulsory education: Regular schooling and other education after kindergarten and before higher education. • Special education: Designed or provided for persons who have special educational needs which prevent them from receiving (wholly) mainstream education. This value can be selected together with any other terms in this vocabulary in order to express special need in any context. • Vocational education: Training or education that is

Recommended elements		
		pertaining or relating to a vocation or occupation. • Higher education: Education provided by a college or university. • Distance education: Instructional delivery that does not constrain the student to be physically present in the same location as the instructor. • Continuing education: The further education of those over ordinary school age. Adult / continuing education is not related to job training in this context. • Professional development: Training or education that is related to improving professional skills. • Library: School libraries/documentation centres are places where the information skills are taught and the access to learning services, books, and multimedia resources in a school environment are organized. • Educational administration: Management and administration of educational and training institutions. • Policy making: Makers of policy decisions. This value is intended to indicate higher levels of decision–making than local institutional management. • Other: Educational context that is not one of the above.
5.7	Educational. Typical Age Range	Element is intended to indicate the typical age of the user of the LO.
5.10	Educational. Description	Element is intended to provide a textual description of educational uses of the LO.
6.1	Rights. Cost	Element is intended to indicate if the use of the LO requires any payment. If the value of this element is "Yes", in element "6.3 Rights. Description" there has to be more information about the cost, i.e., it becomes a mandatory element. Vocabulary values: • Yes: Use of a LO requires payment. • No: Use of a LO requires no payment.
6.3	Rights. Description	Element is intended to provide a textual description of copyrights or other restrictions that apply to the LO.
7.1	Relation. Kind	Nature of the relationship between this learning object and the target learning object identified by 7.2: Relation.Resource.
9	Classification	It is recommended to have one or more classification elements with element „9.1 Purpose“ that equals „Discipline“. In this case, „9.2 Taxon Path“ element is used to store keywords from the LRE Thesaurus. The LRE Thesaurus term identifier is stored in element 9.2.2.1 and the term itself can be stored in 9.2.2.2.

This AP is a multi–part standard that specifies Learning Object Metadata for flexible DLE. This Part specifies a conceptual data schema that defines the structure of a metadata instance for a learning object. For this AP, a learning object is defined as any digital resource that can be reused to support learning.

For this AP, a metadata instance for a LO describes relevant characteristics of the LO to which it applies. Such characteristics may be grouped in general, life cycle, meta–metadata, technical, educational, rights, relation, annotation, and classification categories. The conceptual data schema specified in this part permits linguistic diversity of both LOs and the metadata instances that describe them.

This conceptual data schema specifies the data elements which compose a metadata instance for a LO. This Part is intended to be referenced by other standards that define the implementation descriptions of the data schema so that a metadata instance for a LO can be used by a learning technology system to manage, locate, evaluate or exchange LOs. This Part of this AP does not define how a learning technology system represents or uses a metadata instance for a LO.

The purpose of this AP is to facilitate search, evaluation, acquisition, and use of LOs, for instance by learners or instructors or automated software processes. This AP also facilitates the sharing and exchange of LOs, by enabling the development of catalogues and inventories while taking into account the diversity of cultural and lingual contexts in which the LOs and their metadata are reused. By specifying a common conceptual data schema, this Part of this AP ensures that bindings of Learning Object Metadata have a high degree of semantic interoperability. As a result, transformations between bindings will be straightforward.

This Part of this AP specifies a base schema, which may be extended as practice develops, e.g., facilitating automatic, adaptive scheduling of LOs by software agents.

There are two types of element subsets defined here: the elements that should be filled in every metadata instance (mandatory elements) and the elements that would be very useful to be filled (recommended elements). These essential elements compound Lithuanian LOM AP based on LRE AP v3.0 [58] and the authors' research results.

3.5. Recommendations for System Components

The issue examined in this chapter is possibility to ensure stable interoperable working of *flexible* DLE based on its components' ultimate reusability principle (within DLE and the whole system on European level) based on implementation of effective interoperability guidelines.

The keyword here is “flexible”. The presented concept for flexible DLE is based on the proposition that it should consist mainly on *ultimately reusable* LOs and their metadata repositories as well as appropriate services to create, modify and manage LOs, e.g. modularised open source adaptable VLEs.

The author’s concept is that ultimate reusability of LOs should be ensured by their partition to two main separate parts (Learning assets – LAs and Units of Learning – UoLs) which should work independently and should have clear different functions:

- LAs are considered not to be directly interconnected with particular pedagogical activities / designs, and therefore it should be possible to reuse the same LAs to implement different learning designs.
- UoLs are conversely considered to be LOs containing learning activities / designs reusable for different subjects and different LOs / LAs.

DLE scheme based on flexible, modular architecture and as small as possible open source reusable e-content and e-services components proposed by the author is presented in Figure 20 below.

In conformity with this scheme, the flexible DLE should mainly consist of:

- Central LO metadata repository and metadata tools:
    - Connected to European LRE.
    - TGA compatible to use curriculum mapping tools.
    - DRM system (incorporated).
    - Controlled interoperable vocabularies (incorporated).

- LOs repositories:
    - LOs / LAs (learning content) repositories.
    - UoLs (learning activity) repositories.

- Services / tools to create and reuse LOs:
    - Tools for teachers to create and reuse LOs (e.g. CALIBRATE LeMill toolbox).
    - Tools to create and reuse UoLs (e.g. RELOAD, LAMS, MOT+, etc.).
    - VLEs (e.g. Moodle).
    - E-Portfolio systems based on controlled vocabularies (e.g. competences taxonomy).
    - Social information to tag, comment, rate LOs.

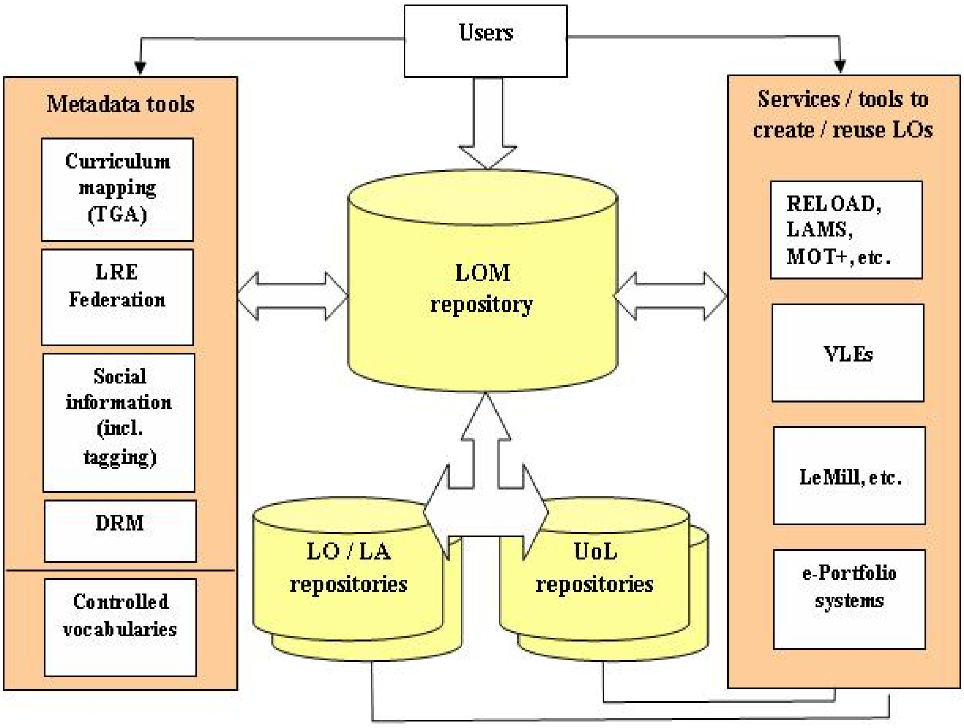

Figure 20. *The scheme of flexible DLE components connection*

Authors' research results presented below in this chapter show that it is possible to ensure stable interoperable working of flexible DLE based on its components' ultimate reusability principle (within DLE and the whole system on European level) based on implementation of effective interoperability guidelines (sections 3.1 – 3.4).

The summary of these results is presented in Table 5 below.

DLE interoperability guidelines include first of all:

- Implementation of *LOs reusability* principle (section 3.1).
- Implementation of *separate* LOM compliant *LO metadata repository*.
- *Connection of LOM repository to to LRE Federation* via Brokerage system and SQI (section 3.2).
- Implementation of *Curricula mapping tools* based on CALIBRATE TGA ontology (section 3.3).
- Implementation of *improved LOM AP oriented towards quick and convenient search of reusable LOs* (section 3.4).

- *Implementation of IMS Common Cartridge specification* to import content LRs to (export from) VLE (see section 2.1.5). *Remark:* IMS Common Cartridge specification provides a common way of specifying the structure, authorization, and interoperability protocols of content and its assessment. The Common Cartridge is a constrained profile of IMS CP integrating QTI and LOM. It is hoped that this approach will overcome some of the remaining interoperability issues which exist between LMS's, even when they claim to be implementing the IMS CP specification.
- *Implementation of IMS Learning Design specification* and LD compliant tools to reuse UoLs and import activity LRs to (export from) VLE (see section 2.1.6). *Remark:* author does not propose to widely use SCORM. In terms of expressivity, SCORM is severely restricted in contrast to IMS LD, which allows for the extraction of pedagogy from content such that it is able to offer the kind of functionality that characterizes structured activity–based learning (e.g. peer collaboration, formative assessment, tracking and sequencing of individual and group work etc.).
- Implementation of interoperable *controlled vocabularies* incorporated into LOM AP (e.g. Topic and Competency taxonomies, section 3.3).
- Implementation of Digital rights management (DRM) based on usage of Creative Commons licences. *Remark:* Creative Commons is by now well adopted but there are however some problems that hamper its adoption (interoperability of variants and usability). Creative Commons Licence has gained popularity as a simple means to ensure that the copyright is respected, as well as to send a clear message to others about the terms of reuse.

Table 5. *DLE components interoperability*

DLE components		**Details, Interoperability**
Learning Content and Learning Activities	LOs / LAs repositories	Contain approved and recommended LOs / LAs evaluated in conformity with appropriate tools presented in section 4.2 below
		Can be physically located in different servers
		All LOs are described in conformity with improved LOM AP (section 3.4)
		All LOs fit Accessibility interoperability requirements (section 2.1.3; these requirements are horizontal for all system's components)
	Learning Activities' repositories	Contain UoLs only
		All UoLs fit IMS LD specification requirements

DLE components		Details, Interoperability
e-Services / tools for e-content creation, modification, use / reuse, and personalisation	Open source tools for UoLs creation and modification: RELOAD [105], LAMS [65], MOT+ [84], etc.	
	Open source tools for standardised collaborative LOs creation and modification, e.g. LeMill	
	VLEs	Open source
		Modular architecture
		Evaluated in conformity with appropriate tools presented in section 4.4 below
		Fit IMS Common Cartridge and IMS LD specifications (sections 2.1.5 and 2.1.6)
	e-Portfolio systems	Fit main European controlled vocabularies (e.g. competence taxonomy)
		Fit IMS LIP or IEEE LTSC PAPI (section 2.1.7)
Central LO metadata repository and metadata tools		All metadata is IEEE LOM standard compatible
		Is connected to LRE Federation via Brokerage system and SQI (section 3.2)
		Uses interoperable controlled vocabularies (e.g. Topic and Competency taxonomies) incorporated into LOM AP (section 3.3)
		Fits Curriculum taxonomies and TGA tools (section 3.3)
		Implements Digital rights management (DRM) based on usage of Creative Commons licences
	Other: social information	Tagging
		Users' comments
		LOs ratings, etc.

DLE components' interoperability scheme based on DLE components' general scheme (see Figure 20), DLE components interoperability table (see Table 8), and results of 2.1 (IMS CC, LAMS, W3C, OAI–PMH, IMS LIP, PAPI) and 3.1 (IMS LD) sections analysis is presented in Figure 21.

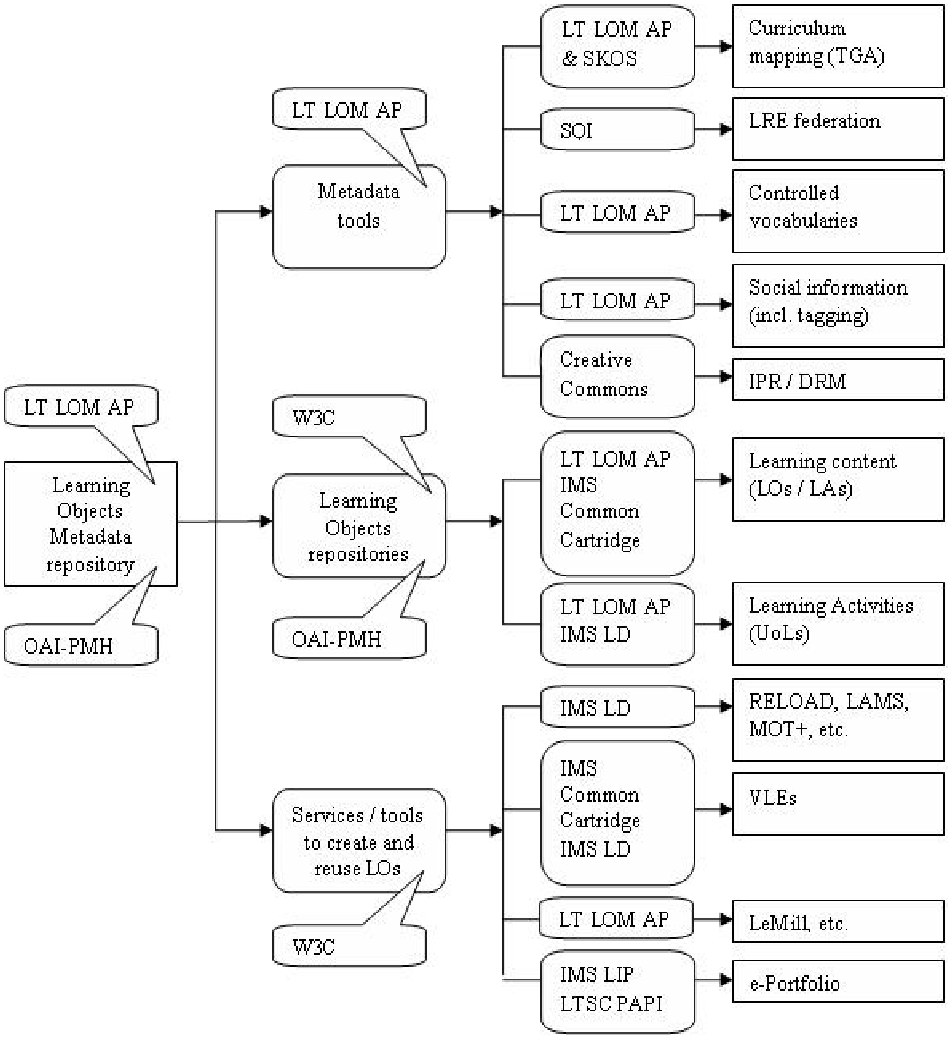

Figure 21. *The scheme of DLE components' interoperability*

3.6. Chapter 3 Conclusions

1. The principle of ultimate increase of reusability of learning objects was considered in the chapter as the main factor of DLE flexibility. It was investigated and deduced that flexible approach to DLE creation and development should be based on the idea of LOs' partition to two main separate parts (LOM compliant small pedagogically decontextualised LAs, and LOM and

IMS LD compliant UoLs). VLEs suitable for flexible DLE should have a high level of adaptation capabilities.

2. LRE validation in Lithuania has shown that the teachers prefer LOs from national repositories which have the potential to "travel well" and can be used in different national contexts. These reusable LOs preferred by the teachers are mainly small decontextualised Learning Assets. Therefore in order to maximise LOs reusability in Europe LRE should consist mainly of decontextualised Learning Assets. There are two main conditions for LOs reusability elsewhere: (1) LOs have to fit different countries national curricula; (2) different countries' LOM application profiles have to be oriented towards quick and convenient search of reusable LRs. Approaches concerning application profiles and curricula mapping (incl. controlled vocabularies) are the main while creating any metadata guidelines or strategies. Therefore the recommendations to curricula mapping and LOM AP are the main in the author's DLE interoperability guidelines.

3. The example of Lithuanian Mathematics for elementary education curriculum mapping and its integration with LOM AP has been presented in Figure 23. A curriculum item can be expressed as a set of targeted competencies. This approach makes interoperability possible by making use of two smaller controlled vocabularies instead of a very large one on competencies. The approach builds on proven technologies, i.e. thesauri, and well–known vocabularies for the action verb expressions and allows for relaxing the search criteria building upon the hierarchical structure of the two vocabularies. We exchange information on competencies in a multi–lingual and multi–cultural environment by: (1) breaking down competencies, and (2) relating these competency components to multilingual controlled vocabularies. The approach fits very well with the current practice of describing LOs. Section 9 of the IEEE LOM standard can be used without alteration. For LOM data element 9.1, indicating the purpose, the value "competence" should be used. One condition to be fulfilled is that curricula are expressed as competencies, which is not always the case. Sometimes they are expressed as activities to be undertaken or simply as subjects to be taught. In that case the targeted competencies should be researched or interoperability can be restricted to the topic vocabulary. There are following recommendations and results based on the method evaluation: (1) not one big competency taxonomy but two smaller vocabularies, (2) more resilient to change; (3) using proven technologies – thesauri (subject, revised Bloom); (4) possibility for relaxing the search: the results of the proposed method are substantially better in comparison with the method of trying to find LOs suitable for developing the same competencies with Google (approx. 1.5 minutes Vs approx. 1.5 hours).

4. The results of investigation of LRE Metadata AP v3.0 based on flexibility requirement for DLE as well as experts survey (section 1.2.5) have shown that it would be purposeful to improve LRE AP v3.0 (model) to provide more quick and convenient search possibilities for those searching ultimately reusable LOs by the means of changing (advancing) the status of a number of LRE AP elements. Proposals for this improvement (i.e., for Lithuanian LOM AP – central LO metadata repository model) were presented in Figure 24 and Table 6. They deal with changing the status of the following LOM AP elements: 1.7 General. Structure; 1.8 General. Aggregation Level; 5.2 Educational. Learning Resource Type; and 7.1 Relation. Kind. It was investigated and deduced that the development of advanced search engine reflecting LOs reusability level based on this research would considerably reduce the time for teachers to find and choose suitable LOs in the repositories. In conformity with author's experiment results, the method reduces ultimately reusable LOs search time about 60 times for Lithuanian biology LOs. There were totally 96 LOs on Biology in Lithuanian LOM repository during the experiment, incl. 37 Learning Assets –pictures.

5. DLE components connection general scheme based on LOs ultimate reusability principle as well as on flexible, modular architecture, as small as possible open source e-content and e-services, has been presented in Figure 25 and Table 8. DLE components' interoperability scheme based on DLE components' general scheme and specification was presented in Figure 26.

4

System Components Technical Evaluation

In this chapter the author analyses existing LOs and VLEs technical evaluation criteria (literature analysis, sections 4.1 and 4.3), and formulates the own, more complex sets of criteria for technical evaluation of LOs (own research, section 4.2) and VLEs (section 4.4) for flexible DLE, and evaluates most popular open source VLEs against these criteria (own research, section 4.5).

The author has published 4 articles on the topic of the chapter [3A–4A, 6A, 8A].

4.1. Analysis of Existing Learning Objects Technical Evaluation Tools

Foreign Approaches to Learning Objects Technical Evaluation

The various approaches to LOs attempt to meet two common objectives:

- to reduce the overall costs of LRs, and
- to obtain better LRs [112].

It can be argued that the provision of LOs provides better access to quality LRs and supports enhanced learning outcomes. The purpose of LOs is to increase the effectiveness of learning by making content more readily available, by reducing the cost and effort to produce quality content, and by allowing content to be more easily shared. These two purposes, effectiveness and efficiency, receive differing emphases from different sectors [32].

Quality as a concept is hard to define and at the same time it is a double–edged sword. On one hand, managing quality is necessary in order to reach certain goals and obtain certain characteristics and properties; on the other hand there is an impending risk to be overambitious about quality and over elaborate things [83].

In ISO 9000 quality is defined as "… a characteristic that a product or service must have…" and ISO 9000 also states that "… not all qualities are equal. Some are more important than others. The most important qualities are the ones that customers want. These are the qualities that products and services must have".

The evaluation of LOs is a comparatively new concern as the quantity of LOs has grown and the development of LO repositories has come about to allow for greater ease in finding and using LOs for both classroom and online instruction. The growth in the number of LOs, the multiplicity of authors, their increasing diversity of design and their availability to trained and untrained educators has generated interest in how to evaluate them and which criteria to use to make judgments about their quality and usefulness.

LORI Quality Criteria

The need to evaluate LOs requires the development of criteria to be used in judging them. Vargo et al. [107] developed a Learning Object Review Instrument or *LORI* to evaluate LOs. The LORI approach uses the following 10 criteria when examining LOs:

- Presentation: Aesthetics.
- Presentation: Design for learning.
- Accuracy of content.
- Support for learning goals.
- Motivation.
- Interaction: Usability.
- Interaction: Feedback and adaptation.
- *Reusability (*technical criterion – author's comment).*
- *Metadata and interoperability compliance (*technical criterion – author's comment).*
- *Accessibility (*technical criterion – author's comment).*

The criteria were drawn from a review of pertinent literature on instructional design, computer science, multimedia development and educational psychology. Each measure was weighted equally and was rated on a four point scale from “weak” to “moderate” to “strong” to “perfect”. The LORI process involved both individual and group rating of LOs.

Paulsson & Naeve Quality Criteria

Six action areas for establishing LOs technical quality criteria are suggested by [83]:

- A narrow definition.
- A mapping taxonomy.
- More extensive standards.
- Best practise for use of existing standards.
- Architecture models.
- The separation of pedagogy from the supporting technology of LOs.

Most LO implementations do not by far meet this vision. For those reasons it is essential to establish common criteria of quality for LOs. By suggesting technical quality criteria for LOs we expect to facilitate the efforts of finding areas in which additional definitions, standards and metrics can enhance the technical quality of LOs in a way that help fulfilling the LO vision. Technical quality criteria are specific characteristics and properties that LOs must (or in some cases ought to) adhere to – including best practice, guidelines and standard specifications – in order to be regarded as LOs.

The focus in [83] is on technical quality criteria for LOs. Other quality criteria, such as pedagogical quality, usability or functional quality are out of scope. Such aspects of quality are addressed by Van Assche and Vourikari in [105], where they suggest a quality framework for the whole life cycle of LOs.

The empirical basis for [83] was collected through a comparative study of previous work on LOs. The result from their study was verified against a technical evaluation of 200+ LOs from three Swedish LOs repositories (LORs). The repositories where selected for being “typical” LORs as well as being among the few LORs that permits public access, which made the study possible. The evaluation focused on: (1) architecture – in terms of separation of data, logics, presentation, and implementation of interaction interfaces; (2) pedagogical contextualization; (3) the use of standards and the extent to which they are decomposable / composable. Many of those issues are directly or indirectly related to the lack of explicit definitions and clear architectural models, together with technical (as well as other) quality criteria that are directly related to technical architecture. Many of the pedagogical dependencies and shortcomings seem to be caused by technical bindings of content to presentation and application logics as well as built in instructional design elements.

The [83] study shows that there is a huge discrepancy between different definitions of the LO concept. This makes it hard (if not impossible) to author LOs that owns the qualities that LOs are often ascribed in terms of *reusability, interoperability, and context independence.* Definitions really range from “anything to everything” [67]. However, the real problem lies in that there is no separation of “anything to everything” from a technological perspective and “anything to everything” from a “content” perspective. “Anything to everything” from a “content” perspective is a good thing as this makes it easier to support different pedagogical directions and methods, but “anything to everything” from a technological perspective becomes unmanageable. The authors of [83] suggest the technical and pedagogical definitions of LOs to be separated – within a common definition of LOs.

The lack of common low–level definitions and models is a threat to interoperability, technical quality as well as for the acceptance of the LO concept itself. The study shows that the pedagogical content is often of good quality and that the ambitions are set high, but that LOs still do not live up to the expectations that would make them context independent, reusable objects. One important reason is that little consideration is given to *fundamental software design principles, such as layering, principles from object orientation, structuring of data* etc., which could enhance such properties that are usually ascribed to LOs. As most implementations do not deliver what they promise, the vision has yet to be fulfilled. There is a need to move on from just describing properties and characteristics, to determine how those can be realized.

To address the identified problems [83] suggest six areas for action in order to establish technical quality criteria for LOs:

(1) There is a need for a common (more narrow) definition of what is, and what is not a LO. Excluding rather than including, which also mean accepting trade–offs in order to gain a functioning concept by defining “must–have” properties and attributes. This includes the separation of pedagogical and technical issues.

(2) In connection to narrowing down the definitions, there is a need for a taxonomy that maps on to the definition and where granularities as well as special properties are regarded. Most taxonomy efforts studied takes on a strictly pedagogical perspective, suggesting desirable properties, but not how those should be implemented. Such taxonomy was suggested, where those issues are discussed in detail.

(3) *Standards used for LOs should be extended to go beyond descriptive information, such as metadata, sequencing, and packaging to also embrace standards for interfaces, “machine readable” descriptions of technical properties and interaction interfaces*. It could be argued that SCORM adds such properties to some extent, but it can also be argued that SCORM does not do this in either a technology– or pedagogically neutral way [86]. The needs for such

efforts are evident from the fact that all interaction and message passing between different parts of the studied "learning packages" was accomplished through "hard coded", proprietary application logics that aggravates reuse and technical independence.

(4) There is a need to establish standards and recommendations that address the internal use of data formats and data structure. Such general technology standards exist, but seem to be rarely used in the LO community. This suggestion is related to area (3) and is important for exchange of data as well as for separating data from logics and presentation.

(5) *It should be prescribed for the architecture of LOs to be layered as a part of best practise, in order to separate data, presentation and application logics. This would enhance the level of decomposability and context independence*, as is also pointed out by Pinkwart et al. [84]. Layering (or multi–tier architectures) is used frequently in many other areas of application/system development for the very same reasons.

(6) *Pedagogy should preferably be kept outside the LO in order to facilitate pedagogical context independence*. It is suggested that the pedagogical model is added as LOs are assembled to form Learning Modules. Using such methodology, it becomes possible to do pedagogical contextualization at a later stage in the authoring process, and enhance reusability of different components as well as components mutual pedagogical context independence. In this process it doesn't actually matter whether the pedagogical contextualization is done using techniques, such as IMS SS, or more sophisticated and fine grained models like IMS LD, what matters is that it is done separated from the modules constituent components. In some cases there might be a need to add such "instructional properties" inside LOs, but in such cases this should be handled in a separate layer, using standard specifications for that purpose, and not by hard coded implementations.

In [83] the authors consider the following future work necessary:

- A lot of research, development and standardization work is still needed in order to realize the technical quality criteria suggested above.
- Issues such as (3) need to be raised and addressed within standards organizations. Some of the issues are already on the agenda, but the focus is mainly on the VLE and not so much on the interaction and interrelations of LOs. The role of Service Oriented Architectures (SOA) for LOs (as well as for the over all Learning Architecture) needs to be further examined.
- The suggested quality criteria (4), (5) and (6) must be further examined through implementation and thoroughly discussed within the scientific community as well as in the standards community.
- For this reason it is essentially important to take on a multidisciplinary scientific view in order to better explore and understand the complex

interplay between Computer Science and Pedagogical Science. Quality frameworks, such as the framework suggested by [105], could be extended to embraced the quality criteria suggested in [83].

Van Assche & Vuorikari Quality Criteria

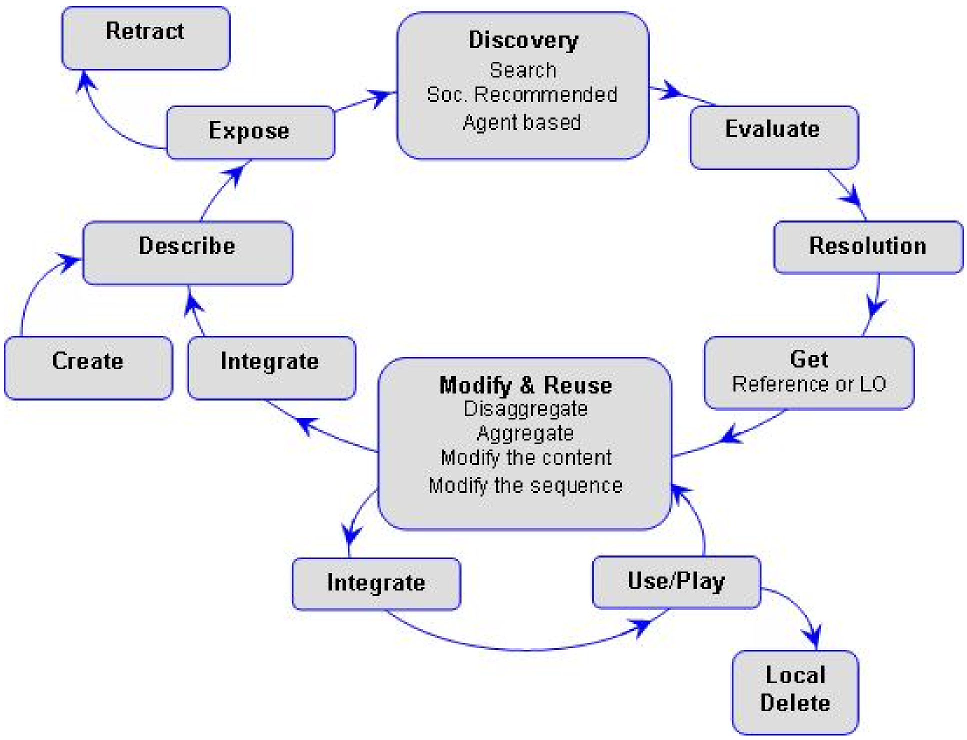

Figure 22. *Typical usage scenario of the learning resource [105]*

The following review based on [105] looks into the different processes of a typical usage scenario of a LR (see Figure 22) and identifies major issues related to the quality at each stage. Quality is related to the roles involved in the process and is much related to the effectiveness of the process. The following explanation of the usage scenario is in reverse order, starting from the usage stage, as the actions are built upon another.

Use

The quality of use of a LR is related to what the learner(s) eventually learn. This is determined by the intrinsic quality of the learning content itself, the methodology (e.g. pedagogy, LR construction methods), and the people delivering and/or using the LR.

Aspects of the LR itself

A LR will be used most effectively if it fits the desired learning situation as defined by the person (e.g. teacher) or system (e.g. LMS) that is supporting the learning process. Some typical quality characteristics are: (1) Accuracy: reliable, valid and authoritative; (2) Clarity: a clear link between objectives and the content; (3) Appropriateness: information for the intended learners' level in appropriate vocabulary, language and concepts; (4) Completeness: information related to self–contained activities, material required, prerequisites, information for obtaining related resources, assessment criteria, link to quality indicators; (5) Motivation: engage the learner with interest and satisfaction; (6) Composition and organisation; easy to use both for teacher and pupil [5].

Pedagogy

Different pedagogical and methodological teaching and learning scenarios should be considered, such as independent learning, group learning, or the LR used by a teacher in a classroom. The learning experience will not solely depend on the quality of the LR, but also on how effectively it is delivered and used.

The pedagogical affordance (i.e. the pedagogical clue to the use of an object) of a LR can depend upon the following: (1) The metadata containing clues of how to use the LR; (2) Added by the teacher in the integration and delivery processes; (3) Built–in, for instance sequencing following IMS LD; (4) Within a "teaching tip" or "teaching resource", i.e. other LRs or comments may explain how other teachers have used it.

Tools and infrastructure

Technical requirements of a LR are usually explained in the metadata description of the LRs. Platform dependence or required software can cause major headaches to teachers who would like to use LRs but lack the knowledge and skills. Novel ways to avoid these situations should be investigated, for example, before downloading the resource system could make a check of relevant software (operating system) availability.

People

The learning experience is influenced by the way the LR is delivered, i.e. on the quality of delivery by the teacher. In this context, professional pre–service and continuous training on the pedagogical use of LRs is key.

Integration, Repurpose & Reuse

Technical integration

A LR will have a specific format. Typically, one would be concerned with the hardware infrastructure, the players or viewers required, and the integration might involve some form of conversion to fit the technical environment.

Repurpose, adaptation and pedagogical integration

Pedagogical integration is effective to the extent that the LR can be fitted into the overall pedagogical approach. This may involve some adaptation of the

LR, sometimes called “repurposing”. The repurposing may be for a different audience, different language, cultural, or pedagogical setting. Teachers actually used LRs quite independently of the intended pedagogical approach of the LR. Thus, possibilities for repurposing should be an integral part of LRs’ design.

Reuse

Reuse is effective to the extent that a LR or any part of it can be fit into another LR or another context for learning. Allowing reuse of LRs has economic consequences, but also adds to the quality, because often improvements are suggested and implemented in this way. The possibility to re– and dis–aggregate the LR enhances the learner’s ability to construct her own knowledge and actively reflect upon the learning experience, as well as share it with other learners and users, who are natural parts of any learning experience.

Resolution & Obtaining

Obtaining

Obtaining a LR is effective to the extent that the LR has become available to the user. There are three basic models: (1) the LR is played remotely; (2) the LR downloaded and played under the control of a shared system such as LMS, LCMS, local server; (3) the LR is downloaded to a personal computer.

Resolution

Resolution can involve the identification of the user or user role by an identity management system, the generation of an agreement based on the rights to use these LRs, and the enforcement of the agreement.

Currently, a number of Digital Rights Expression Languages and schemes exist, as well as identity management schemes. The application of digital rights ranges from closed and commercial content to open and free content. For the latter, the Creative Commons Licence has gained popularity as a simple means to ensure that the copyright is respected, as well as to send a clear message to others about the terms of reuse.

Discover & Evaluate

Discovery and evaluation is effective to the extent that it results in the identification of all relevant LRs. It is often the case that a user (teacher, learner) is looking for a single LR that suits her best. This has been the reason for introducing better discovery and evaluation techniques. The more precise the discovery is, the less effort needs to be made on evaluation.

Discovery

Many techniques can be used, including: (1) browsing; (2) searching; (3) recommendations and advisory models such as based on previous actions, user modelling and social networks; (4) agent–based systems; (5) selective dissemination of information.

Advanced result presentation schemes may use two– (or three–) dimensional presentations or zoomable tree structures, clusters, of different colours or font size, etc. to indicate relevance or another criterion [46].

Evaluation

The user may have many criteria for evaluation and typically they are related to the activities following evaluation (see Figure 22). In order to come to a successful evaluation, the teacher or learner should have access to the LR itself, a LR preview, and metadata. Metadata in the broad sense include all annotations, comments, evaluation, and feedback from other users. More and more, the feedback, reviews and evaluations, either by boards of experts or other users, have become a valuable source of information on a LR's usability.

One of the major issues in the area of discovery and evaluation is semantic interoperability. Does the user understand the information in the same way as the person who provided this information? Semantic interoperability seeks to ensure that this is indeed the case; the challenges are in bridging of differences in language, culture, vocabularies, etc.

It is only when the evaluation is satisfactory that one can say that a user has found a LR. Since discovery and evaluation are usually subjective, more advanced techniques, such as agents, will also use information about the user and her preferences.

Approve and Publish

There are explicit and implicit approval processes before publishing whose intention is to assure the high standards and quality of the content provided. Quality, conformance and other labels are used fairly extensively in e-learning products in general, and nowadays, to a certain extent, also within LRs. Some countries, institutions and consortiums have labels approving, for example, technical compliance, the curriculum compliance or appropriateness of the resources. Many learning platforms and LR producers, for example, note their compliance to IMS specifications.

Describe

The aim of describing a LR is to facilitate the activities of the usage scenario (see Figure 22). The description is effective to the extent that it indeed helps in the discovery, the evaluation, obtaining, modifying, integrating, and using of the LR. The description may be human readable and/or machine readable.

Description is more effective if it uses a model that is shared between the information providers, the readers of the information and the models such as the LOM and DC exist. A further specification tailored to a user community is elaborated in a so–called application profile.

Create

The production of LRs, whether it was creation from scratch or aggregating from already existing components, is the crucial stage where aspects of interoperability, accessibility, transferability, repurposing and reuse are determined. The qualities that have the most effect on the overall quality are based on the usefulness of the content for the learning experience (desired learning outcomes), possibilities to reuse the content or its components (cost–effectiveness), and the pedagogical affordance of the LRs.

Retract and Delete

Retract and delete are effective to the extent that all obsolete material is retracted / deleted and useful material is not retracted / deleted.

MELT Project Quality Criteria

The MELT content audit included an in–depth examination of project partners' existing content quality guidelines and produced a checklist to help them decide what content from their repositories should be made available in the project for enrichment. This checklist is divided into five categories – pedagogical, usability, reusability, accessibility and production [68].

The list is by no means prescriptive and not all of the criteria can always be applied to all LRs. For example, some LRs may score strongly in terms of reusability because they include open source code that facilitates adaptation to different learning scenarios than the one originally intended. However, the same LRs might actually score poorly in terms of its interactivity. The checklist, therefore, needs to be seen more as a minimum framework that should be used in a flexible way.

Content that travels well?

In MELT the partners want to be able to provide access to learning content that meets nationally recognised quality criteria. However, it is also important to appreciate that some very high–quality LRs may meet the specific needs of a national curriculum but may not always have the ability to be used as effectively (or maybe at all) by schools in other countries. For example, a text–heavy, lesson plan in a minority European language may work splendidly in a national context but may simply be unusable by teachers in other countries.

With this in mind during the content audit, MELT partners have begun to develop quality criteria that are defined in terms of the extent to which learning content has the potential to "travel well"; i.e. the extent to which resources/assets can be easily used across national borders and in different curricula frameworks. At a commonsense level, some MELT content will obviously travel better than others. Learning assets such as pictures and sounds, for example, are obviously more reuseable than a complex, Spanish language learning object designed to convey facts about the Spanish War of Independence.

Beyond this, an initial assumption in MELT is that content is more likely to "travel well" if it is:

- Modular: the parts of a content item are fully functional on their own.
- Adaptable: the resource can be modified, for instance from a configuration file, from a plain text file or because it is provided along with its source code or an authoring tool.

Further discussions among partners also suggest that cross–border reuse of content will be more likely if resources:

- Have a strong visual element and users can broadly understand what is the intended learning objective or topic (e.g. resources may have little or no text; and include animations and simulations that are self–explanatory or have just a few text labels or icons/buttons for start, stop, etc.).
- Have been designed to be language customisable ("choose a language option") and are already offered in more than one language.
- Address curriculum topics that could be considered trans–national (e.g. teaching "geometric shapes" or "the parts of the cell" are usually covered in every national curriculum but teaching the folklore of a very specific region is not).
- Are adaptable from a technical (e.g. resources are supplied along with an authoring environment or tools) or IPR perspective (e.g. they are not made available under a "No derivatives" Creative Commons license which would prevent users from even translating the resource) [68].

Quality for Reuse Project Criteria

A quality assurance strategy is implemented in Canadian "Quality for Reuse" (Q4R) [85] project to improve effectiveness, efficiency and flexibility of LOs as well as proper storing and retrieval strategies. To realize this goal, it's necessary to propose policies, guidelines, evaluations grids and checklists, peer review, automated metadata capturing and verification as well as user data of both statistical and qualitative nature.

Q4R project team bases their initial guidelines on the following definition: ISO 9000: 2000 Quality Assurance Definition: "Quality Assurance is the planned and systematic activities put in place to ensure quality requirements for a product or service will be fulfilled. Document all processes."

Accordingly, they have organized these strategies into four main groups, namely organizational strategies, and then three strategies inspired by the life–cycle of a LO, that is from its conception to its use ⁄ reuse (adaptations).

Q4R quality assurance strategy is presented in Figure 23:

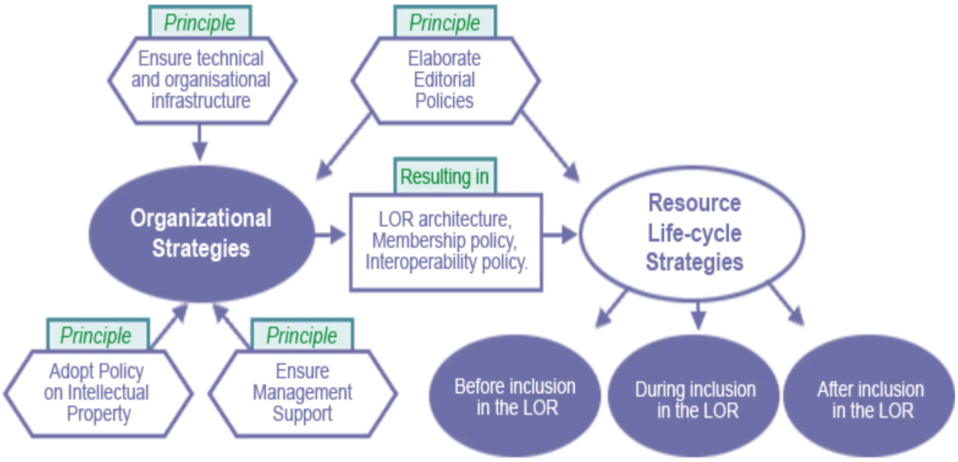

Figure 23. *Quality assurance strategy [85]*

Before LO Inclusion in the Repository

These strategies refer to the authoring, design and development of a LO or LR.

Design and Production Strategies:

- Use a solid and adapted Instructional design method.
- If the LO is compliant with SCORM or IMS LD, use specialized editors.
- Apply cultural diversity principles to make the LO more flexible and widely accessible.
- Support collaborative design by inviting specialists to support their expertise.
- Clearly identify knowledge and user competencies.
- Favour pedagogical strategies putting the learner in the centre.
- Apply evaluation criteria during development.
- Implement at least one learner/peer evaluation cycle.
- Apply access–for–all production principles and apply them at the start of a LO development.

Principles:

- Only build or integrate objects, which can be certified for quality.
- Interactive Objects are software and as such should answer to software quality criteria.

During LO Inclusion in the Repository

Strategies that may help increase quality during inclusion of an LO in the Repository refer to two main aspects:

- Quality control through Membership or Contribution Control Strategies.
- Quality control through technical Interoperability verification.

Contribution Control

The most common strategies for controlling contributions are to:

- Use LO harvesting, which means that the repository imports metadata records from other high quality repositories.
- Obligatory membership, usually free, but you must provide some personal data such as name, occupation and email address.

Technical Interoperability

Here it’s referred to how well a LR conforms to a technical standard.

- Automatic verification of compatibility with known protocols such as SCORM, Metadata schema etc…
- Automatic metadata generation or simplified metadata tagging tools.
- Checklists and Best Practices form the issuing organization of a standard.

Principle:

Reduce form–filling and use guiding wizards, smart automatic and semi–automatic computer agents to assist in assuring technical interoperability.

After LO Inclusion in the Repository

This section introduces types of strategies that are beneficial once the LO has been stored in the LOR and how easily a user can find, retrieve and reuse a LO. These types of strategies refer to two types of quality:

- Retrieval Quality, meaning that the user may freely search metadata records in many ways.
- Information Quality, which refers to how user’s can obtain information on how and in what situations the LO can or has been used as well as techniques and tools that facilitates this type of feedback.

Retrieval Quality

To provide retrieval quality the user should be able to retrieve LO records by:

- Entering free text keywords for search in all metadata fields or in specific ones.
- Browsing a known Classifications, Thesaurus, Competency profile or Organizational Typology.
- Browsing by Ontologies that links known relationships within a domain.
- Using federated search, that is search for a LO in one or many linked repositories.

Information Quality

Here it’s necessary to think about strategies that will on the one hand provide information to the user about reusability options and on the other hand how users can offer suggestions to improve the LO and how this information can be fed back to the author or designer of the LO.

Display Information Strategies:

- Descriptive structured resumes of the ways the LO can be reused.
- Offer simplified or full view of the metadata record.
- Graphical indications on how many people have downloaded and rated the LO.
- What do they think, i.e., star system, etc.

Feedback Techniques:

- Using the Annotation Metadata in LOM or
- Social tagging / bookmarking and Folksonomy
- Collaborative Filtering Techniques
- Recommendations built on Peer Trust Algorithms.

Principles:

- Provide interesting and easily understood user statistics, such as stars, percentages, voting systems.
- Include recommendations for reuse by the user, both to the next user and the designer [85].

Lithuanian Learning Objects' Evaluation Tool Approved by the Ministry of Education and Science

Special "Method of Schools Provision with Computer Teaching Aids" for certification of educational software and content was approved in Lithuania in June 2005 [69], and Computer Teaching Aids evaluation criteria were finally elaborated in January 2006 [16].

Education software and content is evaluated in Lithuania in conformity with the following evaluation criteria:

- Quality of educational material *(*incl. IPR – author's comment).*
- Psychological and pedagogical aspects.
- Learning management and interactivity.
- User interface *(*incl. personalization (e.g., for special needs students – author's comment).*
- Users' management possibilities.
- Tools (design possibilities) *(*suitable for VLEs: incl. LOS creation, storage and search possibilities, compliance with standards, e.g. SCORM – author's comment).*
- Communication and collaboration possibilities and tools.
- Technical features *(*incl. working stability – author's comment).*
- Documentation and additional tools.

- Economic efficiency *(*incl. cost, implementation and maintenance expenditure – author's comment).*

Technical Evaluation of Learning Object Repositories

One of the largest repositories' technical evaluation projects – Open Access Repositories (OARiNZ) [74] – was implemented in New Zealand. Looking particularly for assurances that the selected repository/s had a secure future, the criteria selected for this evaluation were:

- Scalability.
- Ease of working on code–base, extensibility.
- Security.
- Interoperability (ability to integrate with other repositories – OAI–PMH compliance, and ease of integration with systems such as VLEs).
- Ease of deployment, ability to support multiple installations on a single platform (required for hosting facility).
- Ease of system administration (ability to configure for different uses).
- Internationalisation – multiple language interfaces.
- Open source (type of license).
- Quality and configurability of workflow tools.
- Strength of community [102].

Each selected criterion was given an importance rating to be used when evaluating the different Repository systems. Major criteria were also broken down into sub–criteria with each sub–criterion also having an importance rating, and the above mentioned criteria rating system was used to evaluate Repository systems.

Conclusions of Literature Analysis and Problems to Solve

It is obvious that *all analysed LOs technical evaluation tools have a number of limitations:*

- LORI [107], Paulsson & Naeve [83] and MELT [68] *do not examine different LOs life cycle stages.*
- Q4R [85] *insufficiently examines technical evaluation criteria before LOs inclusion in the repository.*
- All tools *insufficiently examine LOs reusability (incl. Interoperability) criteria.*

The approved Lithuanian set of evaluation criteria [16] also has a number of *limitations*, e.g.:

- *All LOs and services (e.g., LAs, UoLs, LORs, VLEs) have to be evaluated against the same criteria.*
- *No metadata–related criteria are included.*
- Approved technical evaluation criteria for e-content and activities *do not reflect their reusability aspects overall.*

Therefore this set of evaluation criteria is not suitable for quality technical evaluation of LOs and VLEs. But at the moment no other tool exists for LOs and VLEs technical evaluation for Lithuanian school sector.

Moreover, almost no LOs–related scientific research was performed in Lithuania, even no investigation on the very LO notion has been executed yet.

It is obvious that more complex LOs technical evaluation tool is needed.

This tool should include LOs technical evaluation criteria suitable for different LOs life cycle stages, including criteria before, during and after LOs inclusion in the repository as well as LOs reusability criteria.

LOs reusability criteria should have the same weight as the other criteria.

The author's research results [5A, 9A] show that Lithuanian education system needs a rapid growth of adapted LOs available for the teachers. It is obvious that this growth due to the limited financial and human resources is impossible without large scale adaptation, localisation, and reuse of LRs available in LRE system and other suitable repositories around the world. It is also clear that Lithuanian LO repositories should include a big number of teachers created LOs.

Therefore Lithuanian education system needs high quality simple to use and clear enough LOs technical evaluation tool based on scientific research in the area.

4.2. Recommended Learning Objects Technical Evaluation Tool

The author proposes the original set of LOs evaluation criteria based on flexible DLE model (i.e., reusability of DLE components) as well as on conclusions of the analysis of foreign LOs technical evaluation criteria presented in section 4.1.

This tool includes LOs technical evaluation criteria suitable for different LOs life cycle stages, including criteria before, during and after LOs inclusion in the repository, as well as LOs reusability criteria. The tool combines [68], [83], [85], [105], [107] and the author's own research results.

This tool is presented in Figure 24 and more in detail in Table 6.

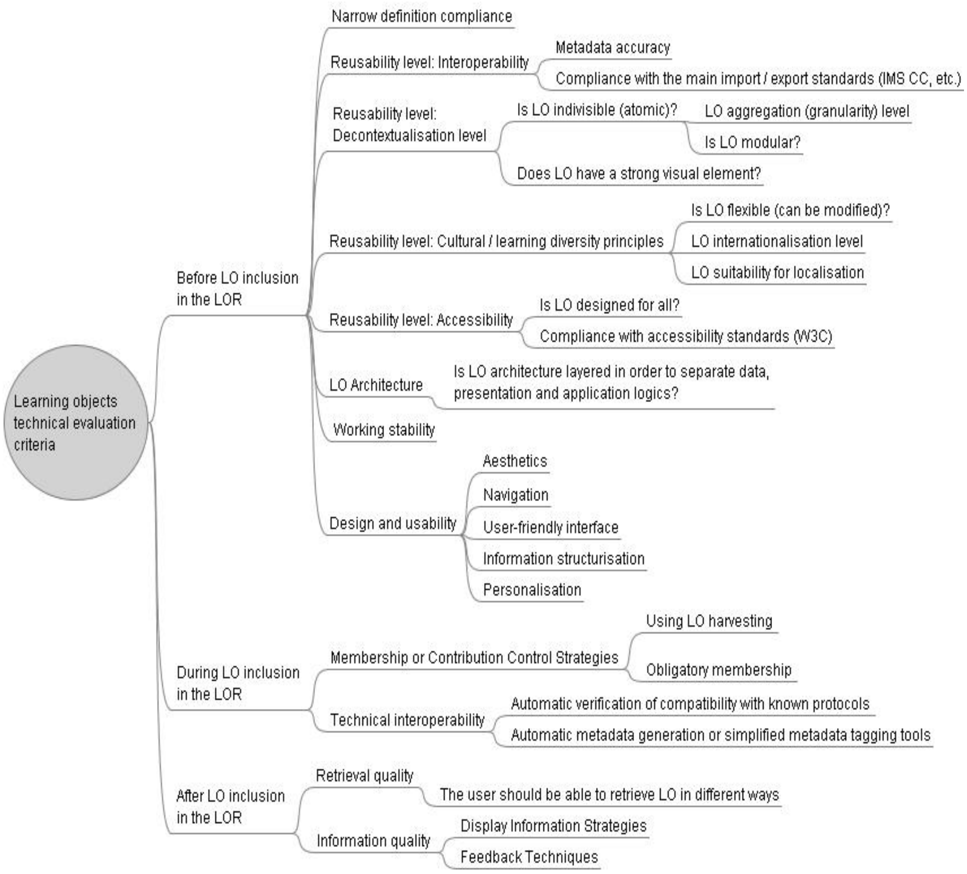

Figure 24. *Technical criteria for LOs evaluation*

Table 6. *Technical criteria for LOs evaluation*

LOs life cycle stage	**Criteria**	**Sub–criteria, explanation**
Before LO inclusion in the LOR	Narrow definition compliance	Does this LR fit the definition "LR that can be reused to support learning"?
	Reusability level: Interoperability	• Metadata accuracy • Compliance with the main import/export standards (e.g. IMS CC, IMS LD) (can LO be used in different platforms / VLEs?)

	Reusability level: Decontextualisation level	• Is LO indivisible (atomic)?
		  o LO aggregation (granularity) level
		  o LO modularity

LOs life cycle stage	Criteria	Sub–criteria, explanation
		• Can LO be reused a number of times in different learning contexts (is pedagogy kept outside the LO in order to facilitate pedagogical context independence)? • Does LO have a strong visual element?
	Reusability level: Cultural / learning diversity principles	• Is LO flexible and can be modified? • LO internationalisation level • LO suitability for localisation
	Reusability level: Accessibility	• Is LO designed for all? • Compliance with accessibility standards
	Architecture	• Is LO architecture layered in order to separate data, presentation and application logics? • What is the level of decomposability and context independence?
	Working stability	
	Design and usability	• Aesthetics • Navigation • User–friendly interface • Personalization
During LO inclusion in the LOR	Membership or Contribution Control Strategies	• Using LO harvesting (the repository imports metadata records from other high quality repositories) • Obligatory membership (usually free, but you must provide some personal data such as name, occupation and email address)
	Technical interoperability	• Automatic verification of compatibility with known protocols such as SCORM, Metadata schema etc… • Automatic metadata generation or simplified metadata tagging tools
After LO inclusion in the LOR	Retrieval quality (the user may freely search metadata records in many ways)	The user should be able to retrieve LO records by: • Entering free text keywords for search in all metadata fields or in specific ones • Browsing a known Classifications, Thesaurus, Competency profile or Organizational Typology • Browsing by Ontologies that links known relationships within a domain • Using federated search, that is search for a LO in one or many linked repositories

LOs life cycle stage	Criteria	Sub–criteria, explanation
	Information quality (how users can obtain information on how and in what situations the LO can or has been used as well as techniques and tools that facilitates this type of feedback)	Display Information Strategies: • Descriptive structured resumes of the ways the LO can be reused (recommendations for reuse by the user, both to the next user and the designer) • Offer simplified or full view of the metadata record • Graphical indications on how many people have downloaded and rated the LO • Voting/rating systems (star system, etc.), percentages Feedback Techniques: • Using the Annotation Metadata in LOM • Social tagging / bookmarking and Folksonomy • Collaborative Filtering Techniques

Additional LOs evaluation criteria interconnected with technical criteria:

- Licensing (clear rules, e.g. compliance with Creative Commons).
- Economic efficiency (taking into account the number of probable users in conformity with LO reusability level) [3A, 8A].

4.3. Analysis of Existing VLEs Technical Evaluation Tools

Flexible personalized approach to DLE creation and development based on implementation of distinct, stand–alone, modularised, as small as possible, open code content and services components has a number of technologic and socio–economic advantages in comparison with monolithic closed proprietary approach to DLE creation. Software and systems that conform to open and international standards that have community support should be favoured when purchasing systems for the public sector. Modularised learning environments with clearly defined interfaces must be produced in order to ease the development of a holistic approach based upon the combination of, as small as possible, content and software components. Therefore LIFE Roadmap project [57] experts propose educational enterprises (institutions) to discourage any proposals for the monolithic system architecture; adopt a distributed model made up of distinct, stand–alone components that communicate over open protocols interfaces.

The author bases his set of VLEs evaluation criteria on flexible personalised

DLE approach as well as mainly on two foreign well–known VLEs evaluation methods suitable for flexible personalised DLE:

- New Zealand methodology of technical evaluation of learning management systems (LMSs) [101].
- Austrian method of evaluation of open source e-learning platforms with the main focus is on adaptation issues [29].

Methodology of Virtual Learning Environments Technical Evaluation

Methodology of Technical Evaluation of Learning Management Systems (or VLEs) is a part of the Evaluation of Learning Management Software activity undertaken as part of the New Zealand Open Source VLE project [101].

One of the goals of the project was to select a best–of–breed open source LMS for development and large–scale deployment among:

- *ATutor Platform:* Apache, PHP, MySQL. Version: 1.3.3 [4]
- *Ilias Platform:* Apache, PHP, MySQL. Version: 3 Beta [35]
- *Moodle Platform:* Apache, PHP, MySQL/PostgreSQL. Version: 1.2 Beta [70]

The evaluation criteria expand on a subset of the criteria, focusing on the technical aspects of the systems:

Overall Technical Evaluation Criteria

- Overall architecture and implementation *(*suitable for technical evaluation – author's comment):*
    - Scalability of the system.
    - System modularity and extensibility.
    - Possibility of multiple installations on a single platform.
    - Reasonable performance optimisations.
    - Look and feel is configurable.
    - Security.
    - Modular authentication.
    - Robustness and stability.
    - Installation, dependencies and portability.
- Interoperability *(*suitable for technical evaluation – author's comment):*
    - Integration is straightforward.
    - LMS standards support.
- Cost of ownership.
- Strength of the development community:
    - Installed base and longevity.
    - Documentation.
    - End–user community.
    - Developer community.

  - Open development process.
  - Commercial support community.
- Licensing.
- Internationalisation and localisation *(*suitable for technical evaluation – author's comment):*
  - Localisable user interface.
  - Localisation to relevant languages.
  - Unicode text editing and storage.
  - Time zones and date localisation.
  - Alternative language support.
- Accessibility *(*suitable for technical evaluation – author's comment):*
  - Text–only navigation support.
  - Scalable fonts and graphics.
- Document transformation [101].

Criterion 1: Overall Architecture and Implementation

To assess software systems for long–term operation, development and support, the key criteria are simple: quality of architecture and craftsmanship. This is comparable to considering other complex man–made objects for their long–term viability.

The modern definition of software architecture defines it as the structure which comprises software elements, their properties, and relationships.

Sub–criterion 1.1: Scalability of the System

Scalability indicates a system's ability to maintain quality performance or service under an increased system load by adding resources. To scale vertically or scale up, means to add resources to a single node in a system, such as adding memory or a faster hard–drive to a computer.

To scale horizontally or scale out, means to add more nodes to a system, such as adding a new computer to a clustered software application. A truly scalable system must also scale down to more constrained resources, to allow small scale deployments.

The three LMSs in the [151] review are strikingly similar in their scalability profile. While most web applications have a common architectural model, the LMSs evaluated use the same middleware and RDBMS solutions.

They embody, however, different strategies database usage, caching, and memory management. These can have a significant impact on scalability and performance (Table 7).

Table 7. *System's scalability [101]*

System is scalable	ATutor	Ilias	Moodle	Comment
Scale up: high end services	Excellent	Excellent	Excellent	Similar architecture
Scale up: allow cashing	Good	None	Uncomp-leted	Hard to achieve with PHP–based solutions
Scale out: multiple app servers	Good	Good	Good	Better performance and availability. Similar limitations – session handling and data directory
Scale up: multiple database servers	Good	Good	Very good	Better availability and reliability, less performance. All support MySQL with log–shipping. Moodle also supports PostgreSQL with log–shipping and phased commits. None segregates read–write from read–only
Scalability constraints	DB writes	DB writes	DB writes	Similar architecture

Sub–criterion 1.2: System's Modularity and Extensibility

The [101] review considered a system to be modular when its implementation is comprised of modules with high cohesion and low coupling. This is a strong indicator of the inherent maintainability and adaptability of a software system.

In short, coupling is a measure of how interrelated two software components are. Cohesion is a measure of how related the functions performed by a software component are.

High coupling implies that, when a component changes, changes to other components are likely.

Low cohesion implies difficulty in isolating the causes of errors or places to adapt to meet new requirements (Table 8).

Table 8. *System's modularity and extendibility [101]*

System is modular and extendible	ATutor	Ilias	Moodle	Comment
Has module architecture	Yes, average	Yes, suffers tight coupling	Yes, simple and complete	Moodle achieves the goal of loose coupling/high cohesion. Ilias has a tightly coupled architecture
Core functionali-ty in modules	No	Yes, inconsiste nt	Yes	
Solid support for modules	No	No	Yes	
Internal API	No	Ad–hoc	Yes, well documen-ted	
External API	No	No	No	Possible to develop external APIs

Modular architecture

Does the application have a modular architecture? An ideal architecture has simple but well defined internal layout, and the modules have small, well defined interfaces, high cohesion and loose coupling.

The modular architecture must be documented, simple and elegant. There is no requirement that is must be object–oriented or functional. The performance/resource trade–offs must be acceptable, and it should not impose artificial bottlenecks or inefficiencies.

ATutor: Monolithic architecture *(*situation in July 2005 – author's comment).* All functionality resides in the core of the application. Extensions must be made part of the application, and are tightly coupled.

Ilias: Architecture is confusing and undocumented. Each module is implemented as a class, exposes an arbitrary interface, and behaves as a special case.

Moodle: Simple, straightforward and complete module architecture. The code is split in modules (mod directory) and libraries (lib directory). Modules must expose certain entry points as functions and particular files. Authentication is modular and segregated from the rest of the modules.

Core functionality in modules

Highly modular applications provide most of their end–user services as modules. Experience indicates that systems that do not follow this rule hint at a module infrastructure without extensive use, therefore incomplete and immature.

ATutor: There are no modules as such. All functionality resides in the core application.

Ilias: Most functionality resides in ad–hoc modules without interface consistency.

Moodle: Most of the end–user functionality is in modules. While about 50 % of the code is in core libraries, 30 % is in modules.

Solid support for modules

Solid support for modules means that the core application sets up a framework of services.

Modules must have means to register with the framework (for user–level navigation, compatibility checking, etc.), set up database tables to store their data, schedule backend processes, retrieve user data, presentation templates, and offer configuration interface (either for the user or the administrator).

If the application is being upgraded, modules must be able to execute upgrade routines.

Additionally, for modules to maintain their loose coupling with the core application, the framework must offer other well documented services such as retrieval of configuration data, database access, logging, authentication and authorization.

ATutor: There is no framework in place.

Ilias: There is no framework in place.

Moodle: The framework is well developed and mature. Modules can set–up their own DB tables, run upgrade scripts, cron scripts, etc.

Internal API

Internal mechanisms must be documented and expose functions or methods that act as entry points to trigger its functionality. These must follow documented (or well known) conventions, and be consistent and straightforward.

ATutor: There is no well defined internal API.

Ilias: Internal classes are documented using PHPDoc, but do not constitute an organized API.

Moodle: The modules infrastructure imposes a standard API for modules. Libraries are well documented.

External API

Key services are exposed to suitably authenticated programs that need to be integrated with the LMS but are not on the same server or are not part of the same application. This must be done over an RPC or ORB interface; popular implementations of such interfaces are XML–RPC and SOAP.

None of the systems reviewed exposed an external API. It is possible, however, to build it for any of the three system using existing PHP libraries.

Sub–criterion 1.3: Possibility of Multiple Installations on a Single Platform

Can one hardware set–up – at any point of the scalability range – handle multiple instances of the system independently? To achieve this configuration files (covering hostname, database, installed path and, data directory) and logging services must be abstracted.

Ideally a single installation of the program can be made to run with different configuration files.

ATutor: Can run multiple instances in different URLs. Configuration is restricted to a single file and well abstracted. Logging services are provided by Apache and can be segregated per instance.

Ilias: Can run multiple instances in different URLs. Configuration is spread across several files, but well abstracted, and prepared to run several instances from the same set of configuration files. Logging services are provided by Apache and also internal logging facility; can be segregated per instance.

Moodle: Can run multiple instances in different URLs. Configuration is restricted to a single file and well abstracted. Logging services are provided by Apache and can be segregated per instance.

Scripted administration

It must be possible to automate the creation, administration and deletion of server instances using common Unix scripting tools. Scripted upgrades should be possible.

ATutor: Possible to manage through shell scripts, some parts of the installation/upgrade process may need extra work.

Ilias: Possible to manage through shell scripts, configuration files and database set–up more complex.

Moodle: Simple to manage through shell scripts. Version upgrades can be scripted across many instances.

Table prefixes

The use of configurable table prefixes allows many application instances to share one database using segregated database tables. This benefit allows many instances to be run in environments limited to one database (virtual hosting at an

ISP, for instance), and also derive a marginal benefit in the use of persistent database connections.

ATutor: Yes.
Ilias: No.
Moodle: Yes.

Sub–criterion 1.4: Reasonable Performance Optimisations

Strategies that maximize performance and make efficient use of resources are clear signs of good architecture and craft. Furthermore, application systems must be deployed at reasonable cost for large user bases. Strategies and practices relevant to the PHP engine can and should be used to ensure the system delivers acceptable performance and scales well (Table 9).

Table 9. *System's performance [101]*

System has reasonable performance optimizations	ATutor	Ilias	Moodle	Comment
Compatible with precompiled code caches	Yes	Yes	Yes, limited compatibi-lity	Moodle is not compatible with one of the code caches available
Persistent connections	Yes	Yes	Yes	

Sub–criterion 1.5: Look and Feel is Configurable

Table 10. *System's Look and Feel is Configurable [101]*

Look and feel is configurable	ATutor	Ilias	Moodle	Comment
Headers and footers customisable / use themes	Yes, untidy	Yes, limited	Yes, as themes	Ilias and ATutor have an untidy setup for headers/footers, where several files must be edited

End of Table 10

Look and feel is configurable	ATutor	Ilias	Moodle	Comment
CSS and other applied styles are customisable / use themes	Good, as themes	Good	Good, as themes, well documented	
Theme scope	Site–wide, with course and user themes	User theme	Site–wide theme	Centralized theme control is better for wide–scale deployments

Sub–criterion 1.6: Security

The security of a web–based system consists of strategies that address three interdependent but well defined areas (Table 11). Server security covers strategies to secure the server against attack. Applications must be designed to avoid being an avenue of attack against the server.

User security and privacy must be preserved; the LMS/VLE system must keep communication and data private and avoid exposure of user's computers (client computers) to attacks. Application security covers restrictions on what users can do (to prevent attacks and misuse) and data privacy. To prevent unintended access, the application must have mechanisms for authorization (checking of credentials) and authentication (checking of right to perform an action). In these three areas, secure applications implement strategies that monitoring and log attack attempts and minimise exposure. Security strategies involve the whole stack, from the operating system up through the libraries, framework, components and application layers. The Apache/PHP framework provides outstanding security features, which these applications should take advantage of.

Table 11. *System's Security [101]*

Security	ATutor	Ilias	Moodle	Comment
User privacy security: SSL integration	Good	Good	Good	
Server security: permission lock–down	Good	Bad	Good	Ilias requires lax permissions on config files, and cannot be easily managed otherwise

End of Table 11

Security	ATutor	Ilias	Moodle	Comment
App security: authentication	Good	Good	Good	PHP Session management needs to be configured tightly
App security: authorization	Limited	Good	Limited	
App security: logging and monitoring	Bad	Bad	Bad	None offers logging of abuse attempts
App security: validation of input	Good	Weak	Good	Security issues in input validation were identified during the review

Sub–criterion 1.7: Modular Authentication

Institutions deploying a LMS/VLE are highly likely to have a pre–existing infrastructure, one that is already maintaining authentication data, and maintaining segregated user lists is inefficient and error–prone. It is also very likely that a LMS/VLE will be coupled with other tools, web–based or otherwise, such as blogs and content management systems. Such scenarios make modular and flexible authentication a key feature, which was evaluated separately from overall system modularity (Table 12).

Table 12. *Modular Authentication [101]*

Modular authentication	ATutor	Ilias	Moodle	Comment
Authentication is modular	No	Yes	Yes, own modules	
Interoperates with standard authentication back–ends	No	Yes	Yes	Ilias offers a wider range of authentication back–ends
Interoperates with external authentication ticket system	Yes	Yes	Yes	All use PHP's session management, which can use an external system
Authentication services API	No	No	No	

Sub–criterion 1.8: System’s Robustness and Stability

Robustness and stability are key concerns when deploying applications in large scale and long term. These criteria are observed not only in the passive count support issues during operation, but also on the proactive strategies taken by the application developers (Table 13).

Table 13. *System’s Robustness and Stability [101]*

System is robust and stable	ATutor	Ilias	Moodle	Comment
Cross–browser support	Good	Good, requires frames	Good	Ilias does not work correctly with screen readers and text–only browsers
Not dependent on JavaScript	Yes	Yes	Yes	Moodle loses WYSIWYG HTML editor
No maintenance downtime	Good	Good	Good	
Backup	Good	Good	Excellent	Moodle implements an XML based backup/restore facility in addition to standard DB backups

Sub–criterion 1.9: Installation, Dependencies and Portability

Table 14. *Installation, dependencies and portability [101]*

Installation, dependencies and portability	ATutor	Ilias	Moodle	Comment
Overall portability	Widely portable	Widely portable on Unix, limited on Win32	Widely portable	

End of Table 14

Installation, dependencies and portability	**ATutor**	**Ilias**	**Moodle**	**Comment**
Dependencies are robust	Yes	XML dependencies not robust	Yes	
Dependencies can be replaced	Yes	Some	Yes	XML–related dependencies cannot be replaced in Ilias
Dependencies are FOSS	Yes	Required	Yes	Some optional dependencies for Ilias require commercial and non–FOSS licenses
Dependencies are easily installed	Yes	Required	Yes	Some optional dependencies (Java) require separate installation on Debian systems
System is easily packaged	Yes, packages not available	Partially. Packages available	Yes, Debian packages available	

Ease of installation and maintenance is critical for a scenario of wide deployment, covering both large–scale centrally managed installations and stand–alone installations in the Local Area Network of education organization.

Considerations cover portability, robustness, freedom and overall ease of installation (see Table 14).

Criterion 2: Interoperability

Systems are seldom deployed in a vacuum.

Deployment scenarios include integration with pre–existing systems and networks talking a myriad of protocols.

Integration of authentication systems is by far the most likely scenario, which is explored fully under “Modular Authentication”.

Integration efforts other than authentication also benefit from a clean, modular, architecture, discussed under “System is modular and extendible”.

Sub–criterion 2.1: Integration is Straightforward

Ease on integration depends as well on the availability of libraries that implement common protocols. This is actually a feature of the framework, which the three systems share.

The three layers of the stack that comprises the framework have a very good availability of protocol libraries. The PHP library repository (PEAR), plus libraries and modules available outside of PEAR, have a wide spectrum of modules implementing internet–related protocols.

Additionally, there is a small range of Apache modules that implement common protocols, such as LDAP, Kerberos and RADIUS. Finally, there are hardly any modern protocols without an available (and open) implementation on Linux.

Put together, the Linux–Apache–PHP framework provides one of the most comprehensive development platforms available.

Sub–criterion 2.2: LMS / VLE Standards Support

The system is compliant with common standards for LO creation, retrieval and use, i.e., SCORM 1.2, IMS, DC metadata (Table 15).

Table 15. *Standards Support [151]*

LMS standards support	ATutor	Ilias	Moodle	Comment
LO Standards	IMS/SCORM export	IMS import	SCORM 1.3	Moodle has an IMS LD module in development
Search and Retrieval standards	No	No	No	ATutor's future plans mention TILE

*LO standards – IMS Content Packaging, SCORM (*situation in July 2005 – author's comment)*

The LMSs are rated on their ability to use externally supplied LOs packaged in IMS format (also known as SCORM 1.2), their ability to provide SCORM 1.3 runtime environment support for LOs that are SCORM–aware. Additionally, the ability to export content in IMS packages was evaluated in the [151] review.

ATutor: Can export course material as an IMS/SCORM 1.3 packages.

Ilias: Can use externally generated IMS package. There is no SCORM 1.3 runtime environment support.

Moodle: There is SCORM 1.3 environment support.

Future plans mention IMS LD.

In his presentation in Braga in May 2005 Martin Dougiamas, lead programmer of Moodle, explained that “Moodle has an implicit sequencing of activities, which are listed. The exporting of this structure as an LD file is fairly simple. The file contains the standard tags, and it would be good to describe as much as possible using them. Anything that is not can standard be added using XML processing instructions, although these are only really useful for Moodle at the moment because they are Moodle specific. For example, in Moodle we have the glossary activity. Not many other systems have anything like that, but the export could be made in a way which would be useful, even without the full functionality. However, the importing is trickier. Some things which can be done in LD are not yet in Moodle, but they have been part of the plans for some time. Moodle 1.5, has just been released, and this the culmination of work carried out since August 2004. A lot of core development has been done, making it possible to target tiny elements and restyle them. 1.6 is the next version, and it seems reasonable that we can get LD export for that, in a few months. 1.6 also includes a database module similar to Filemaker for making collections of information, creating a photo gallery with text, comments etc. Blogs are very popular, and there are some interesting ideas for their use in Moodle. If you have blogs in an educational environment then you can have rss streams of a single student, or a group, or a site, or an institution. For each entry in the blog it is possible to target who it is for. There are also plans to improve the user profile, making it more like a homepage. At the moment it is rather a dashboard look. It will be able to access LAMS transparently from Moodle, but they are going to be separate systems. They will be easy to work with together. Version 2 coming up in 2006 will be a big break, with major core changes, and it is planned to include LD input. We will add conditional activities. For every activity there will completion criteria, and a second criterion is that the activity is only available when this other activity is done. You can still be free and easy, but there will be the option of using them. This ties in well with LD. The way that roles work will also be reviewed. We currently have hard coded roles, but the idea is to make them completely configurable. The administrator can make a new role, say “parent”, and assign a role to a user in an activity. LD import would require this. The current groups’ implementation in Moodle is rather basic: each activity can choose whether to use groups or not. The aim is to improve that to the kind of level that LD is talking about, with people in activity groups”. He has said that LD is the only standard that he has really felt comfortable with. “SCORM adds very little to functionality, but is necessary, for example you can’t run Moodle in Italy unless you are SCORM compliant.

Other improvements which are not LD related is networking between Moodles. It would be great to have a button for community, where the system asks you some questions, and then you get logged in automatically to a Moodle server where you can share ideas, content, etc. The administrator can choose if they want their learners going off to Moodle.org, but by default it'll be on. It's also intended to make it possible to have one code base that appears to be many different sites. There will also be a documentation management system, which will enable students to have space to store assignments, where they can link to them. Hive's Harvest Road is being incorporated, but in the future it would be good to have an OS back end too.

Moodle is described as "social constructionist", which means that it is a learning system where learners can create things for each other, they can see each other making things for each other, and the system also tells you what is going on in the system. If you are on a website which reminds you about what is going on then activity heats up. In forums there is always a reminder to ask questions. All of that is social constructivism.

There is a lot more which could be done to support this and plenty of ideas for things which could be done better" [4A].

Criterion 3: Internationalisation and Localisation

Some programs assume text is written in English (ASCII). For people who use non–English languages, these programs are barely usable. And more, though many systems can handle not only ASCII but also ISO–8859–1, some of them cannot handle multi byte characters for Chinese, Japanese, and Korean languages, or combined characters for Thai.

The [101] review evaluated support for multiple languages at the data handling level and user interface levels.

Internationalisation is needed in the following places:

- displaying characters for the users' native languages;
- inputting characters for the users' native languages;
- handling storage and retrieval of data and files written in popular encodings that are used for the users' native languages;
- using characters from the users' native languages for file names and other items;
- printing out characters from the users' native languages;
- displaying messages by the program in the users' native languages;
- formatting input and output of numbers, dates, money, etc., in a way that obeys customs of the users' native cultures;
- classifying and sorting characters, in a way that obey customs of the users' native cultures;

- using typesetting and hyphenation rules appropriate for the users' native languages.

The [101] review puts emphasis on the first three items, which are the base of internationalisation support.

The following terminology is used:

- *Internationalisation* means modification of software or related technologies so that software can potentially handle multiple languages, customs, and so on in the world.
- *Localisation* means implementation of a specific language for an already internationalised software.

Sub–criterion 3.1: Localisable User Interface

Strings (texts) belonging to the user Interface (UI) are managed through an Internationalisation library, such as GNU Gettext, that separates UI strings from the code, and support locales for date and number formats. Must be Unicode compliant and support easy localisation (tools such as those supplied with gettext are a plus).

It is desirable that the UI supports BiDi text (for right–to–left languages). None of the systems used standard libraries, preferring instead to roll their own. These solutions have different tradeoffs between memory consumption, execution speed and ease of maintenance. Not all the systems support date and number format locales.

ATutor: Straightforward localisation scheme using a list of localised strings held in the database (slow execution, hard to maintain, less memory consumption). Does not seem to support Unicode, it only to supports the ISO–8859 code page. Does not support BiDi text or format locales.

Ilias: Straightforward localisation scheme, using a list of localised strings stored in specially formatted files that are (slow execution, easy to maintain, low memory consumption) and a locale setting. Supports Unicode – all localisations are using UTF–8. Does not seem to support BiDi text.

Moodle: Straightforward localisation scheme, using a list of localised strings stored in PHP–formatted files (fast execution, easy to maintain at the cost of more memory consumption) and a locale setting. Supports Unicode – although most localisations are using legacy codepages – and BiDi text.

Sub–criterion 3.2: Localisation to Relevant Languages

It is expected that LMSs/VLEs have already existing locale and strings for English. It is desirable that they have a wider range of already implemented Localisations using UTF–8.

ATutor: 12 languages available, none uses UTF–8. Lithuanian localisation – partly *(*situation in July 2005 – author's comment)*

Ilias: 10 languages available, all in UTF–8, with the Simplified Chinese Localisation making use of high characters.

Moodle: 31 languages available, plus seven national Localisations. 66 language packs in July 2005. Lithuanian localisation – partly, interface only; no localisation for glossary and help *(*situation in July 2005 – author's comment)* [4A].

Sub–criterion 3.3: Unicode Text Editing and Storage

Where the system allows content editing, it must support editing of wide Unicode characters.

- Data storage must support Unicode.
- Editing interfaces (forms for forums, etc.) must support Unicode.

ATutor: Only supports ISO 8856 posts, some browsers (Mozilla, for instance) work around this limitation HTML–encoding high characters. Other browsers display but not post outside of ISO 8856 characters.

Ilias: Uses UTF–8 as charset, application–wide. This makes support for high characters transparent, at the expense of legacy browsers.

Moodle: With the default ISO–8856, some browsers (Mozilla, for instance) work around this limitation HTML–encoding high characters. Other browsers display but not post outside of ISO 8856 characters. Setting the locale to use UTF–8 and altering the templates charset setting provides consistent Unicode support.

Sub–criterion 3.4: Time Zones and Date Localisation

All dates must be stored with an unambiguous time zone (TZ), preferably UTC. This is to support scenarios where users are in different time zones.

ATutor: Supports only one TZ.

Ilias: Supports only one TZ.

Moodle: Stores time/dates in UTC, and recognizes in which TZ the server and each user is.

Sub–criterion 3.5: Alternative Language Support

The system should allow for alternative language versions of the same resource.

Content negotiation support: The system should allow the user to choose directly (or indirectly via browser settings) to access alternative language versions for resources that have them.

ATutor: No support.

Ilias: Supports multiple languages for some content types, doesn't support content negotiation.

Moodle: No support.

Criterion 4: Accessibility

Sub–criterion 4.1: Text–only Navigation Support

The system supports text only navigation and other accessibility hooks, such as:

- Hidden links.
- Link shortcuts.
- Descriptive link texts.
- Full support for ALTs for images and rich media.

ATutor: Excellent text–only navigation, including link shortcuts, ALT texts, etc.

Ilias: Cannot be used with text–only navigation, due to frames.

Moodle: Limited or no support for text–only navigation. Images lack ALT texts, navigation does not provide hidden links nor keyboard shortcuts. Some links use ambiguous link texts.

Sub–criterion 4.2: Scalable Fonts and Graphics

Graphics and text scale correctly when the user requests large fonts on the browser.

ATutor: Text and images are scalable.

Ilias: Text is scalable, graphics are fixed–size. Due to use of frames, the interface is not usable with large fonts.

Moodle: Text is scalable, graphics are fixed–size [101].

Summary of Findings on VLEs Technical Evaluation

Open source systems short–listed in [101] show significant differences in their design, architecture and implementation. On the overall evaluation, Moodle shows a clear advantage, particularly in criteria that is critical to the long–term viability of the system. The primary differentiating advantage of Moodle is *System Architecture.*

Moodle's main strength is its simple but solid design and architecture. Moodle's architecture sets an excellent foundation, following good practices of low coupling and high cohesion, which the other LMSs fail to achieve. This yields a system that is simple, flexible and effective; and easily accessible to developers. A modular, extensible architecture is a key criterion. The Moodle approach is pragmatic, using intelligent strategies, e.g., the code is split into modules and standard libraries, and a standard API for modules. Authentication is modular and separate from the rest of the modules. This will allow easier integration with a portal framework, and an interface to student management systems.

Moodle does have limitations, notably it currently lacks IMS support, and its roles and permissions system is limited. However these problems can be fixed.

ATutor, while strong in features and usability, has serious architectural problems although some features in ATutor warrant further investigation, and may be candidates for porting to Moodle.

Ilias, while promising, has a complex architecture with tight coupling that is hard to work with and debug. The code is new, and lacks maturity.

Virtual Learning Environments Adaptation Evaluation Instrument

The Graf and List paper [29] presents an evaluation of open source e-learning platforms / VLEs with the main focus is on adaptation issues.

Adaptation received very little coverage in e-learning platforms. An e-learning course should not be designed in a vacuum; rather, it should match students' needs and desires as closely as possible, and adapt during course progression.

The extended platform will be utilized in an operational teaching environment. Therefore, the overall functionality of the platform is as important as the adaptation capabilities, and the evaluation treats both issues.

There are only a few e-learning platform evaluations available in the current literature. Their main focus is on commercial products. In contrast, the work [29] is focused on open source products only. In [15] and [75] general purpose evaluations have been conducted. Both applied a simple evaluation approach.

This evaluation [29] is also based on the qualitative weight and sum approach. After a pre–evaluation phase, nine platforms were analyzed in detail. The detailed evaluation approach is focused on the adaptation category and its results.

Qualitative Weight and Sum Approach

The qualitative weight and sum (QWS) [93] approach is a well–established approach for the evaluation of software products. It establishes and weights a list of criteria. QWS is based on the use of symbols.

There are six qualitative levels of importance for the weights, frequently symbols are used:

- E = Essential.

- = Extremely valuable.
- # = Very valuable.
- + = Valuable.
- | = Marginally valuable.
- 0 = Not valuable.

The weight of a criterion determines the range of values that can be used to measure a product's performance. For a criterion weighted #, for example, the product can only be judged #, +, |, or 0, but not *. This means that lower–weighted criteria cannot overpower higher–weighted criteria.

To evaluate the results, the different symbols given to each product are counted. Example results can be 2*, 3#, 3| or 1*, 6#, 1+. The product can now be ranked according to these numbers. But the results are sometimes not clear.

There is no doubt that 3*, 4#, 2| is better than 2*, 4#, 2| but it is not clear whether it is better than 2*, 6#, 1+. In the latter case further analysis has to be conducted.

Applied Evaluation Approach

In [29] the authors have selected the QWS approach for this evaluation, because of the differentiated results, which highlight the strengths and limitations of the platforms. They have adapted the approach in a way where the essential criteria are assessed in a pre–evaluation phase.

These minimum criteria cover three general usage requirements: an active community, a stable development status, and a good documentation of the platform. The fourth criterion incorporates the didactical objective and means that the platform's focus is on the presentation of content instead of communication functionalities.

At the beginning of the evaluation, 36 platforms and evaluated these according to the minimum criteria have been selected in [29]. Nine platforms (ATutor 1.4.11, Dokeos 1.5.5, dotLRN 2.0.3, based on OpenACS 5.1.0, Ilias 3.2.4, LON–CAPA 1.1.3, Moodle 1.4.1, OpenUSS 1.4 extended with Freestyle Learning 3.2, Sakai 1.0, and Spaghettilearning 1.1) meet the criteria. Next, these nine platforms were tested in detail. A questionnaire and an example of a real life teaching situation, covering instructions for creating courses, managing users and simulating course activities, were designed and applied to each platform.

Finally, [29] established *eight categories: communication tools, learning objects, management of user data, usability, adaptation, technical aspects, administration, and course management.* These categories act merely as a classification and include several subcategories. Only the subcategories are weighted and evaluated. Several attributes measure the characteristics of each subcategory.

Furthermore, a rule was defined for each subcategory, which assigned the combination of measured attribute values to an evaluation value of the subcategory. According to the QWS approach, these values were summarized for each category by building the number of each symbol. The evaluation value of the platform was calculated equivalently.

Adaptation Capabilities

This section is focused on adaptability, personalization, extensibility, and adaptivity capabilities of the platforms. [29] focused on customizable adaptation only, which can be done without programming skills.

- *Adaptability* includes all facilities to customize the platform for the educational institution's needs (e.g. the language or the design).
- *Personalization* aspects indicate the facilities of each individual user to customize his/her own view of the platform.
- *Extensibility* is, in principle, possible for all open source products. Nevertheless, there can be big differences. For example, a good programming style or the availability of a documented application programming interfaces (API) are helpful.
- *Adaptivity* indicates all kinds of automatic adaptation to the individual user's needs (e.g. personal annotations of learning objects or automatically adapted content).

The evaluation results of the adaptation category are presented in Table 16.

Table 16. *Platform Adaptation Evaluation Results [29]*

	Adapta-bility	***Persona-lization***	***Extensibi-lity***	***Adaptivity***	**Ranking**
Maximum values	*	#	*	*	
ATutor	|	#	#	|	3
Dokeos	|	0	*	+	2
dotLRN	+	+	*	0	2
Ilias	+	#	*	0	2
LON–CAPA	+	#	#	|	2
Moodle	#	+	*	|	1
OpenUSS	#	#	#	0	2
Sakai	0	0	*	0	3
Spaghettilearning	+	#	+	0	3

The maximum values represent the values, which can be achieved at maximum per subcategory. Examining the results from a vertical perspective, it can be seen that the adaptability and the personalization subcategories yield a broad range of results. The majority of the platforms were estimated as very good with regard to extensibility. In contrast, adaptivity features are underdeveloped.

Looking at the results in a platform specific way, it can be seen that an exact ranking is not possible. Due to the use of the QWS approach, a pair–wise comparison of all platforms is necessary to determine the ranking. Because these comparisons do not result in a sequential order, the platforms need to be grouped into clusters.

As a result, Moodle can be seen as the best platform concerning adaptation issues. Moodle provides an adaptive feature called "lesson" where learners can be routed automatically through pages depending on the answer to a question after each page. Furthermore, the extensibility is supported very well by a documented API, detailed guidelines, and templates for programming. Also adaptability and personalization aspects are included in Moodle. Templates for themes are available and can be selected by the administrator. Students can choose out of more than 40 languages.

Overall Evaluation Results

In [29] the evaluation results are also shown for each platform and each subcategory, classified by categories. These subcategories are:

- Communication tools: forum; chat; mail / messages; announcements; conferences; collaboration; synchronous and asynchronous tools.
- Learning Objects: tests; learning material; exercises; other creatable LOs; importable LOs.
- Management of user data: tracking; statistics; identification of online users; personal user profile.
- Usability: user–friendliness; support; documentation; assistance.
- *Adaptation: adaptability; personalization; extensibility; adaptivity.*
- *Technical aspects: standards; system requirements; security; scalability (*correspond with [101] VLEs technical evaluation criteria – author's comment).*
- Administration: user management; authorization management; installation of the platform.
- Course management: administration of courses; assessment of tests; organization of course objects.

Moodle dominates the evaluation by achieving the best value five times. The strengths of Moodle are the realization of communication tools, and the creation and administration of learning objects. Additional strengths of Moodle are the comprehensive didactical concepts and also the tracking of data. Furthermore, the outstanding usability of Moodle leads to the maximum evaluation value in the usability category. Concerning the other platforms, ILIAS obtained the best values in the categories technical aspects, administration, and course management.

To get the overall evaluation result, the symbols of all categories were summarized in [29]. Similar to the adaptation category, it is not possible to assign an exact ranking for each platform. However, it can be seen that Moodle achieved the best evaluation values. Also the second and third rank can be assigned clearly to Ilias and Dokeos. According to the pairwise comparisons ATutor, LON–CAPA, Spaghettilearning, and Open–USS are ranked equally at the fourth position, whereas Sakai and dotLRN are ranked last. The reason for the low ranking of Sakai is that so far only the basic features are realized. But, the quality of these features is very good.

The aim of [29] evaluation was to identify the most suitable open source e-learning platform for extending to an adaptive one. The evaluation applies an extended qualitative weight and sum approach. After a pre–evaluation phase, nine platforms were analysed in detail.

Moodle obtained the best results in the general as well as in the specific adaptation evaluation.

In [29] authors' future work, they are planning to extend the selected platform in a way that the courses adapt to the unique strengths, learning objectives, knowledge levels, and learning styles of each individual learner.

Conclusions of Literature Analysis and Problems to Solve

Both analysed VLEs technical evaluation tools have a number of limitations:

1. [101] tool practically *does not examine adaptation capabilities criteria.*
2. [29] *tool insufficiently examines general technical criteria.*

More complex VLEs technical evaluation tool is needed.

It should include general technical evaluation criteria based on modular approach and interoperability, as well as adaptation capabilities criteria.

VLEs adaptation capabilities criteria should have the same weight as the other criteria.

4.4. Recommended VLEs Technical Evaluation Tool

Results of Virtual Learning Environments Overall Evaluation

VLEs overall evaluation results [4A] show clearly that open source VLEs are not less quality on module level than proprietary products while being more attractive for educational institutions from financial point of view (no licensing fees). Therefore it was suggested Lithuanian educational institutions to widely implement open source VLEs.

Several typical proprietary and open source VLEs evaluation against well–developed pedagogical, organisational [8] and technical criteria has shown that Moodle seems to be the best VLE suitable to use on the module level [4A].

Moodle was evaluated as the best among open source VLE evaluated under technical criteria. Therefore currently Moodle is the most suitable VLE for wide implementation in Lithuanian general education and vocational training institutions, as well as for teacher in–service training system.

Its fundamental advantages in comparison with the other open source systems are:

- Clear social constructivist philosophy and design.
- Modular, extensible architecture.
- Wide and lively developer and user community [4A].

Results of the Lithuanian Virtual Learning Environments Consultants Survey

The first large–scale teachers' in–service training programme on VLEs in Lithuania was performed on 15–28 November 2006 in Vilnius. Its target group was 60 teachers from general education and vocational schools as well as municipal educational divisions' servants. Its scope was 120 academic hours, 60 for face–to–face seminars / workshops and 60 for Moodle–based distance training course.

During this training programme the author (having been the first lecturer) had asked the participants to answer:

- Which VLE (ATutor–based or Moodle) seems them to be more suitable to be used in their schools.
- What are the most suitable VLEs usage areas and scenarios in their schools.
- What are the main problems in VLEs implementation in schools.

The results of these questionnaires were the following [9A]:

- *VLEs suitability evaluation*

Moodle was evaluated by VLEs consultants as more suitable VLE for usage in schools. The comparison was implemented using [8] VLEs pedagogical and organisational evaluation methods as well as [101] VLEs technical evaluation criteria proposed by the author. These results conform to VLEs overall evaluation results obtained by the author [4A].

- *Possible scenarios of VLEs usage in schools*

VLEs usage for learning during the lessons, as well as for project work and homework is of the highest priority for VLEs consultants (minimal sums of place numbers, see Figure 25).

The variety of VLEs usage scenarios preferred by VLEs consultants requires VLEs to have the high level of flexibility and adaptability.

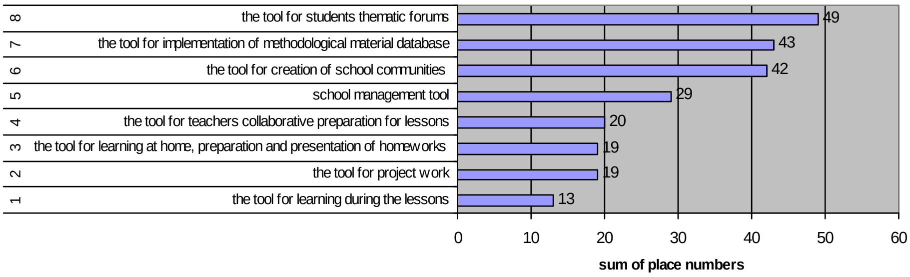

Figure 25. *Scenarios of VLEs usage in schools [9A]*

- *Problems of VLEs usage in schools*

The problem of lack of digital learning content (LOs) for usage in VLEs is of the highest priority problem to be solved for VLEs consultants (see Figure 26).

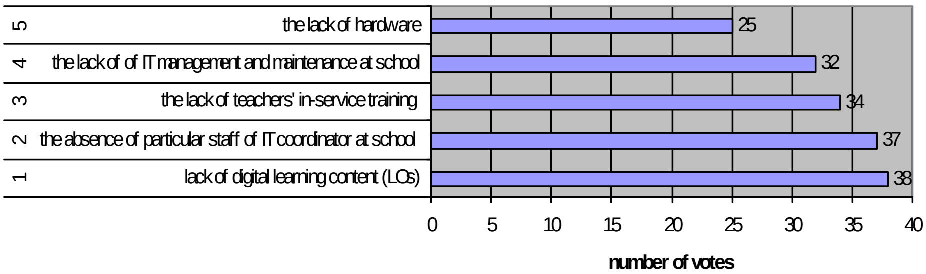

Figure 26. *Problems of VLEs usage in schools [9A]*

Recommended Virtual Learning Environments Technical Evaluation Criteria

The author bases his set of VLEs evaluation criteria on flexible personalised DLE principles as well as mainly on presented evaluation methods suitable for flexible personalised DLE:

- New Zealand methodology of technical evaluation of learning management systems [101].

- Austrian method of evaluation of open source e-learning platforms with the main focus is on adaptation issues [29].

As it was assessed earlier, both these tools have a number of limitations.

Therefore the author proposes the original complex set of VLEs technical evaluation criteria combining general and adaptation criteria (see Figure 27 and more in detail Table 20).

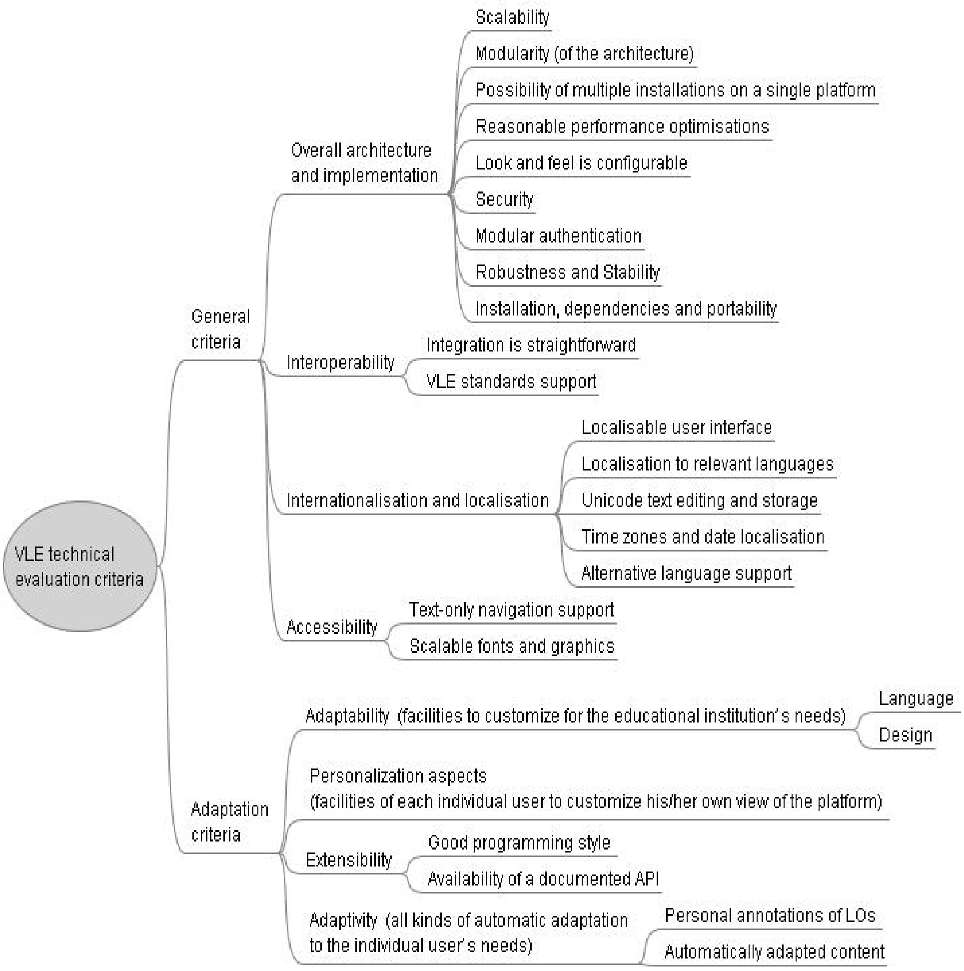

Figure 27. *Technical criteria for VLEs evaluation*

Table 17. *VLEs technical evaluation criteria*

General criteria	
Criteria	**Sub–criteria**
1. Overall architecture and implementation	1.1 Scalability of the system
	1.2 Modularity of the system
	1.3 Possibility of multiple installations on a single platform
	1.4 Reasonable performance optimisations
	1.5 Look and feel is configurable
	1.6 Security
	1.7 Modular authentication
	1.8 Robustness and stability
	1.9 Installation, dependencies and portability
2. Interoperability	2.1 Integration is straightforward
	2.2 VLE standards support
3. Internationalisation and localisation	3.1 Localisable user interface
	3.2 Localisation to relevant languages
	3.3 Unicode text editing and storage
	3.4 Time zones and date localisation
	3.5 Alternative language support
4. Accessibility	4.1 Text–only navigation support
	4.2 Scalable Fonts and Graphics
Adaptation criteria	
Criteria	**Explanation**
5. Adaptability	Includes all facilities to customize the platform for the educational institution's needs (e.g. the language or the design)
6. Personalization aspects	Indicate the facilities of each individual user to customize his/her own view of the platform
7. Extensibility	Is in principle, possible for all open source products. Nevertheless, there can be big differences. For example, a good programming style or the availability of a documented application programming interfaces (API) are helpful
8. Adaptivity	Indicates all kinds of automatic adaptation to the individual user's needs (e.g. personal annotations of learning objects or automatically adapted content)

This tool includes general technical evaluation criteria based on modular approach and interoperability, as well as adaptation capabilities criteria.

VLEs adaptation capabilities criteria have the same weight as the other criteria.

Virtual Learning Environments Experimental Technical Evaluation Results

DLE components' technical evaluation criteria rating tool

The author proposes universal DLE components' evaluation rating tool for evaluation of all main DLE components: LOs, their repositories and VLEs.

It is clearer in comparison with [101] tool and more convenient in comparison with [29] tool.

The tool is based on analysis of the level of feature's support and the level of modification needed to reach the desired level of support (see Table 21).

Table 18. *Evaluation importance rating [102]*

Rating	Explanation
0	Failed or feature does not exist
1	Has poor support and / or it can be done but with significant effort
2	Fair support but needs modification to reach the desired level of support
3	Good support and needs a minimal amount of effort
4	Excellent support and meets the criteria out of the box, minimal effort

The tool was used for evaluation of LO repositories during the large–scale OARiNZ [74] project in New Zealand.

Each selected criterion is proposed to be given an importance rating to be used when evaluating LOs, repositories and VLEs. Major criteria have to be broken down into sub–criteria with each sub–criterion also having an importance rating.

The importance rating range is 0–4, with 0 being the lowest and 4 being of the highest importance. Each sub–criterion has then to be rated using a range of 0–4.

The author proposes to weight each LOs evaluation criteria equally and to use this simple and clear criteria rating system for evaluation of all components of DLE: LOs, LO repositories and VLEs.

This universal DLE components' evaluation rating tool was used by the author to evaluate three most popular open source VLEs against technical (both general and adaptation) criteria. The results of this evaluation are presented in Table 19.

Table 19. *VLE technical evaluation summary*

Technical evaluation criteria	ATutor	Ilias	Moodle
General criteria			
1. Architecture and implementation	Rating 2	Rating 1	Rating 4
2. Interoperability	Rating 3	Rating 3	Rating 2
3. Internationalisation and localisation	Rating 1	Rating 2	Rating 3
4. Accessibility	Rating 4	Rating 1	Rating 2
Interim evaluation rating:	*10*	*7*	*11*
Adaptation criteria			
5. Adaptability	Rating 1	Rating 2	Rating 3
6. Personalization	Rating 3	Rating 3	Rating 2
7. Extensibility	Rating 3	Rating 4	Rating 4
8. Adaptivity	Rating 1	Rating 0	Rating 1
Interim evaluation rating:	*8*	*9*	*10*
Total evaluation rating:	***18***	***16***	***21***

In conformity with this practical evaluation results, Moodle is the best VLE from technical point of view.

4.5. Chapter 4 Conclusions

1. The author has analysed existing criteria for technical evaluation of LOs in section 4.1. It was investigated that these criteria have a number of limitations. E.g., (1) LORI, Paulsson & Naeve and MELT do not examine different LOs life cycle stages, and (2) Q4R insufficiently examines technical evaluation criteria before LOs inclusion in the repository. All tools insufficiently examine LOs reusability criteria. Therefore more complex LOs technical evaluation tool is needed.

The approved Lithuanian set of evaluation criteria has many limitations, e.g. (1) in conformity with this set all LOs and services (e.g., LAs, UoLs, LORs, VLEs) have to be evaluated against the same criteria, (2) no metadata–related criteria are evaluated, and (3) these criteria do not reflect e-content and activities reusability aspects overall.

Therefore the author has proposed the original more complex set of LOs technical evaluation criteria based on flexible DLE approach as well as on foreign LOs technical evaluation criteria analysed in section 4.1. These criteria were presented in Figure 29 and Table 6.

They are: (1) Before LO inclusion in the LOR: Narrow definition compliance; Reusability level: Interoperability, Pedagogical decontextualisation level, Cultural / learning diversity principles, and Accessibility; Architecture; Working stability; Design and usability; (2) During LO inclusion in the LOR: Membership or Contribution Control Strategies and Technical interoperability; (3) After LO inclusion in the LOR: Retrieval and Information quality.

LOs reusability (incl. Interoperability) criteria should have the same weight as the other criteria.

2. The author has examined several VLEs technical evaluation tools suitable for flexible DLE in section 4.3. It was investigated that these tools have a number of limitations, e.g. (1) New Zealand tool practically does not examine adaptation capabilities criteria, and (2) Austrian one insufficiently examines general technical criteria. More complex VLEs technical evaluation tool is needed.

Therefore the author has proposed the original more complex set of VLEs technical evaluation criteria combining (1) General (Overall architecture and implementation; Interoperability; Internationalisation and localisation; Accessibility) and (2) Adaptation (Adaptability; Personalization; Extensibility; Adaptivity) technical evaluation criteria (see Figure 32 and Table 17).

VLEs adaptation capabilities criteria should have the same weight as the other criteria.

The author has also selected and proposed to use the universal DLE components' evaluation rating tool which is clearer and more convenient than investigated other foreign tools, and has evaluated three most popular open source VLEs against technical (both general and adaptation) criteria in conformity with this rating tool. The results of this evaluation have been presented in Table 19.

5

System Experimental Implementation

In this chapter the author presents the own experimental example of flexible DLE software for Lithuanian general and vocational education (situation analysis and own developments, section 5.1), and formulates recommendations for its future development (own research, section 5.2).

The author has published 4 articles on the topic of the chapter [1A–2A, 5A, 8A].

5.1. Contemporary State

National open source DLE for general education and vocational training systems is currently (December 2007) under implementation in Lithuania. The core players in the field are the Centre for Information Technologies in Education (ITC) under the Ministry of Education and Science, and Institute of Mathematics and Informatics (IMI).

DLE for Lithuanian general education and vocational training is under creation and development in ITC mainly using scientific and technologic resources funded by European Commission while implementing following international projects:

- 6th Framework Programme's IST CALIBRATE project [10].

- e-Learning programme's P2V project [79].
- eContent*plus* programme's EdReNe project [23].

These developments are on the pilot stage coordinated by the author.

The main components of Lithuanian DLE at the moment are learning object (LO) repositories and LO metadata (LOM) repository as well as related services such as open source VLEs Moodle and ATutor (enriched by several new functions) and LeMill learning toolbox developed and localised by CALIBRATE team.

Main Components of DLE for Lithuanian Education: Learning Resources

Learning Resources and their Repositories

At the moment there are several LR repositories in Lithuania established and developed on ITC Web server which provide several keywords–based non–standardized search possibilities for users.

- [61]: The central repository of valid, recommended and experimental computer teaching aids for further testing by schools (see Figure 28).
- [62]: The repository of all valid and recommended educational web sites available for all Lithuanian schools (see Figure 29).
- The repository of methodological material on the use of ICT in education prepared mainly by teachers (under reconstruction).
- [63]: The repository of lesson plans and ideas designed with Microsoft Power Point template "Virtual Classroom Tour" (see Figure 30).
- There are also a number of distance learning courses for gifted children and children with Special Education Needs in VLE Moodle for Lithuanian schools. [21].

All LRs in these repositories and VLEs were evaluated and approved on state level by independent IT and subjects experts in conformity with approved computer teaching tools evaluation criteria [16].

Almost all these learning resources have complex structure and high aggregation level, and therefore do not fit learning objects' [110] notion.

The author's research results [5A, 9A] show that Lithuanian education system needs a rapid growth of adapted reusable LOs available for the teachers. Large scale adaptation, localisation, and reuse of LOs available abroad (e.g., LRE system) is needed. Lithuanian LO repositories should also include a big number of teachers created LOs.

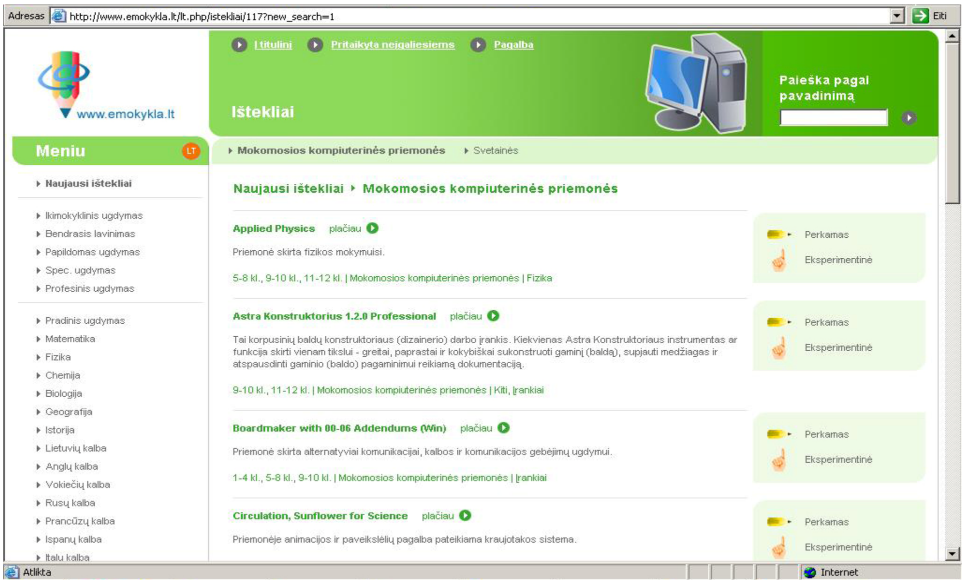

Figure 28. *The central repository of valid, recommended, and experimental computer teaching aids*

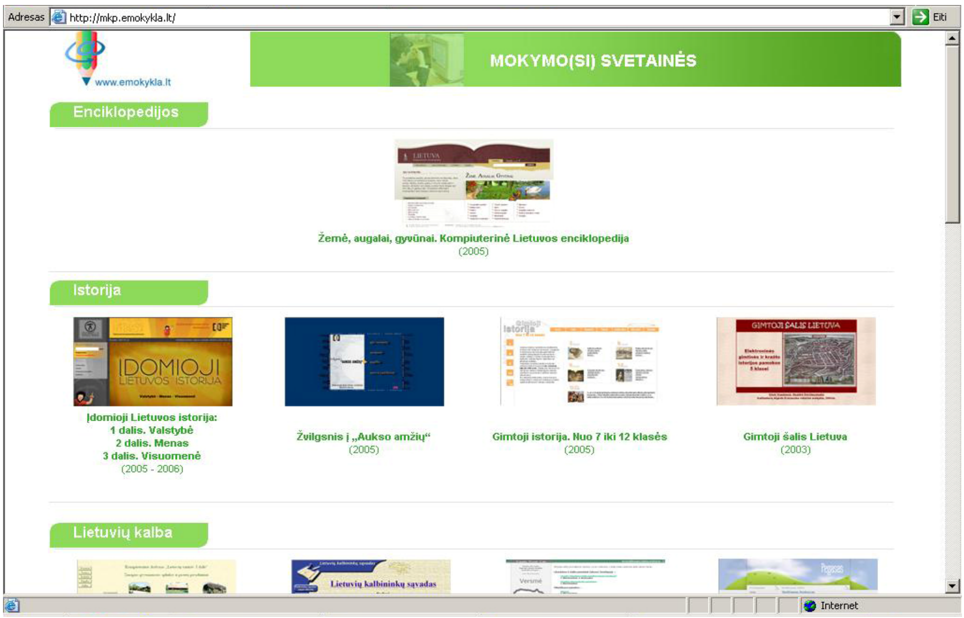

Figure 29. *The repository of all valid and recommended educational web sites*

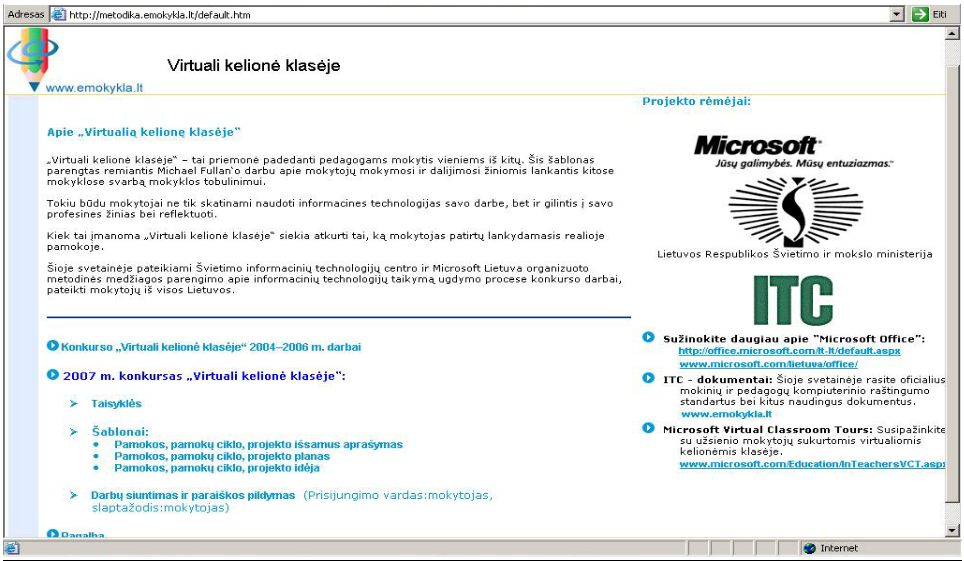

Figure 30. *The repository of lesson plans and ideas designed with Microsoft Power Point template "Virtual Classroom Tour"*

Learning Object Metadata Repository

Several important developments were carried out by ITC after that while implementing FP6 IST CALIBRATE project during summer and autumn 2006:

- EUN LOM AP 2.0 was localised to Lithuanian by IMI.
- More than 1200 Lithuanian LRs were described in conformity with this AP by specially trained LOs indexers: English language – 46, Biology – 126, Chemistry – 99, Art & Design – 43, Economics – 43, History – 90, Physics – 99, Geography – 28, IT – 166, Lithuanian language – 116, Mathematics – 122, Primary education – 35, Russian language – 7, German language – 4, Design & Technology – 33, for special needs students – 37, etc.
- Central LO metadata (LOM) repository [60] based on MySQL database management system, PHP software package (internet programs handling environment) and Java technology was created (see Figure 31). ITC Apache web server and Linux operating system were used for creation of LOM repository [2A].
- User–friendly interface to aggregate LOs metadata into LOM repository was created (see Figure 32).
- All these LOs metadata were created and filled into LOM repository on ITC server.

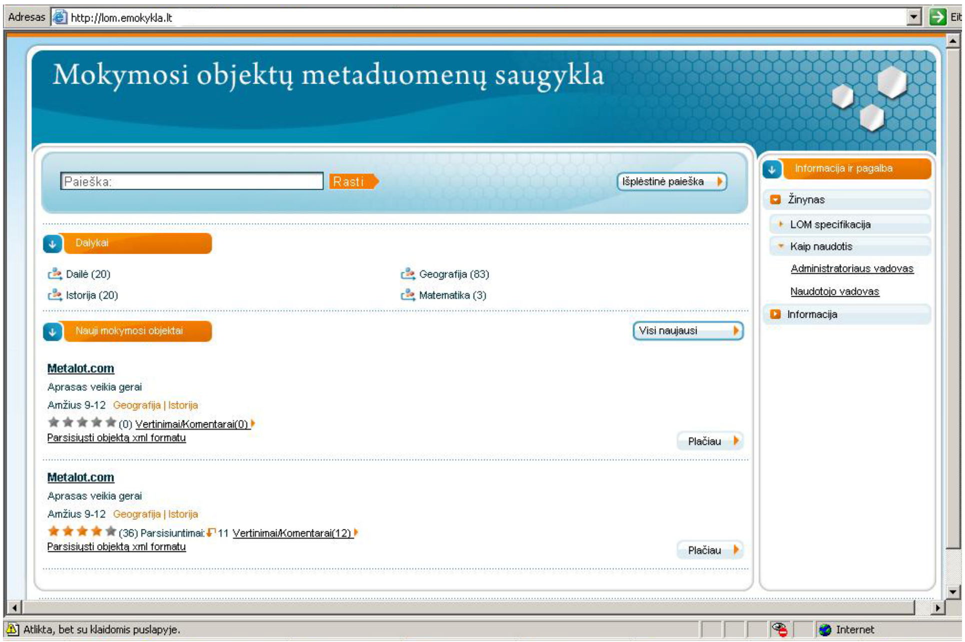

Figure 31. *Central LOM repository for schools*

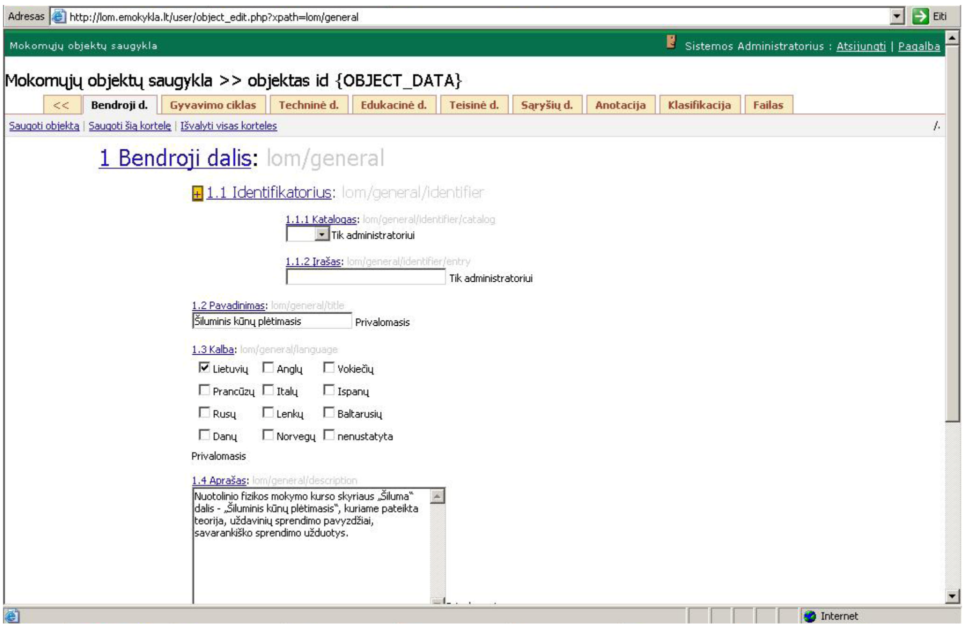

Figure 32. *Interface to aggregate LOs metadata into LOM repository*

- *All approved distance learning courses were disaggregated to smaller courses and even to LOs level and were described in conformity with LOM. Disaggregated smaller courses were introduced as SCORM 2004 packages to reuse in different VLEs (e.g SCORM 2004 compliant Moodle v. 1.6.3) [2A].*
- All these LOs are available in central LOM repository.
- LOM repository was connected to European learning resource exchange (LRE) system via Simple Query Interface technology and Brokerage system (see Figure 33).

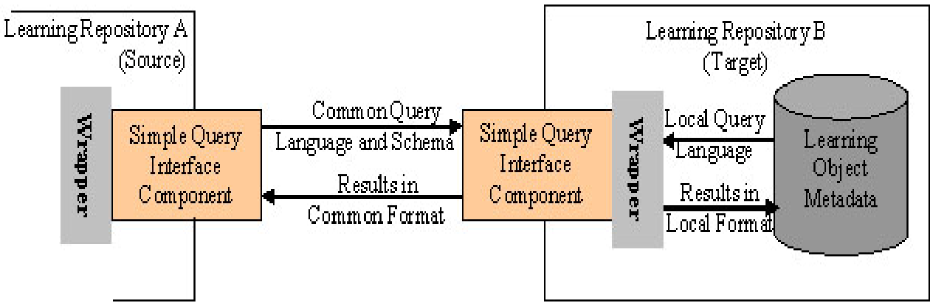

Figure 33. *Communication between two repositories [1A]*

LOM repository is currently under reconstruction in order to enrich it with additional functions / services.

These additional services involved into technical specification by the author are:

Additional services planned for its open part for users:

- LO searching and browsing by subject (area) and key word.
- *Extended (advanced) search by desirable LOM elements (incl. elements 1.7, 1.8, 5.2 and 7.1 reflecting LOs reusability level investigated and proposed to use in section 1.2.5, see Figure 34 below).*
- Search by metadata creation period.
- Brief and extended (XML) metadata production for the users.
- Users' comments.
- Statistics of LO downloads and repository users.
- LO ranking possibility.
- Automatic production of new LO metadata during the desirable period.
- User's guide.

Additional services planned for closed part for administrators:

- Metadata import in XML format.
- Fixation of LRE AP version used.
- Portrait of LRE AP versions' comparison.
- Taxonomies management by desirable elements.
- Metadata elements creation using taxonomies.
- Management of users' comments.
- Extended search by desirable elements.
- Lgal mark if LO could be exported to LRE.
- Aministrator's guide.

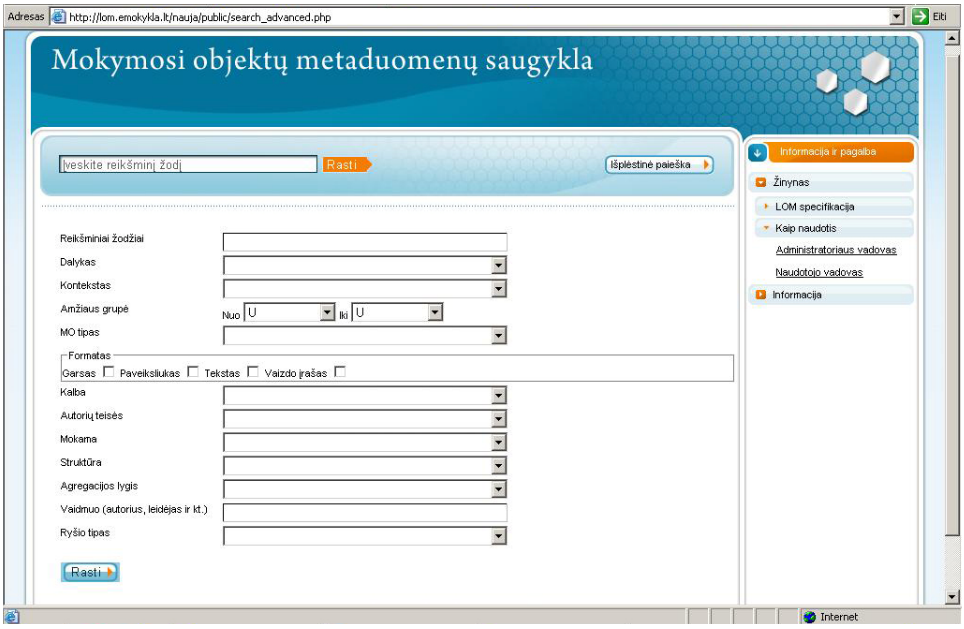

Figure 34. *Extended (advanced) search service in central LOM repository for schools*

The scheme of additional open (users) part services implemented in Lithuanian LO metadata repository is presented in Figure 35:

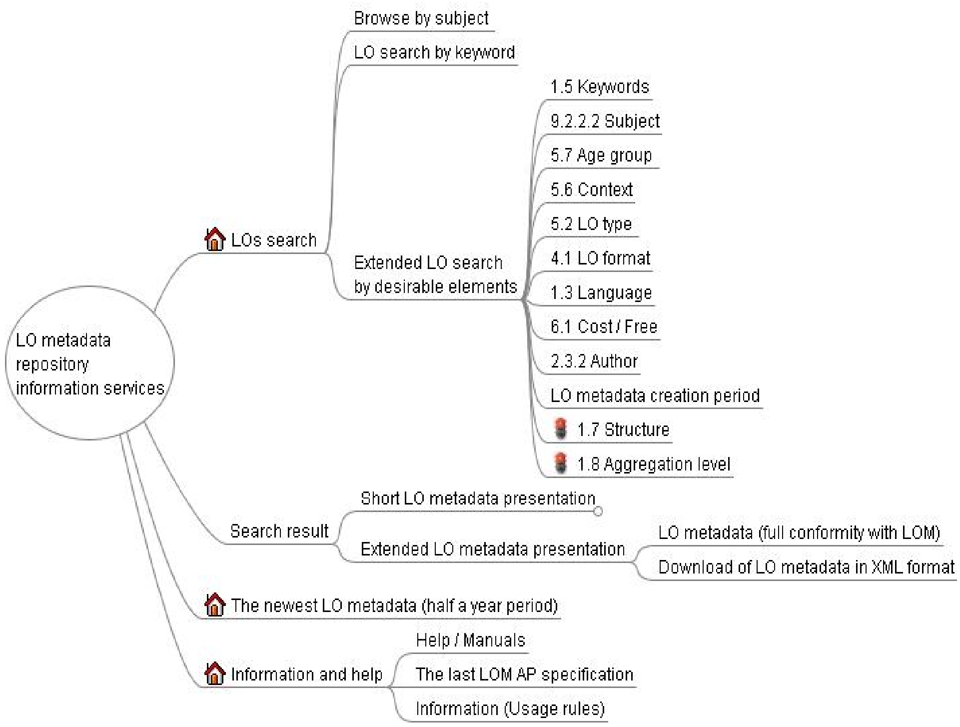

Figure 35. *LOM repository additional services scheme (open part)*

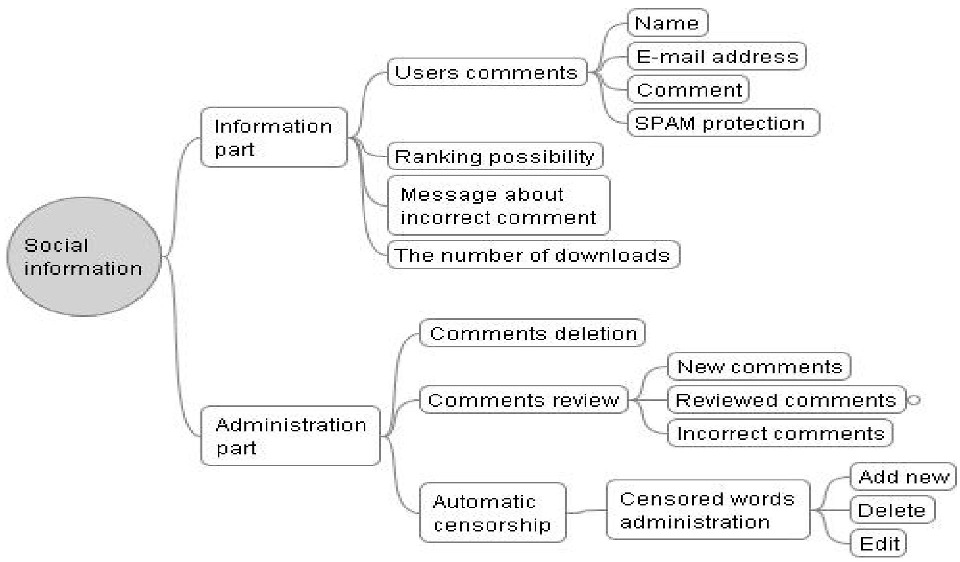

Figure 36. *Social information services scheme*

The scheme of social information services implemented in Lithuanian LO metadata repository is presented in Figure 36.

Main Components of DLE for Lithuanian Education: Services to Create and Reuse Learning Objects

Virtual Learning Environments

VLEs in Lithuania have been used primarily for distance learning in universities, but currently they are being used increasingly as a supplement to traditional classroom based teaching. Educational institutions seek ways to use VLEs to make teaching more effective on campus as well, e.g. in comprehensive and vocational schools [6A].

Scientific research results had shown clearly that the best open source VLEs are not less quality on module level than the best proprietary products while being more attractive for educational institutions from pedagogical and financial points of view [4A]. Therefore it was proposed Lithuanian educational institutions to comprehensively implement open source VLEs such as Moodle and ATutor.

It was also investigated that VLEs are not neutral in their impact on pedagogical methods and scenarios [4A]. We could divide VLEs to more “content centred” and more “learner centred” systems. Course material in content centred systems is aggregated into “courses” to which learners are assigned, coupling the learner closely to the content. Learner centred systems organise students into groups. Course design will involve moving from “content centred” to a “learner centred” system [6A]. The more VLEs are “learner centred”, the more they fit the aims of schools development as e-learning communities [10A].

Scientific research on evaluation of the most popular open source VLEs was performed in Lithuania in 2004 and 2005 by IMI [90]. Several scientific methods and frameworks (such as [8] and [101]) were used as basic tools for this research.

As the result, Moodle VLE was evaluated the best VLE suitable to use on the module level, therefore it was proposed as the most suitable VLE for wide implementation in Lithuanian comprehensive and vocational schools, as well as for teacher in–service training system. Its fundamental advantages in comparison with the other open source systems are:

- Clear social constructivist philosophy and design.
- Modular, extensible architecture.
- Wide and lively developer and user community [4A].

In summer 2006 Moodle version 1.6.3 was fully localised by IMI while implementing national scale project on vocational teacher training on ICT implementation in vocational education. At the moment localised VLE Moodle is downloadable from ITC server for installation in schools (see Figure 37). This Moodle version is SCORM 2004 compliant and therefore suitable to import distance learning courses SCORM 2004 packages from LOM repository.

VLEs most suitable for usage on module level were chosen for comprehensive implementation in Lithuania, therefore de facto decentralised way of VLEs implementation was chosen in Lithuania to strengthen schools as e-learning communities [10A].

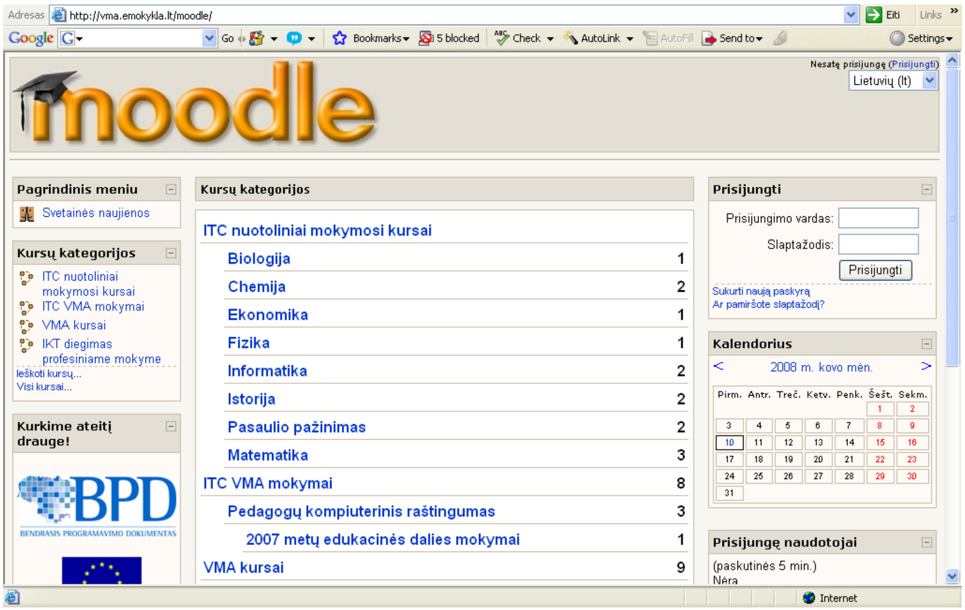

Figure 37. *Localised VLE Moodle for Lithuanian schools web site*

LeMill Learning Toolbox

Open source LeMill learning toolbox (see Figure 38) was developed in CALIBRATE to provide European teachers the possibility of collaborative learning and creation of LOM compliant LOs.

Its interface was localised, training course for teachers was prepared by Lithuanian CALIBRATE team, and training was provided to target group of Lithuanian CALIBRATE teachers [2A].

Its main aim is to provide teachers the possibility to collaboratively create and modify LOM compliant LOs.

Lemill together with LRE are the main DLE international services developed by the author and CALIBRATE team. They are the essential parts of Lithuanian DLE for schools.

Figure 38. *Localised LeMill toolbox web site*

5.2. Recommendations for Development

The next recommended developments to provide the ultimate reusability and interoperability of proposed DLE for Lithuanian education are yellow coloured in Figure 39 (based on Figure 21). DLE developments already implemented by the author and his team are not coloured in this figure.

These recommendations for development are:

- Horizontal implementation of W3C accessibility standards for all components of DLE.
- *Recommendations for repositories:*
    - Implementation of repositories interoperability based on ability to integrate with other repositories (OAI–PMH compliance), and ease of integration with systems such as VLEs.

- Creation of fully LD–compliant environment to reuse UoLs and implementation of Learning Activity (UoLs) repository.
- Implementation of IMS Common Cartridge and Learning Design specifications.

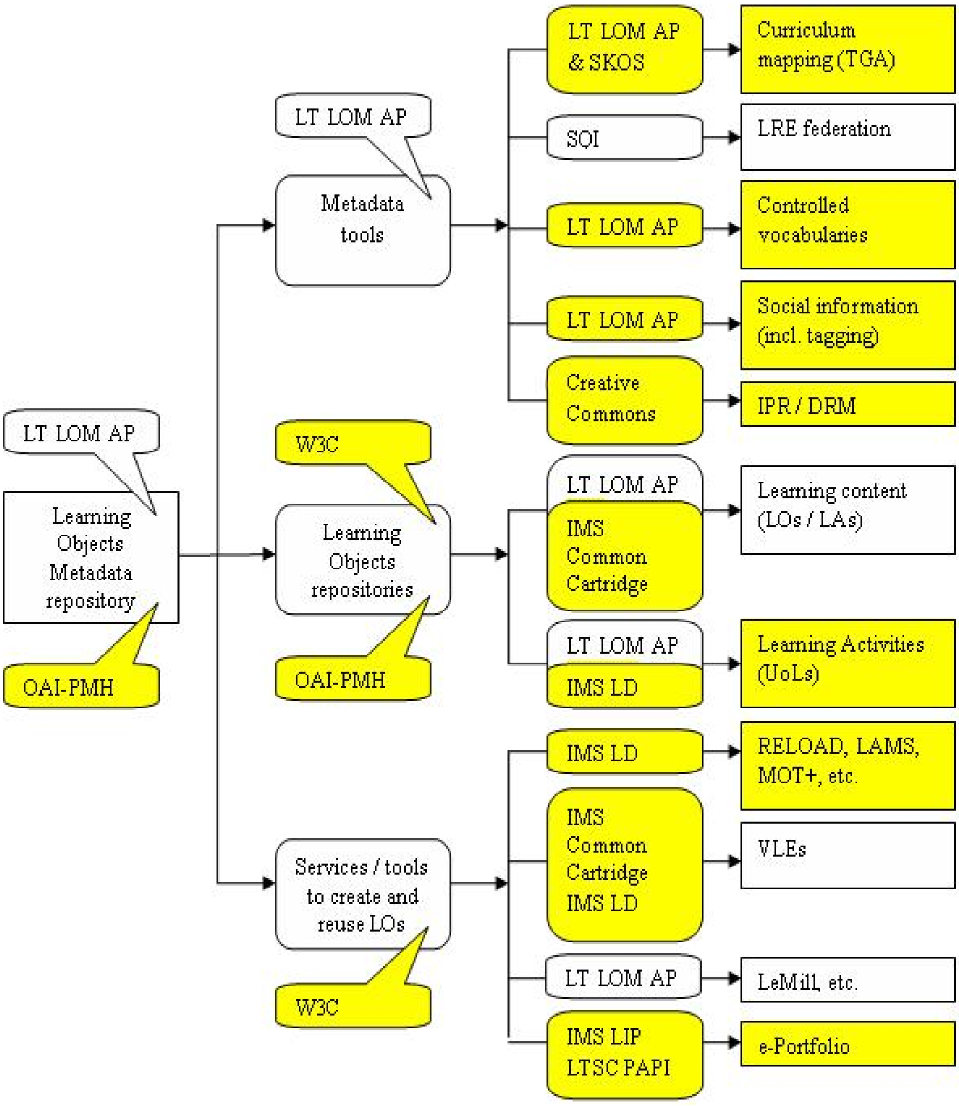

Figure 39. *Recommendations for future development of DLE for Lithuanian education*

- *Recommendations for metadata tools:*

    - Implementation of Topic– Goal – (Learning) Activities (TGA) ontology–based curriculum mapping in main subjects to search for LOs in the repositories and VLEs.
    - Implementation of main controlled vocabularies (e.g., Topic and Competency taxonomies).
    - Implementation of social tagging and bookmarking tools to enrich LO metadata with the learning practice experience.
    - Implementation of LOs digital right management (DRM) system based on localised and approved Creative Commons licences.

- *Recommendations for services and tools to create and reuse LOs:*

    - Implementation of LD–compliant tools (e.g. RELOAD, LAMS v.2.0.3 together with Moodle v.1.8, MOT+ etc.) to create and reuse UoLs.
    - To localise and implement IMS CC and IMS LD compliant VLEs.
    - To implement teachers' and students' e-Portfolio systems based on IMS LIP or IEEE LTSC PAPI.

6

Generalization of the Results

General Conclusions and Recommendations

1. The research has shown that the principle of ultimate increase of reusability of Learning Objects is the main factor of DLE flexibility. It has been investigated that flexible approach to DLE creation and development should be based on the idea of Learning Objects partition to the two main separate parts (Learning Assets and Units of Learning). Virtual Learning Environments suitable for flexible DLE should have a high level of adaptation capabilities.

2. It has been investigated that there are two main conditions for Learning Objects reusability elsewhere: (1) Learning Objects have to fit different countries' national curricula; (2) different countries' LOM application profiles have to be oriented towards quick and convenient search of ultimately reusable Learning Objects. Research has shown that approaches concerning LOM standard application profiles (i.e., models to construct Learning Objects (metadata) repositories) and curricula mapping are the main problems while increasing and improving Learning Objects usability and creating any metadata guidelines or strategies.

3. The research has shown that curricula mapping should make interoperability possible by the method of making use of two smaller controlled vocabularies instead of a very large one on competencies. There are following recommendations based on the method evaluation: (1) not one big competency taxonomy but two smaller vocabularies, (2) more resilient to change; (3) using proven technologies – thesauri (subject, revised Bloom); (4) possibility for relaxing the search: the results of the proposed method are substantially better in comparison with the method of trying to find LOs suitable for developing the same competencies with Google (approx. 1.5 minutes Vs approx. 1.5 hours).

4. The method of improvement of existing Learning Object Metadata application profiles resulting in provision of more quick and convenient search possibilities for those searching ultimately reusable Learning Objects was created. It has been investigated that it would be purposeful to improve Learning Resource Exchange Metadata application profile v3.0 to provide more quick and convenient search of ultimately reusable Learning Objects possibilities by the means of changing (advancing) the status of four of Learning Resource Exchange Metadata application profile v3.0 elements: 1.7 General.Structure; 1.8 General.Aggregation Level; 5.2 Educational.Learning Resource Type; and 7.1 Relation.Kind. It would be purposeful to include search service against these elements into extended search service in the repositories (e.g. about 60 times for Lithuanian biology LOs).

5. Complex Learning Objects technical evaluation tool based on flexible DLE approach as well as on analysed foreign LOs technical evaluation criteria was created. Proposed Learning Objects technical evaluation criteria are: (1) Before Learning Object inclusion in the Learning Object Repository: Narrow definition compliance; Reusability level: Interoperability, Pedagogical decontextualisation level, Cultural / learning diversity principles, and Accessibility; Architecture; Working stability; Design and usability; (2) During Learning Object inclusion in the Learning Object Repository: Membership or Contribution Control Strategies and Technical interoperability; (3) After Learning Object inclusion in the Learning Object Repository: Retrieval and Information quality. Learning Objects reusability (incl. Interoperability) criteria should have the same weight as the other criteria.

6. Complex Virtual Learning Environments technical evaluation tool based on (1) General (Overall architecture and implementation; Interoperability; Internationalisation and localisation; Accessibility) and

(2) Adaptation (Adaptability; Personalization; Extensibility; Adaptivity) technical evaluation criteria was created. It is proposed that Virtual Learning Environments adaptation capabilities criteria should have the same weight as the other criteria. Using this tool, Moodle was evaluated as the best among three most popular open source Virtual Learning Environments.

The Results

The following results based on aforementioned conclusions have been obtained:

1. Recommendations for European Learning Resource Exchange system.

2. Recommendations for curriculum mapping tool and curriculum integration with Learning Objects on European and Lithuanian level.

3. Recommendations for improvement of existing IEEE LOM application profiles.

4. Recommendations for flexible DLE components and their interoperability.

5. Creation of Learning Objects and Virtual Learning Environments complex technical evaluation tools.

6. Popular open source Virtual Learning Environments practical evaluation results.

7. Practical example of implementation of flexible DLE – DLE software for Lithuanian general and vocational education, and formulation of recommendations for its future development.

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