# Studienarbeit/Project work: Structuring of content repositories for adaptive e-learning content: Reusabilty through metadata and ontologies

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**Abstract**

The internet has brought a lot of changes to our lives. One part being affected is education. New ways of conveying knowledge have been developed leading to the notion of "e-learning". Online education is becoming more and more important in our globalized world. But with new opportunities come also new challenges. E-learning still lacks in many areas and requires a lot of improvements.

One field of study is the structuring of learning materials - or "learning objects". Universities and organizations collect a vast amount of learning resources without adequate means for accessing and using them. Rich and valuable metadata standards have been developed, but these are not enough for the goals of the education community. Semantic information about e-learning content is needed for both, human users and computer programs.

This project work tries to develop a common understanding of what these "learning objects" are and develops ways to structure them. It analyzes the metadata standards used for description of the learning resources. Special focus is put on the capabilities to describe semantic information for pedagogical purposes. It develops an ontology as means of a semantic layer on top of metadata to facilitate accessibility and reusability of these resources.

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Part I

# Introduction

## 1 Motivation

### 1.1 The importance of e-learning

The advent of the Internet has brought a lot of change. From the way we do basic things in our lives, like communicating or shopping, to the way we work together with other people. It has also brought a general paradigm shift in how we treat information. The "information age" has begun, where knowledge is a very (if not the most) important asset. A knowledge "economy" has developed, with a lot of different parties involved. Knowledge is becoming not only more easily accessible, but also tradable. This means that new ways to gain, process and store knowledge are being developed. One of the mayor fields of interest is distance learning/instruction/support with the help of the Internet.

In the beginning the Internet was just a big network of people sharing documents. Today there's "A shift of mind-set is also gathering momentum, away from building systems for networking printed information toward systems for managing networked information"[32].

One good example where for this are universities which function on the basis of a "Virtual Campus". These universities have no "physical" campus, no class rooms or computer labs, but only an online virtual representation of all these things. Students and teachers access all information via a sophisticated web-interface and small communities around courses or study programs develop. Virtual classrooms have replaced real ones and add benefits like faster communication, common work processes and an always accessible digital library of resources for everybody. Collaboration of students is facilitated and the process of learning is moving away from the dimensions of time and space. These universities make intensive use of new technologies, especially in the field of design, creation and management of multimedia contents. Figure 1 shows the educational model of the Universitat Oberta de Catalunya, which is the biggest online distance-learning university in

Spain. The student is fully integrated into the learning experience.


Figure 1: The Educational Model of the UOC

But not only educational institutions or non-governmental organizations have interest in the global e-learning market. According to [19], "E-learning is the fastest-growing sub-sector of a $2.3 trillion global education market, and the market for online higher education is estimated to exceed $69 billion by 2015". This is also evident by the dedication shown by all big IT companies in the field of internet-based training. The IMS Global Learning Consortium, who's mission is to "support the adoption and use of learning technology worldwide", is exclusively funded by membership. The highest level of commitment is a "contributing member" membership. A contributing member donates $50.000 each year, retroactive to the start of the IMS project. The list of contributing members has by 2006 grown to 51 members, and reads like the who's who of software developing companies and high-powered organizations: Apple, IBM, Microsoft, Oracle, Sun Microsystems, the U.S. Department of Defense, the California State Universities, International Thompson Publishing, to name just a few.
E-learning or distance education in general has become one of the biggest

topic of today's information society. It is still in it's infancy, with relatively few benefits over traditional learning, but innovations are coming fast and continuously.

## 1.2 Changes in e-learning

The e-learning community has grown significantly in the last decade. As said before, big alliances like the AICC, the IEEE LTSC, the IMS Global Consortium and ADL have been formed with the main goal to develop widely accepted standards for e-learning. Standards like the ADL Sharable Content Object Reference Model (SCORM) have reached this goal and become the norm for sophisticated e-learning technology. The big problem is that the so far developed standards are good but don't meet the requirements of the new "e-learning age".

Content repositories are becoming bigger and bigger and new means for classifying, searching and storing learning resources are needed. Reusability of content is becoming a big topic as the development of sophisticated multimedia e-learning content becomes more expensive. New aspects like personalization and instructional design influence the creation of learning content. The industry needs to make the jump from online text-based instruction to adaptable learning content. New topics like metadata and learning design have surfaced and are already picked up by the community. IEEE LTSC Learning Object Metadata [25] and IMS Learning Design [14] are two relativly new standards dealing with these problems.

There is also a major change in the way educational materials are designed. The concept of a "Learning Object" (LO) has emerged and is the primary topic of many organizations right now. The idea is grounded in the object oriented paradigm of computer science and the main goal is to create small, independent and reusable entities which represent learning resources.

## 1.3 An Overview of the project work

This project has the two goals: develop a common understanding of the term "Learning Object" and a taxonomy for the structuring of LOs. This report is split into three parts:

1. Introduction

   This part gives an introduction into the world of adaptable e-learning systems and LOs. Firstly the term "reusability" is specified for an e-learning context, as that is one of the basic features common to all definitions of LOs. As "there are as many definitions of Learning Objects as there are users" [33], the next step is to develop a working definition of what exactly a LO means for this project work. After we know what a LO is, I will explain why a content repository is needed to store these LOs and why reusability is one of the main criteria for such a storing system. Lastly, I will develop an example scenario which gives the instructional context for the whole project work. This has to be done limit the scope of the project work to a reasonable amount both regarding time and meaningful outputs. The goal of this chapter is to develop a set of requirements for the structuring of LO's.

2. The Structuring of Learning Activities

   The second part of this report will develop a new ontology for structuring the aforementioned and defined LO's. To achieve this, the first step is an in-depth analysis and comparison of two metadata standards, MPEG-7 [26] and LOM. Once I have discussed the features and abilities of metadata standards, I will develop additional requirements for a taxonomy that thoroughly describes LO's. As course creation is an important part of LO design I will also take a look at the IMS Learning Design standard and it's contribution to the process.

3. Accomplishments And Future Directions

   The third part concludes the project work and discusses the gained knowledge and experience. It also discusses likely future research topics and offers a discourse on alternative methods for structuring and organizing adaptable e-learning content, namely "Tagging" and "Conceptual Content Management".

## 2 What is "Reusability" in an e-learning context?

When talking about adaptable e-learning and LO's, one of the main topics is reusability. But what exactly does reusability mean in this context? Taking a look back in history to the roots of the term, one can find a definition of reusability by the IEEE [7]: "[Reusability is] the degree to which a software module or other work product can be used in more than one computing program or software system". When this definition was made the Object Oriented (OO) programming paradigm was the hype in computer science. As we will see later, the idea of OO has many things in common with the notion of a LO, and thus this is not so far from a definition of reusability in an e-learning context.

When we look into literature the goals of computer science reusability are defined as:

- Faster Development

  The reuse of classes and objects shortens the development of new applications massivly.

- Increased Quality

  The faster development process and the increased reusability of objects, make for a clearer, more efficient design of software. The testing and debugging process is also improved and leads to an overall higher quality.

- Modular Architecture

  The modular architecture allows for much more flexibility and makes system parts much easier replaceable and maintainable.

- Adaptability

  Through the reuse of classes/objects and the modular architecture software can much more easily be adapted to end-user needs.

- Extensibility

> Computers, software and end-users needs change faster then developers can develop. The OO paradigm allows to completely exchange whole parts of the software if new requirements arise.

All these goals seem also viable for reusability in an e-learning context. The problem is that reusability in an e-learning environment is very context dependent. Take for example a university that builds the (theoretically) perfect repository for it's courses. It has outstanding reusability, in that every resource can be reused in various other learning contexts (e.g. as an introduction in one course, as an example in another, that exercises can be reused in the next semester, etc.). Does that mean, that this reusability is 1-to-1 transferable to another university offering the same courses? No, because in learning in general and in e-learning especially not only the content is important, but also the form of the content. In OO a class is a class. It has a specified interface and every computer programmer out there can use it in the same way he has used every other class so far. But a statistics course at one university can be totally different from a statistics course in another university. There are lots of variables, like the teacher, the universities technical equipment, the tutors, the previous knowledge of students, etc..

The separation of content and form needs further explanation when talking about the reusability of LOs. Content refers to the pure information contained within a resource. The picture, the text, the video or the simulation program. But this alone is just a piece of the whole "knowledge process" associated with the activity of studying this resource. Without further additions such a resource is often not of much value. What needs also to be described is the way of how to gain the competency associated with the resource. This means that when we talk about LO's later, it is important to make sure it also contains information about the context as well as pedagogical information (like learning styles or hints to difficulty and prerequisites).

## 2.1 Reusability and Learning Objects

What does the importance of both - content and form - mean for the reusability of LO's? Literature states this as one main problem of the concept of LO's. "Reusability Paradox" it is called by Wiley [38]. He states that "A content module's stand-alone pedagogical effectiveness is inversely proportional to its reusability" or more comprehensible summarized by Norman [30]: "If a learning object is useful in a particular context, by definition it is not reusable in a different context. If a learning object is reusable in many contexts, it isn't particularly useful in any." This reveals a general contradiction between reusability and learning design.
Figure 2 illustrates the relationship between context and reusability and is based on [20].

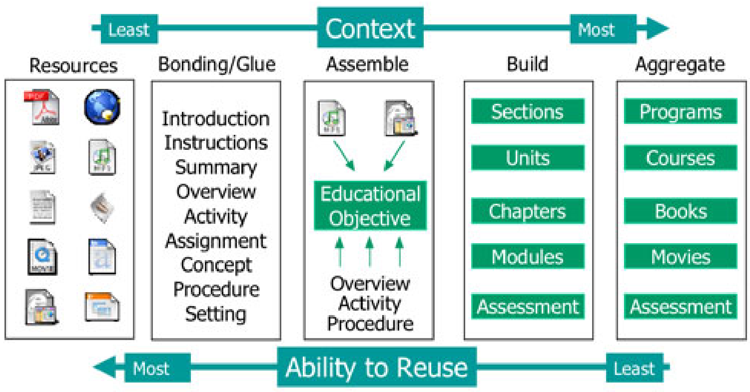


Figure 2: Context vs Reusability

Other authors also try to address this problem. Ferdinand Krauss states in "The Reusability Myth of Learning Object Design" [24] that reusability contradicts best practices in learning design. "One of the first rules of instructional design is to identify a specific target audience", which prevents the reuse of a carefully designed LO's in a different context.
An approach to solving the problem is done by Bosic [10], who distinguishes two types of reusability: technical/operational and instructional/pedagogical reusability. These two types capture the problem of reusability of LO's very well, as the goals of these two types often contradict each other. Technical reusability tries to achieve platform and format independence of LO's.

Instructional reusability on the other hand aims to reuse one LO in different learning contexts. The LO itself becomes a knowledge gaining experience/process that can be integrated into different learning scenarios. One possible solution is to capture content and context independently and to add context and good pedagogy through the learning design process, but this leads us again to a division of content and form.
What becomes clear from this discussion is that reusability is context dependent. So before we can start thinking about the repository and the LO's, we have to clearly define our context scenario. This is made because finding a solution for the whole world of e-learning is not only out of the scope for this project work, but also futile in that way, that there are an endless number of possible contexts. One university might have a totally different approach to a statistics course than another. Just think distance, "normal" and online-distance universities.

## 3 The working context - Statistics classes

The scenario-based definition of LO's is not a new approach in the world of LO's. Miguel-Ángel Sicilia and Miltiadis D. Lydras focus on this idea in [29]. They state that "learning object-based technology is becoming quickly widespread" and that there is a necessity "to get rid of the ambiguity that the diverse conceptions of the term produce in technical literature and actual practice". They propose a scenario-oriented characterization of LO's, which "takes a concrete perspective on the topic: that of the implementers, designers or users of software that deals with learning objects to attain certain learning or learning-management objectives."
For this reason and the fact that a special focus is needed to make reasonable assumptions for the necessary features of the LO's and the repository, the project work will also be based on a concrete scenario.
The Open University of Catalunya (UOC) is a very young university. In spite of this it has managed in it's twelve years of existence to attract a large number of students. It offers 19 official degrees and several graduate and postgraduate studies. Today more than 40000 students are enrolled and over 1800 people including teachers, instructional designers, tutors, aca-

demic and technical staff care for their needs. The UOC virtual campus is a fully integrated e-learning environment, which offers users a mailing system, agendas, news services, virtual classrooms, a digital library and e-learning related tools.

One problem that has arisen is the overlapping of different degrees. A good example for this are the Statistics courses which are part of many different degrees. Humanities, Economics, Computer Science and Environmental Sciences are just a few of the fields that incorporate statistic analysis at one time or the another. It is clear that in all these different fields of research the statistics courses are not the same, but build upon the same basics. The definition of "mean" is the same for all different courses. The problem is that in the last years for every single course an author was employed (and payed) to create an introductory course in Statistics, which included the explanation and definition of "mean". Why should the university spend seven times the resources it has to? Another reason why the resources are not reused is the accessibility of these resources for students as well as teaching staff. Every course uses it's own file directory for storing and accessing resources, a cross-linked database is not available.

Thus the focus of the project work is a repository which contains all content relevant to all statistics courses (and at a later time possibly all courses available at the university) at the UOC. Every teacher, student and tutor can then access these resources as he likes and use it in his own defined context. In addition to human users, an Intelligent Tutoring System (ITS) should also have access and be able to make use of the repository.

This means the repository will be accessed in two distinct ways:

- Classical way

  Resources are tagged in a descriptive manner, for easy search and use by students as learning resources during the semester. This is also a help for teachers who build new courses, develop new exercises and create new exams.

- Automated suggestions by Intelligent Tutoring system (ITS)

  Content is not only tagged about the content itself, but also about the way it can be used (technology, accessibility, learning style, etc).

> The ITS may add value to the content (for example through suggesting HTML links etc) and select appropriate resources for the learning needs of students.

To specify this repository four questions have to be answered:
1. What is contained in the repository?
A statistics course consists of several lectures, exercises and examples. It may make use of statistical programs like SPSS or Minitab, and include sophisticated simulation programs, for example in the form of Java Applets. There may be additional supportive resources like textbooks, audio-files or videos. Table 1 shows a list of possible resources in the repository and their possible uses. This list is not complete, just a representative subset used to get a decent scope.

| Type and Format | Possible use of resource |
|---|---|
| Textbooks (PDF/HTML) | Reference book, additional material |
| Examples and exercises (PDF) | Exercises and examples |
| Short videos (AVI) | Alternative to a textual representation |
| Minitab or SPSS files | As exercises and examples |
| Statistical tables (PDF / Excel) | As help to solve exercises |
| Java Applets | Simulations |
| Online evaluation tests | Student self evaluation |

Table 1: Types of Resources in the Repository

2. Who is accessing the repository?
As said before it is important to think about who is accessing the learning objects and in which way. In the UOC teachers don't conduct courses, they only design them. They have the content responsibility and thus are responsible for the quality of the courses. The actual course is held and monitored by so called consultant professors. Each consultant is responsible for one classroom and for a specific topic. He/she is a specialist in his/her area, answers students questions, assigns exercises and marks students according to tests. Students enlist in different courses belonging to their curriculum. They also have a tutor, who is their guide throughout the whole degree. Last but not least, the university employs content designers. They work

together with the teachers/professors to develop and design new content for the courses.
In addition to human users an Intelligent Tutoring System will also use the repository.
3. In which way are the contents of the repository accessed?
This question is important, because it also defines the functional requirements of the repository. It is impossible to find all possible ways in which contents can be used, so I will list some characteristic uses for each group of users.
Teachers

- Search and Retrieve (S&R) context specific resources
- Composition of resources to courses

Consultants

- S&R supportive material
- S&R exercises and examples
- Build exams from exercises and examples

Students

- S&R supportive material
- S&R exercises and examples
- S&R material for their specific learning style, accessibility issues

The ITS

- S&R material based on student profiles
- Suggest material to students based on these searches

4. Which information is needed by users of the repository?
We can divide the users into two groups: humans and non-humans/computer programs. The question that arises is if both groups need the same information about the resources. Does for example a student need to know which

learning style he/she prefers? Wouldn't it be sufficient if the system automatically generates the information, from the resources he/she has accessed so far and his/her style of work. The ITS on the other hand needs this information to make appropriate suggestions to the student.
This is again a very context dependent question and not all eventualities can be taken into account. Thus I list the most important features that should be captured. All of the resources in the repository should be tagged accordingly to:

- A Basic resource description (type, format, etc.)
- A "Pedagogical" description: difficulty level, mandatory / optional / recommended, etc.
- Learning styles (e.g. Felder and Brent, 2005)
- Accessibility issues

Now that the repository and it's features are specified, I will take a look at the content of the repository - the LOs.

# 4 Introduction to Learning Objects

The term "Learning Object" was first popularized by Wayne Hodgins in 1994 when he named a CedMA (Computer Education Management Association) working group "Learning Architectures, APIs and Learning Objects". The concept of LO's has is roots in the Object Oriented Design paradigm of Computer Science. Here prototypes of objects encapsulate data and behavior. These can then be cloned and used by other software as needed. They can also be composed to a much bigger and richer object. LO's promise to "cure" two big problems that have arisen in the last years.
Firstly the extraordinary high costs for developing high-quality multimedia learning content. Right now every university, school or educational institution develops it's own courses. How does this work? Usually the teacher sits down with a book or some other resource, splits the whole topic into small independent parts and assembles them in a specific way (his "instructional

design" for the course). But what if a repository of all these small, independent elements already existed? Then every teacher would just grab what he needs and could still assemble it the way he wants. This would save time and money and foster the collaboration between educational institutions. These economies of scale are one of the main reasons for the popularity of LO's.

The second problem is reusability. If one thinks for example about the digital representation of an art picture, it is well possible that this picture - as a LO - could be used in a variety of learning contexts. It could be used as an example in an art course about a specific art epoch or it could be used as an example picture in an exam. It could also be used as an example for a specific painting style. The value LO's are now offering is that in all three scenarios the same LO is employed.

To encourage the widespread use of LO's, the IEEE formed in 1996 the Learning Technology Standards Committee (LTSC) with the goal to "develop accredited technical standards, recommended practices, and guides for learning technology". Without a de jure standard, universities, corporations, and other organizations around the world would have no way of assuring the interoperability and reuse of their LOs. Three other big organizations, the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE), the Instructional Management Systems Global Learning consortium (IMS Global) and the Advanced Distributed Learning Initiative (ADL) are also developing technical standards to support the broad deployment of LOs.

# 5 Development of a working definition of "learning activity"

## 5.1 Analysis of existing definitions

What (exactly) is a learning object? - This is a question to which many people have tried to find an answer and to which as many people have actually come up with different answers. Basically, every institution or private person in contact with e-learning has at one point in time (tried) to define

what a LO means for them. There is a broad common understanding of what the basic functions of LO's are, but what hasn't been achieved so far is to find a common definition.
This chapter will take the most known definitions and analyze them. The goal is to find the common ground of all these definitions, what they do capture and what not. I will summarize and collect all the qualities the authors demand from LO's, so that I can derive a common definition from them afterwards.
The three definitions I have chosen are:

1. IEEE LTSC Learning Object Metadata Standard, Version 6.1:

   "A learning object is defined as any entity - digital or non digital - that may be used for learning, education or training" [25]

2. Wiley: "Connecting Learning Objects to Instructional Design Theory: A Definition, a Metaphor, and a Taxonomy."

   "...a Learning Object... [is] 'any digital resource that can be reused to support learning.' This definition includes anything that can be delivered across the network on demand, be it large or small. Examples of smaller reusable digital resources include digital images or photos, live data feeds (like stock tickers), live or prerecorded video or audio snippets, small bits of text, animations, and smaller web-delivered applications, like a Java calculator. Examples of larger reusable digital resources include entire web pages that combine text, images and other media or applications to deliver complete experiences, such as a complete instructional event" [37]

3. Polsani: "Use and Abuse of Reusable Learning Objects"

   "For any digital object or media asset to acquire the status of a LO it should be wrapped in a Learning Intention, which has two aspects: form and relation."

   "Reusability is the second principle that serves as the foundation for defining a LO. While form and relation provide a mechanism for the internal constitution of a LO, reusability accords value to it."

> "A Learning Object is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts." [33]

### 5.1.1 The IEEE LTSC definition

The definition by the LTSC is the oldest and the most comprehensive one. This is good and bad together. The good thing about it, is that every other definition out there is a subset of the LOs defined by the LTSC LOM standard. The bad thing is that this definition is unpractical and not suited for real use. As Polsani points out "non-digital objects such as computer hardware and digital objects like images enjoy the same conceptual status, thereby making it impossible to use the term Learning Object in a meaningful way" [33]. It has over time become more narrow as version 4.1 of the standard even included people, organizations or events related to CBI.
The properties/functions of LOs defined by the LTSC are:

- "digital or non-digital entity"

  This is the most controversial point of the definition. Can "non-digital" entities, like a book in the old sense, really be used as learning objects in the digital environment of computer based training? One of the main goals of LO design is easy accessibility. How can a hardcopy of a book be easy accessible for all users?

- "that may be used for learning, education or training"

  This refers to the "learning intention" (this term will be explained in more detail later) of the LO. The purpose is education in every field thinkable. Many people see the "or" as critical, as this indicates a non-universal reusability of a LO.

### 5.1.2 The definition of David A. Wiley

The second definition is almost as broad as the first one. Wiley says the "definition captures what ... [he] feels to be the critical attributes of a learning object, reusable, digital, resource, and learning," and differs in two

important aspects from the LTSC LOM one. a) It "explicitly rejects non-digital .. and non-reusable .. resources" and b) "the phrase 'to support' has been substituted in place of 'during'". The second point is of no consequence any longer, because Wiley's work is based on the LOM standard v4.1's definition, and has since been rephrased.
The properties of LOs as defined by Wiley are:

- "any digital resource"

  As said before, he reasonably excludes non-digital objects.

- "can be reused"

  That is a valid addition to the definition, because as pointed out before reusability is a critical feature of a LOs.

- "supports learning"

  With this term Wiley refers to the fact that a learning object's use should be linked to the learning activity. This means that for example a banner advertisement on top of a web page, even if it's content is theoretically connected to the studied topic, is not a LO.

- "the critical attributes of learning objects are: reusable, digital, resource and learning"

  These four attributes are a reasonable good choice to describe the basic properties of LOs.

### 5.1.3 The definition of Pithamber R. Polsani

The last definition I want to analyze is one of the most recent ones. Polsani was one of the first to try to find a conceptual definition of a LO. He based his final definition on two fundamental concepts: a) Every LO should be wrapped in a "learning intention", which consists of a form and a relation and b) the concept of reusability.
The learning intention is the internal constitution of a LO. The form of a LO describes the framework in which a digital object is embedded. This may be for example the course in which it is integrated. The form changes the LO from an object of intuition (which means an object that generates some

kind of personal response in us) to an object of understanding. The relation on the other hand describes the interface to the LO itself. This is necessary because the learner has to be guided on his process of understanding.
By this definition of the inner construct of a LO, Polsani makes sure that each LO, small and independent as it may be, has an innate structure which gives the LO the purpose of instruction. This means that for example just a digital image is not a LO! Only if you give it the form of a course about the content of the picture and add for example a discourse about the job of painting the picture it becomes one. One has to be careful though, because this doesn't mean that the whole instructional design is hardcoded into the LO. How the discourse is used, and if it is at all used or just parts of it, still depends on the teacher who employs the LO.
The second point of interest for Polsani is reusability. He argues that while the learning intention "provides a mechanism for the internal constitution of a LO, reusability accords value to it". To reach this goal it is very important for Polsani "to separate the object development and instructional usage of LOs", because he considers the former as the strategy and the latter as the tactics to implement the strategy.
Summarized the important features of Polsani's definition are:

- "every LO is wrapped in a learning intention, consisting of a form and a relationship"

  This guarantees that every LO describes actually a learning process and has a learning objective attached to it.

- "independent and self-standing unit"

  Independent goes with reusability, but the interesting point here is "self-standing". This again implies that a LO is more than just an "object". If it still has a learning intention innate in it's construction, wouldn't that mean that the LO is becoming more like an "experience" than a "object"?

- "predisposed to reuse in multiple instructional contexts"

  This point emphasizes the reusability aspect of Polsani's idea of a LO.

One can see that these three definitions have a common ground, but that there is also an evolution visible in the definitions. In the next section I will combine the features of learning objects to develop a working definition of a "learning activity".

## 5.2 Definition of a "learning activity"

The last section has shown which properties of LOs are the most important. Organizations and researchers agree on a set of common features. These are:

- The idea of LOs is grounded in OO Design

  This yields the possibilities of interoperability, reuse and concurrency.

- Each LO has an internal structure, aimed at a knowledge developing process

  LOs are to be used in instructional contexts, thus they have to be build with the idea of conveying knowledge in mind.

- LOs are digital entities deliverable over the internet

  This has the benefit of easy distribution and reuse.

- Each element can be drawn into a momentary assembly for various instructional contexts

  This is the basis for reuse of LOs in different contexts.

- LOs are independent and self-standing units of learning content

  This means, that no LO is bound to another, in such a way, that it cannot be used without it. It may be the case though, that another LO may be a requirement regarding previous knowledge, but if you have all the knowledge to understand the content of one specific LO, one can do so without additional help.

These features capture the necessary requirements of LOs, but when one wants to define a unified usable LO, some specifications which directly attribute to the usability and value of LOs are missing.

The first thing missing refers to the fact that not only the use, but also the creation of a LO has to be structured in such a way, that collaborative work and simultaneous use is possible. For LOs to be widely accepted as the means to develop e-learning content, producers of such content have to have the opportunity to work concurrently. The second requirement is related to the ever growing number of available content. If all kinds of people have to access arbitrary LOs simultaneously, accessibility becomes a very important point. This means efficient ways to organize, search, retrieve and distribute Learning Objects are needed. The third thing missing comes from the ultimate goal to perform fully automated personalization in e-learning. I refer to this aspect as generativity of learning objects. This has importance regarding the technology employed.
Summarized I extend the list of features for LOs by the following:

- Easy collaboration and simultaneous use is possible
- Generativity
- Accessibility

The last point of interest I want to rise, is the term itself. Learning "object" seems inadequate if we look at all the definitions found. [32] rightfully states: "The 'knowledge objects' ... will be much more like 'experiences' than they will be like 'things', much more like 'programs' than 'documents'". This is also reflected in the approach Polsani takes. As said before, for him "Form and relation shape a cohesive internal composition of a LO" [33]. This is also reflected in the recent Bologna Declaration. In this declaration 29 european countries pledge to reform the structures of their higher education systems in a convergent way. One part of this consolidation is a competency based approach to university degrees. This means that there are no longer learning objectives to reach in a course, but that the course consists of several "learning activities" that lead to specific competencies.
Thus I suggests to adopt the term "learning activity". This expresses both - the learning intention that Polsani has described, and the process that is associated with a learning resource in this context.

Taking everything developed so far together I come to the final definition of a
"Learning Activity":
An independent, self-standing piece of learning content, that has an innate learning intention. It is a digital entity which is predisposed for easy accessibility and reusability in different instructional contexts.

# Part II

# Structuring Learning Activities

## 6 E-Learning Standards Overview

Throughout the past few years many communities have developed their very own set of unique metadata standards. Examples are standards for cultural heritage in museums like CIDOC CRM[1], standards for geographical information like FGDC Metadata [6] and standards for digital libraries like Dublin Core [2] and MARC 21 [4].
Two standards important for this work are the Learning Object Metadata Standard (LOM) [25], developed by the IEEE Learning Technology Standards Committee and the MPEG-7 standard [26], developed by the Moving Picture Experts Group. While LOM is focused on the description of learning content, MPEG-7 aims to describe all types of multimedia resources. As shown before the content repository for statistics courses contains both - learning materials and multimedia content - and thus these elements will be described either one of the standards.
The third important standard is the IMS Global Learning Design (IMS LD) [14]. IMS LD is different from the other two standards as it's aim is not to describe content, but to describe the process of content assimilation. It is based around the concept of activities, which employed to reach a learning objective associated with a course, and thus captures the idea of process-based learning content very well.
The rest of this chapter examines all standards. Every standard is introduced and then analyzed with focus on the capabilities to structure learning

content. Special focus is put on the ability to describe pedagogical features, like accessibility issues and learning styles.

## 6.1 IMS Learning Design

IMS LD was published in February 2003 and is based on the Educational Modeling Language EML [27], which was developed at the Open University Netherlands. The objective of IMS LD is to provide a framework of elements that can describe any design of a teaching process in a formal way.
As said before, IMS LD is based around structured learning activities. IMS LD describes persons in the roles of either learner of staff, that perform these activities within a learning environment. This environment contains LOs and services, that help the learners to achieve their learning objectives. Figure 3 depicts these sequence of events.

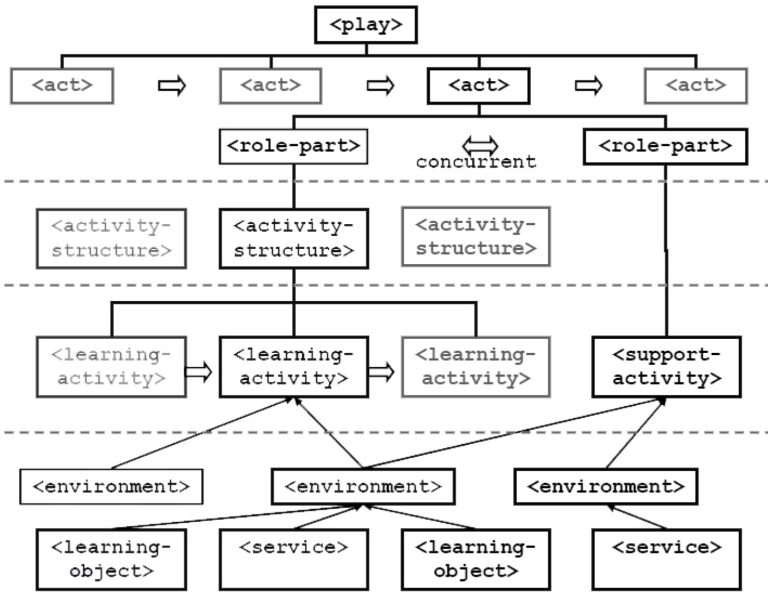


Figure 3: Taxonomy of sequencing in IMS LD

IMS LD does not try to capture every available pedagogical approach, but it provides a generic and flexible language. The problems evident with IMS LD are that it is still a very young standard (still in version 1) and thus subject to change. On the other hand it is already very complex and not easy to use.

For our scenario of a repository of statistics learning material, IMS LD is not applicable. The content repository may contain whole courses, but the focus is not the creation of these, but to ease the use and foster the reuse of these objects.

## 6.2 MPEG-7

The sheer amount of available multimedia resources is so overwhelming, that identifying and managing them is becoming increasingly difficult. The value of information often is dependent on the ease of use, meaning how things can be found, retrieved, accessed, filtered and managed. In addition there is need of forms of representation that not only capture information about the content, but also about the content's meaning, and allow to some degree an interpretation of this meaning.
MPEG-7 is an ISO/IEC standard, is developed by the Moving Picture Experts Group (MPEG) and tries to achieve all these things. It's formal name is "Multimedia Content Description Interface" and it provides a rich set of standardized tools to describe multimedia content. The goal of MPEG-7 is not to standardize applications for audiovisual content handling. It tries to support as broad a range of applications as possible. The ultimate aim is to "make the web as searchable for multimedia content as it is searchable for text today" and allow for "fast and cost-effective usage of the underlying data, by enabling semi-automatic multimedia presentation and editing".
The mayor components of MPEG-7 are

1. MPEG-7 Systems - the tools needed to prepare MPEG-7 descriptions for efficient transport and storage and the terminal architecture.
2. MPEG-7 Description Definition Language - the language for defining the syntax of the MPEG-7 Description Tools and for defining new Description Schemes.
3. MPEG-7 Visual - the Description Tools dealing with (only) Visual descriptions.
4. MPEG-7 Audio - the Description Tools dealing with (only) Audio descriptions.

5. MPEG-7 Multimedia Description Schemes - the Description Tools dealing with generic features and multimedia descriptions.

6. MPEG-7 Reference Software - a software implementation of relevant parts of the MPEG-7 Standard with normative status.

7. MPEG-7 Conformance Testing - guidelines and procedures for testing conformance of MPEG-7 implementations

8. MPEG-7 Extraction and use of descriptions - informative material (in the form of a Technical Report) about the extraction and use of some of the Description Tools.

9. MPEG-7 Profiles and levels - provides guidelines and standard profiles.

10. MPEG-7 Schema Definition - specifies the schema using the Description Definition Language

The description tools used by MPEG-7 are Descriptors and Description Schemes. Descriptors define the syntax and the semantics of a metadata element and Description Schemes specify both, structure and semantics, of the relationships between their internal components which can be Descriptors and Description Schemes. Descriptors and Description Schemes are defined by the Description Definition Language. Figure 4 shows the how these components work together.
Three components are of interest for this project work. The MPEG-7 Visual component provides structures that cover color, texture, shape, motion, localization, and face recognition of visual content. MPEG-7 audio provides structures for describing audio content, both general low-level Descriptors for audio features that are valid across applications and high level Descriptors for features like sound recognition Description Tools, spoken content Description Tools, an audio signature Description Scheme, and melodic Description Tools. Sadly, both of these Description Sets provide no structures for describing semantics of relationships between audio/visual resources. The biggest and most interesting component are the Multimedia Description Schemes (MDS). Figure 5 shows an Overview of the MDS.

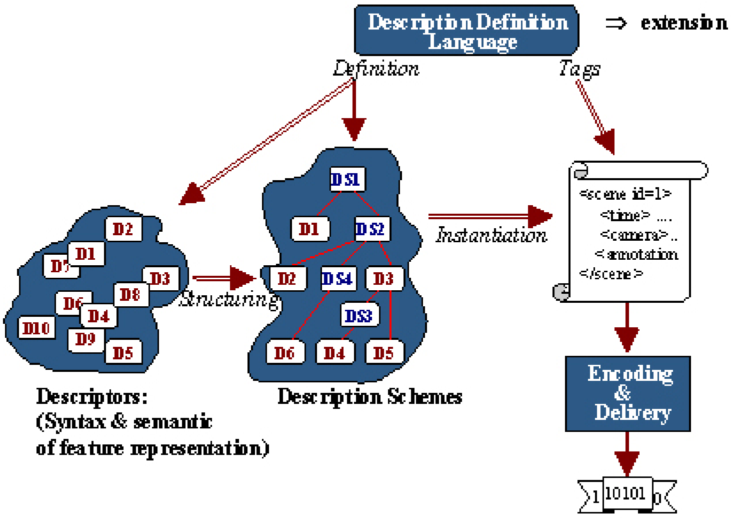


Figure 4: The basic properties of MPEG-7

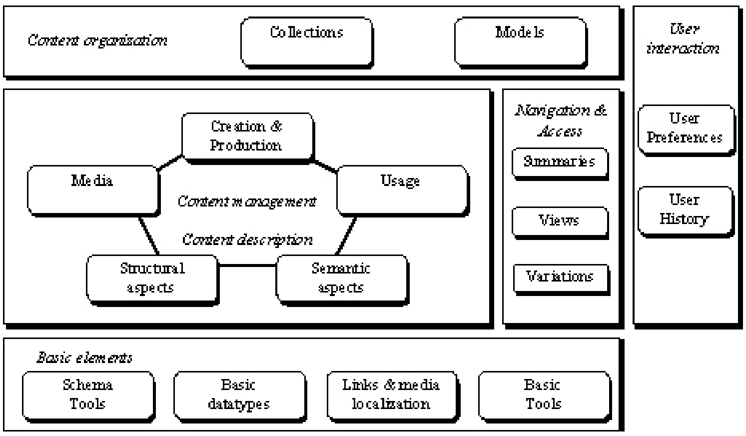


Figure 5: Overview of the MPEG-7 Multimedia DS

The MDS are trying to comprehensively capture all aspects of audio-visual resources. The component is organized in five parts: Content organization, content management, navigation & access, user interaction and basic elements. As the MDS is the most used component for the description of multimedia content, the ontology will integrate terms and features of it.

MPEG-7 has another very interesting feature. It is extraordinary flexible. As a complete definition of MPEG-7 in it's own Description Definition Language is part of the standard, every application developer can easily adapt

the standard to the needs of this own application.
MPEG-7 is excellent in describing multimedia content. The use of XML as the content description language and the possibility to describe your own Descriptor's make a very powerful language. One example showing the amount of flexibility, are the efforts to integrate LOM into MPEG-7. This is also necessary, because MPEG-7 has no means to describe pedagogical features of content.

### 6.2.1 Describing conceptual aspects with MPEG-7

The Content Description Tools of the MDS include structural and semantical aspects. Figure 6 shows the available DS.

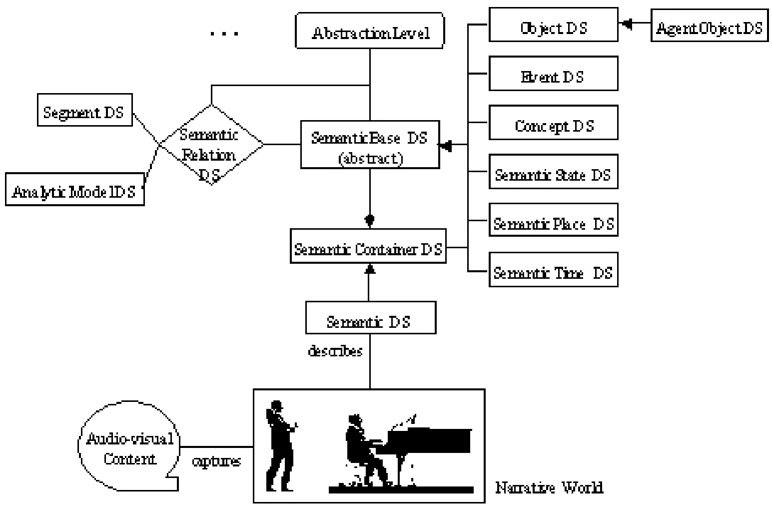


Figure 6: MPEG-7 tools for describing conceptual aspects of content

The "SemanticBaseDS" can describe narrative worlds and semantic entities in a narrative world. In addition a number of specialized DS' are available which describe objects, agent objects, events, places, and time in a narrative world.
For the purposes of this project work, these Descriptors and Description Schemes are not useful. These semantics are not transferable on objects not described by MPEG-7. They don't allow the description of the semantics of relationships between different multimedia objects and thus are not helpful in describing pedagogical information about the content.

## 6.3 LOM

The idea for a common metadata standard is quite old. In 1998 IMS and ARIADNE submitted a joint proposal and specification to the IEEE LTSC. On the basis of this the IEEE LTSC Working Group 12 was founded and in June 2002 the final draft of the LOM standard, based on working draft 6.4, was published.
The LOM standard incorporates a conceptual data schema that defines the structure of metadata for learning objects. A "learning object" is defined by the IEEE LTSC as "any entity -digital or non-digital- that may be used for learning, education or training". A metadata instance for such a learning object describes relevant characteristics of the learning object.
LOM metadata is split in 9 categories and over 77 elements. Figure 7 shows the basic categories and elements of LOM. As not all applications need the same set of metadata it is possible do specify so called "application profiles", which only include the metadata fields valuable for a specific application.

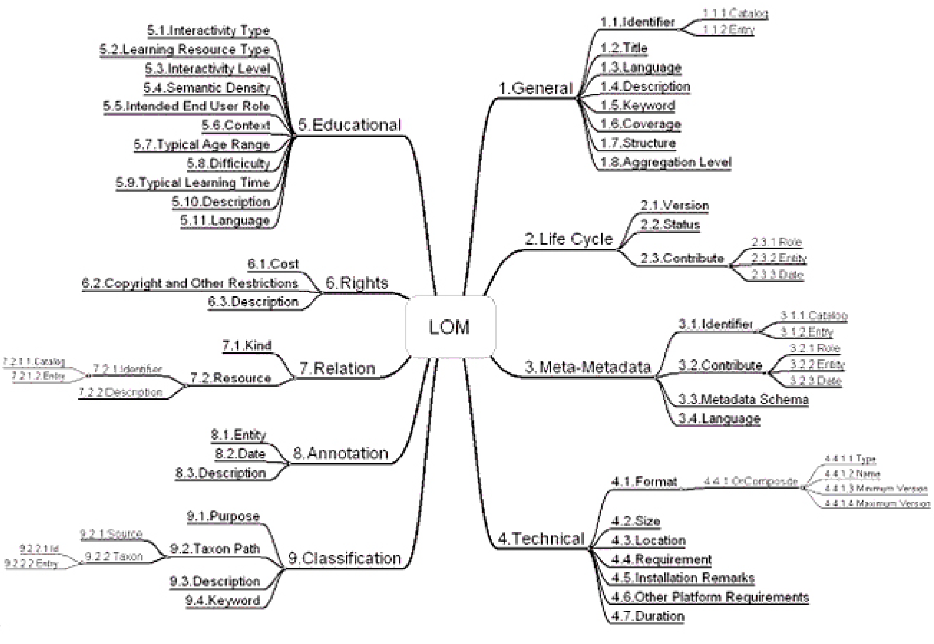


Figure 7: The elements and structure of the LOM conceptual data schema

The basic categories of LOM work well to describe the facets of LO's. I will take a closer look at two of LOM's categories, namely the "Educational" and the "Relationship" categories, as these capture a lot of information which could possibly be called "semantic".

### 6.3.1 The "Educational" Category of LOM

The Educational category of LOM tries to fulfill pedagogical description needs, but many experts agree that it does not reach this goal. Roya Foroughi for example states that the elements of the educational category "... do not address the pedagogical value of the [learning] object in a comprehensive manner." [8]. The elements of the educational category are:

1. Interactivity Type

   Describes the predominant mode of learning supported by this LO. This field is not adequate as the only values allowed are "active", "expositive" and "mixed".

2. Learning Resource Type

   These are the different kinds of learning resources supported by LOM. This list is quite comprehensive and captures the most used types very well. These types will be used in the ontology to create the link to LOM.

3. Interactivity Level

   This again is not a sufficient qualifier for the pedagogic characteristics of a LO. This field only allows values ranging from "very low" to "very high" and thus is again only a relative quantifier for a specific context.

4. Semantic Density

   This is a confusing field, because many people state that the semantic density is an attribute of quality and not a pedagogical feature. THE IEE LTSC describes it as the "degree of consciousness" of a LO.

5. Intended End User Role

   This field makes only sense, if not only LOs intended for a learner are being described, but also the authoring tools itself.

6. Context

   This refers to the learning environment. Allowed values are "School","Higher Education","Training" and "other". The value of this field depends on the reusability of LOs.

7. Typical Age Range

   This field is of no use for university education, but may be of use for schools.

8. Difficulty

   This is a relative value ranging from "very easy" to "very difficult". It is very hard to measure and can only give a rough guideline.

9. Typical Learning Time

   This is like "Difficulty" a very subjective element. It gives the average time needed to understand/complete the learning object, but that is only valid for the context of a learner with equivalent skills.

10. Description

    This field allows for comments.

11. Language

    This is not the language of the LO, but the typical language of the user of the LO. For example a spanish course for an english student, would fill this field with "en-GB".

As seen, the use of most of these fields depends on the context of the LO. The problem with the LOM "Educational" category, is that it is not able to sufficiently describe pedagogical characteristics of learning material. Fields for describing accessibility issues or learning styles are missing completely.

### 6.3.2 The "Relationship" Category of LOM

The relationship category of LOM is designed fairly simple. A LO can have as many relationships as the author wants and a relationship consists of two things: a "kind", which describes the character of the relationship, and the identifier of the target LO. The problem of the "Relationship" category stems from the fixed vocabulary assigned by the LTSC. The vocabulary is based on Dublin Core and shows clearly that it's roots lie in the world of digital libraries. The allowed kinds of relationships are:

- "is part of" and "has part"

  When constructing a course or lecture this type of relationship is necessary, but as it fails to describe the sequence in which a LO appears in another, it it useless.

- "is version of" and "has version"

  This relationship is useful, as learning content typically evolves through it's lifetime.

- "is format of" and "has format"

  The LOM standard already specifies other fields like Technical.Format or Educational.LearningResourceType which capture the format of a LO.

- "references" and "is referenced by"

  This is clearly derived from bibliographical uses and not useful for learning content.

- "is based on" and "is basis for"

  With "is part of" and "requires", the "is based on" relationship isn't necessary at all for describing LOs.

- "requires" and "is required by"

  This again fails to describe the sequence in which dependent LO have to be used.

Another problem with these properties is that they are not transferable to other types of resources, which are not described by LOM metadata. This includes multimedia files described by MPEG-7. Thus the ontology will capture these relationship features, which will also enable a ITS to reason over them.

### 6.4 Accessibility

Accessibility is a big issue for current content developers and it is also very important that these features are represented in the description of the LOs. As shown before even the standards developed for the description of learning content, don't incorporate such features.

So what does accessibility mean for e-learning? When accessing e-learning content, people with disabilities are often at a disadvantage. This means that often not only the needed alternatives (Braille and audio output for blind people or subtitles for deaf people) are missing, but that also the restrictions internet based training puts on them are ignored. People with motion disabilities for example, might not be able to use a mouse efficiently. This has also consequences for the design of e-learning content. Take for example a course about 3D graphics. The text description of the mathematics needed for this is very well understandable (and with Braille output also readable) by blind people. But when this LO incorporates a 3D Space simulation Java applet, this simulation has no value to a blind user. The goal of making accessibility issues transparent through metadata and ontologies is to enable teachers/course designers to select and content appropriate for disabled people. It is not to restrict the access to specific content, but to allow for the awareness of these issues.

One effort in this direction are the IMS Learner Information Package Accessibility for LIP (IMS ACCLIP) and IMS AccessForAll Meta-data (IMS ACCMP) standards [3]. This set of standards is able to describe both - the accessibility needs of a learner (e.g. through user profiles) and the accessibility properties of a LO. In fact they are an extension of the IMS Learner Information Package standard.

ACCMP distinguishes two categories of resources: primary and secondary resources. Primary resources are the initial resources, they are the default resource. The metadata attached to it describes access modalities (whether the user requires vision, hearing, touch and/or text literacy to access the resource), adaptability (display transformability and control flexibility) and equivalents (if equivalent resources exist) of the resource. An equivalent alternative resource provides equivalent semantic and behavioral functionality

and has the same learning objective but in an alternative form. Equivalent alternative resources are grouped into two different categories - supplementary and non-supplementary. While the former augment the primary resource (e.g. by providing an audio representation of the text contained in the primary resource) the latter are a complete substitute for the primary resource.
ACCLIP allows learner profiles which include accessibility preferences. For this ACCLIP includes three groups of accessibility choices:

1. display (how the user interface and content should be presented)
2. control (alternative ways of controlling a device)
3. content (specification of auxiliary, alternative or equivalent content requirements).

This set of standards helps in recognizing accessibility needs of users and in classification of e-learning content, but they help not in building semantic relationships, describing these accessibility needs.

## 6.5 Learning Styles

Another important component of learning design are learning styles. Students have different ways of assimilating knowledge. They have different levels of motivation, different attitudes toward teachers and their specific learning methods, and different reactions on learning environments. The recognition of different learning styles and preferences is quite new. The traditional school uses mainly linguistic and logical teaching methods and teachers only slowly begin to acknowledge differences in each student.
The problem is that learning styles not only differ from person to person, but that every person has a mix of different learning styles, that are in addition subject to constant change. People might develop capabilities in areas they didn't prefer before, because the circumstances have changed. Or they improve on there skills in areas, which they already preferred the most. Thus it is hard to anticipate which learning style is the most appropriate one for a student. Often the student doesn't know himself.

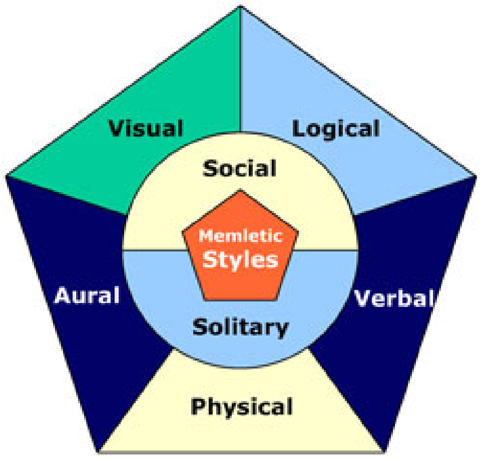


Figure 8: Overview Learning Styles

Figure 8 depicts one possible view on the categorization of learning styles. I will take this as the basis for my development of the ontology, that captures these aspects, but it can always be exchanged or expanded with any other description.
Thus the basic learning styles covered are:

- Visual (spatial) - One prefers the use images and pictures over text and has a good spatial understanding
- Aural (auditory-musical) - One prefers sound and music as the primary source for gaining knowledge
- Verbal (linguistic)- One prefers using words, both in talking to others and in writing things down
- Physical (kinesthetic) - One relies on the senses of the body to experience things
- Logical (mathematical) - One likes to use logic, reasoning and systems
- Social (interpersonal) - One prefers to learn together with other students, rather than studying alone
- Solitary (intrapersonal) - One prefers to learn alone, rather than with a group of students

## 7 The need of an additional semantic layer

After looking at the possibilities of metadata, especially in the field of pedagogical information, it becomes clear that a lot of necessary information is missing. There exists a semantic and conceptual gap between what humans need and what computers can understand. Regarding the accessibility (in terms of search and retrieval) and reusability properties of the LO repository, metadata is clearly necessary, but certainly not sufficient. The problem is that with metadata alone, only syntactic information about the LO's can be stored. This problem is partly related to the fact that all metadata standards use XML as the representation language. As Jane Hunter points out in [22] "Although XML Schemas provide support for explicit structural, cardinality, and datatyping constraints, they provide little support for the semantic knowledge necessary to enable efficient and flexible mapping, integration, and knowledge". Metadata lacks means to describe semantic relations between LO's, and although LOM tries to achieve this through it's Relationship category, it fails because the vocabulary is solely based on a library context.

Ontologies enable machines to "understand" and generate the descriptions of the resources and cover the gap described above. The ultimate goal is to exploit these implicit semantics for intelligent services. Hunter states it in the following way: "The knowledge representation provided by such ontologies can be used to develop sophisticated services and tools which perform knowledge-based reasoning, knowledge adaptation, knowledge integration and sharing and knowledge acquisition" [22].

## 8 Introduction to ontologies

The term "ontology" originally refers to a philosophic discipline. It deals with the study of entities and their relations. "Ontology" in it's genuine meaning is less concerned with what is than with what is possible.

The term has been adapted by the knowledge-management and especially by the artificial-intelligence community. Here an ontology is a "an explicit specification of a conceptualization". The common ground in these disci-

plines is that an ontology describes what things exist in a specific domain. To achieve this goal an ontology consists of a taxonomy and some rules, which enable reasoning over the entities in the ontologies domain.
As ontologies need to be machine-readable and understandable the computer science community quickly developed several languages for describing them. The Resource Description Framework (RDF) of the W3C, the DARPA Markup Language (DAML+OIL), and the Web-Ontology Language (OWL) of the W3C are the three most sophisticated examples. For easy interoperability almost all languages build on XML as the document format.
This project work will describe the new-found ontology not with one of these languages. This has several reasons. Firstly, the scope of most of these languages is much too wide for the thin semantic layer that should be developed. Secondly, as said before, the scope of this project work is not to develop a complete solution, but to hint on, and explore critical questions and areas. The graphical tool of choice for ontology development is Protégé [5]. Protégé is a free, open source ontology editor and knowledge-base framework, developed by Stanford Medical Informatics at the Stanford University School of Medicine.

# 9 Development of a ontology for structuring learning objects

The ontology proposed for structuring LA's is based on three goals:

- make LA's more readily accessible

  This was one of the key features of LAs and their use. The ontology tries support users in accessing and retrieving the most appropriate LAs for their usage context.

- make LA's reusable

  Only when the ontology captures the semantics of sequencing and ordering of LAs, true value through reusability is created.

- make LA's usable by both human users and computers

> The automated suggestion of the most appropriate learning material is an acceptable middle course between fully automated content adaption and the presentation of textbooks. When an ITS is using the ontology to suggest materials to users, it has to know everything a human user can possibly know through the ontology.

The first step to building an ontology is to define classes and a class hierarchy. In this ontology two types of resources will be used - those described by MPEG-7 and those described by LOM. It is necessary to integrate types declared by these standards into the ontology, to create a relationship between the metadata standards and the ontology. For the LOM standard the most useful field to use as classes is the "Learning Resource Type" field of the "Educational" category. These types reflect the uses of LA's. The MPEG7 standard defines five basic "content entities" - image-, audio-, video-, audiovisual-, and multimedia-segments. These content entities describe the basic characteristics of a multimedia file and will be used as classes in the ontology.
The second step in building an ontology is to define the properties of the classes. The problem here is to decide what becomes a class, and what becomes a property of a class. In the case of MPEG-7 and LOM metadata it was clear that the most characterizing features, terms with a meaning to both, computers and humans, had to be used as classes. It is also clear that metadata fields like the LOM identifier and the MPEG7 ID have to be added as properties to these classes, so that the LA's can be uniquely identified. The real decision has to be made when the pedagogical features of LA's are taken into account. The intuitive way is to model these features as properties of the different content-type classes. This has the advantage that all features of a LA are instantly visible. The disadvantage of this model becomes evident when one looks at the requirements of the repository and the ontology. Teachers, course designers and the ITS have to be able easily search over these quantifiers. When designing a course or searching for alternative resources it is valuable to have a class of alternative resources. If all pedagogical features are modeled as properties the search and retrieval becomes more complicated. Thus I have decided to model all these features

as additional classes. This means that the categorization process is a little bit more complex, but has two important advantages. Firstly it makes the whole ontology very flexible and extensible. Secondly it makes the search over these features detached from the actual type of learning activity possible.

Figure 9 shows the complete structure of the ontology.

After the properties of the classes are defined the last step is the specification of relationships between the classes. For this ontology the relationships can be divided into two categories - structural and pedagogical relationships.

The construction of courses requires relationships that describe the semantic dependencies of learning activities. What is a proper itinerary to achieve a learning objective? Which learning activity is the logical consequence, when one learning activity is finished? In addition it is necessary to not only link pedagogical information and learning activities via classification, but also through relationships. This enables users of this ontology to make queries like "I have resource R of topic T, show me all activities for visually impaired people, that are alternatives to resource R".

Figure 10 shows the structural relationships applicable for the ontology. There are two types of relationships. The first groups expresses horizontal relationships - the sequencing of LAs. The second group describes vertical relationships, like the inclusion of LAs by other LAs. Together these relationships enable users to describe structures of complete courses.

Figure 11 depicts the pedagogical relationships represented by the ontology. These relationships attribute pedagogical features to LAs. In addition they allow the connection of LAs in the context of pedagogical features.

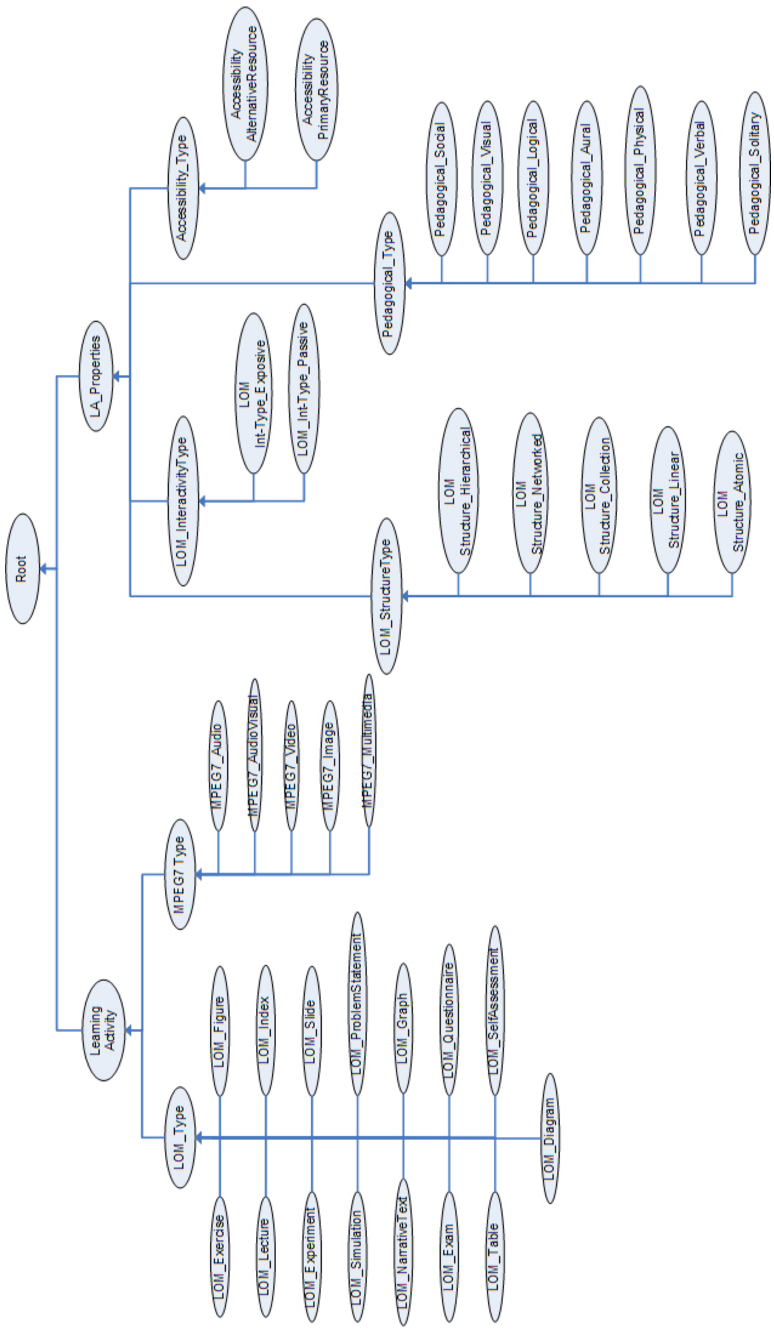


Figure 9: The class-structure of the ontology

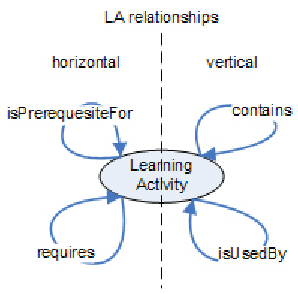


Figure 10: Structural LA relationships

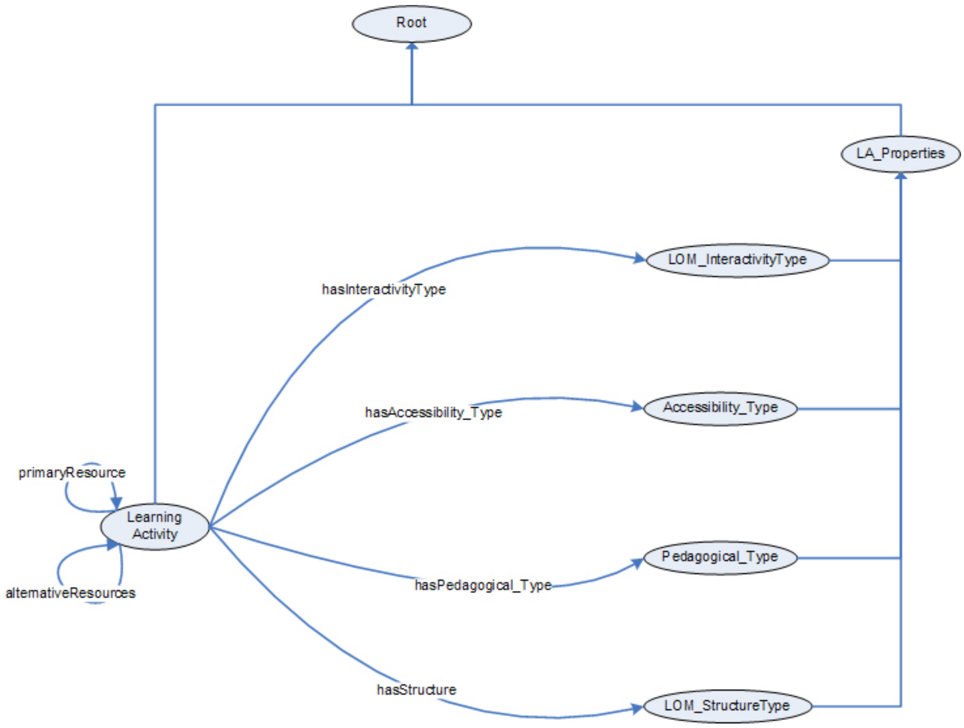


Figure 11: Pedagogical LA relationships

Neither is there enough space in this document, nor is it of any value to describe every detail of the ontology here. The full specification of the ontology can be found in the appendix as a RDF-Schema and is also available as Protégé-Files.

What follows is a concrete example, where I describe five example LAs and show what is gained by describing them with the ontology.

## 9.1 A concrete example

To make an abstract thing a bit more concrete and to improve the understanding of the ontology, I will take five example LA's, which all belong to the same lecture, and describe them and their relationships with the help of the ontology. These five sample resources are:

1. An Online Text Book in PDF format

   This is a textbook on which a whole course is based. It guides a student through the course and acts as support material. It is described with LOM metadata, which classifies it as a "narrative text". The LA_Properties valid for this resource are:

   - LOM_Structure_Atomic
   - LOM_Int_Type_Passive
   - Pedagogical_Visual
   - Pedagogical_Solitary

   As it is a secondary resource to the actual lecture and in this specific case can replace the lecture it is also classified as a Accessibility_Alternative_Resource.

2. Exercises, where each exercise resides in it's own word document

   These exercises are mandatory for completing a course. They are available as small documents - the format being Word, but they could also be an XML-Files. They have a structure, as they increase in difficulty and are described with LOM metadata, which classifies them as "exercises". The LA_Properties valid for these exercises are:

   - LOM_Structure_Hierarchical
   - LOM_Int_Type_Exposive
   - Pedagogical_Visual
   - Pedagogical_Solitary
   - Pedagogical_Social

The last two qualification sound contradicting, but exercises can be solved alone as well in a group, and the learning effect may even differ in these two cases. It is a primary resource for the lecture and in this means they are also classified as Accessibility_Primary_Resource.

3. A Minitab file, which contains statistical exercises

   These exercises are supplementary material for a course. They are available as a Minitab File. It is described with LOM metadata, which classifies it as an "exercise". The LA_Properties valid for this exercise are:

   - LOM_Structure_Atomic
   - LOM_Int_Type_Exposive
   - Pedagogical_Visual
   - Pedagogical_Solitary

   It is a primary resource for the lecture and thus classified as a Accessibility_Primary_Resource.

4. A Java Applet, simulating a statistical calculator

   The Java Applet is supporting material for a statistics lecture. It is described via MPEG-7 as an "Multimedia" entity. The LA_Properties valid for the applet are:

   - LOM_Structure_Atomic
   - LOM_Int_Type_Exposive
   - Pedagogical_Visual
   - Pedagogical_Solitary
   - Pedagogical_Social

   Although it is only a supplementing resource for the lecture, it is a primary resource in the pedagogical sense as their is no other way to do the calculations. Thus it is classified as a Accessibility_Primary_Resource.

5. A video presentation of a lecture about the "mean" at a "classical" university This is a video, which can fully replace the lecture. It contains a visual as well as an audio description of the lecture. It is described via MPEG-7 as an "Multimedia" entity. The LA_Properties valid for the applet are:

   - LOM_Structure_Atomic
   - LOM_Int_Type_Passive
   - Pedagogical_Visual
   - Pedagogical_Audio
   - Pedagogical_Solitary

   It is also classified as a Accessibility_Alternative_Resource as it can fully replace the lecture.

When one takes a look at the described elements now, one can see the additional information the ontology yields. These five resources are now related in such a way, that a human user or an ITS can easily find and retrieve fitting material for specific needs. It is possible to search for supporting material for different learning styles, or even find a complete alternative for visually impaired people. In addition this example shows the flexibility and power of the ontology, regarding the integration of different metadata standards. Resources usually only described by MPEG7 now get LOM attributes and get a lot more pedagogical meaning than with only MPEG7.

## Part III

# Conclusion and future directions

## 10 Open questions and future research points

This project work was intentionally tailored to a very specific context. This means that although a lot of questions for this specific domain have been answered and solutions for specific problem were found, a lot of questions remain unanswered. The ontology so far hasn't been used and tested and as ontology design is an evolutionary process it will surely change over time. It works well for the proposed types of learning activities, described by MPEG7 and LOM, but there exist other types of learning resources and other metadata standards, which would fit into the repository.

The proposed ontology is specialized but very flexible. Future research points might include the addition of more types of LA's. It would also be valuable to research the inclusion of other metadata standards like Dublin Core. The ontology doesn't cover all semantic information helpful for reusing learning content. Course design/construction and user preferences are only scratched on the surface and the ontology delivers only basic approaches to these topics.

Another topic is the combination of multiple ontologies for a more sophisticated adaptation of content. Ontologies for course design, user profiles and resource specification could be aggregated to yield better and more accurate results. It may also be valuable to include other ontologies completely. Jane Hunter for example has transformed the MPEG7 XML Schemas into an ontology in [21], and it would be very interesting to develop connection points to this ontology.

# 11 Related work

As said before e-learning is becoming an important topic all over the world. This is also shown in conferences like the "MTSR - The Online Metadata and Semantics Research Conference", which was first held in November 2005, covering topics like the Semantic Web applications, Learning Object concepts and knowledge management approaches.

Institutions like distance universities try to make heavy use of the new evolving technologies. The Universidad Oberta de Catalunya for example supports strong research activities in this field. The PERSONAL project around Prof. Minguillón and his research staff is reinventing the Virtual Campus of the University with heavy focus on personalization.

From 1999 - 2002 the HARMONY project, a joint cooperation of UK Joint Information Systems Committee (JISC), the US National Science Foun-

dation (NSF) and the Australian Distributed Systems Technology Centre (DSTC), researched ways to describe complex multimedia resources in digital libraries. The Harmony collaboration has led to a metadata representational model (the ABC Ontology (add link here!) and an XML/RDF query implementation that supports resource discovery applications over multimedia, multi-vocabulary metadata descriptions. Although this project has ended this research is valuable for the integration of several metadata standards. Especially Jane Hunter's contributions and her continuous efforts in this field are very interesting.
The extension of metadata standards with pedagogical properties is topic for many researches. LOM's educational category is a starting point for many and the integration of several metadata standards the ultimate goal.
–¿ add cites and references to polsani
Another very interesting project related to ontologies is the "Cyc Knowledge Server". The Cyc Knowledge Server is a very large, multi-contextual knowledge base and inference engine developed by Cycorp [15]. It tries to describe basically everything that exists in the world through one gigantic ontology. Currently it is available in version 1.0, which contains hundreds of thousands of terms, along with millions of assertions relating the terms to each other.

# 12 Other means for structuring Learning Activities

The project work has shown reasons and uses for the use of ontologies as means of adding semantic information to learning content. But this doesn't mean that other possible ways for categorization and structuring are not viable. This chapter will introduce two alternative ways - Tagging and Conceptual Content Modelling - to achieve this. I will shortly introduce each topic and try to lite up the pros and cons.

## 12.1 Links and Tags as means to structure content

Web 2.0 and it's community features are dominating the internet world right now. Each day a new way of socializing in the Internet pops out of nowhere. Many ideas don't survive, but two prominent examples show clearly that concepts like these can work.

The first example is del.icio.us, a "social bookmarking" website. People can open an account and store their favorite bookmarks online. Everyone else can freely access these links, and can also add them to their own favorite links. The page then produces a ranking of the most linked web pages. In addition people are able to "tag" these links with keywords. The keywords can be anything the user thinks of. That means for example that some link to a new movie trailer could be tagged by one person with "movie", by another with "film", and by a third with "cinema".

The second example is flckr.com. Flickr is a picture management page, with a lot of addition social features. People can upload picture from a web-interface, via e-mail or even via their picture taking mobile phone. Pictures can then be sorted into albums, rights can be attached to them, and comments can be added. Picture can also be directly uploaded to a Blog or can also be tagged. This works in the same way as del.ico.us' way of tagging. flickr also creates rankings of pictures, based on the number of views, comments and tags added by other users.

Can this way of adding personal semantics to web-links or pictures be used as means to categorize other things on the internet, namely learning resources? Clay Shirky has picked this topic up in "Ontologies are overrated" [35], and he postulates that links together with tags provide a more organic way of organizing information and are a more appropriate way for categorization.

He defines ontological classification or categorization as "organizing a set of entities into groups, based on their essences and possible relations" and argues that a perfect classification is not possible. This is because the context of things may change and people cannot predict these changes. His prominent example is the classification of "noble gases" in the periodic system. At the time the table was made people didn't have the means to generate such low temperatures to see that these gases can well be in a liquid state.

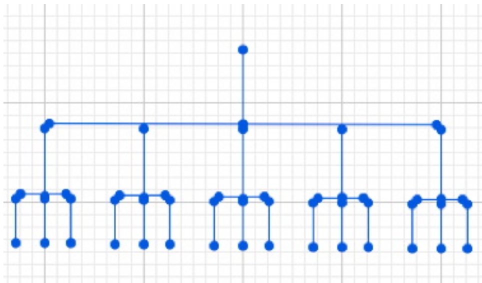

Figure 12: From pure hierarchy...

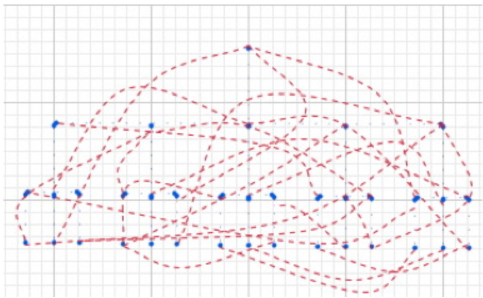

Figure 13: ...to just links

Relating this to the internet and ways to structure things here, he argues that people think too much in old ways of structuring things. In a library the librarians can assume a common view on the things that are archived there. People want to search for books from a specific author or with a specific topic. This common view no longer exists in the internet. Figures 12 and 13 depict the process from going from a hierarchical organization to just a link based organization, with tags adding semantics to these links.
Shirky is right in that way, that tagging provides a way for human user to efficiently add semantics to existing information on the web. However two problems prohibit the use of tagging for structuring learning content. First, tags offer not enough semantics to inference any kind of additional information from them. Secondly, Tags have almost no value when processed by machines, except if a common set of tags is agreed upon by all users. Examples are the "geotags" of flckr, which users can use to describe the location where a picture was taken, using latitude and longitude.

## 12.2 Conceptual Content Management

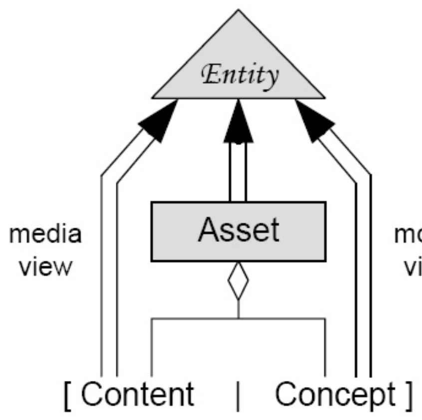


Figure 14: Asset represent entities by [content—concept]-pairs

The Software Systems department of the Technical University of Hamburg is working in close collaboration with the art history department of the University of Hamburg, to develop the Warburg Electronic Library (WEL). The WEL is a prototypical open dynamic conceptual content management system. The content are reproductions of artworks. The basic idea is that content is rich, and not easy to classify and the project searches for new ways to structure these artworks and apply semantics to them.

Their basic idea is to represent resources together with a conceptual schema that describes the resource's semantic content and allows reasoning over it. Figure 14 shows these "assets", as these content-concept pairs are called.

They have created an asset-definition language, that allows for the description of asset classes. These consist of content and a concept, that is refined through "characteristics" and "relationships". Domain specific models, developed with this asset-definiton language can then be compiled into platform-independent with the help of an asset compiler. This allows for a modular architecture and easy adaptation to new requirements.

To apply this approach to e-learning would mean to develop a conceptual schema for LAs. One could classify reoccurring elements in learning resources similar to the ontology. For example an exercise then would be described by a conceptual schema consisting of the pedagogical information

contained in the learning resource. If the schemas for this are developed further classification of new resources would be easy and could be supported by a suggestion system. This would remarkably increase the search and retrieval of these resources.
The advantages of this approach are the flexibility and the ease of developing new components because of the modular architecture. Trying to structure learning content with the help of assets is a valuable future research point.

# 13 Conclusion

This project has achieved to things in the domain of e-learning content for university courses.
Firstly I have analyzed the current insights in the field of Learning Objects. The definitions available are all working in the context of a special community that uses them, but they all together fail to specify the conceptual background of LO's. I have collected the common ground of the definitions available and developed a definition of a "Learning Activity". This LA captures not only the traditional aspects of LO's, like digitization and reuse in specific contexts, but also covers the community aspect of collaborative work. It also includes the possibility of automated use by computers of these LA's. The term itself is future oriented and hints at the paradigm change, when developing and using e-learning content.
Secondly I have analyzed the needs for an additional semantic layer on top of existing metadata structures for these LA's. As the available standards either don't cover pedagogical and reusability aspects at all, or only in a way that is not sufficient, an additional structure which captures the semantic meaning of LA's and their relationships is necessary. The proposed ontology captures several facets of MPEG-7 and LOM and adds semantic information to that. It is very flexible and can easily be extended through the integration of other metadata standards or ontologies. As shown the semantic information added to the repository helps in search, retrieval and reuse of LAs.

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<rdfs:range rdf:resource="&rdf_;LOM_ResourceType"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;isOfResourceType"
 rdfs:label="isOfResourceType">
<rdfs:range rdf:resource="&rdf_;LOM_ResourceType"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;isPrerequesiteFor"
 rdfs:label="isPrerequesiteFor">
<rdfs:domain rdf:resource="&rdf_;Learning_Object"/>
<rdfs:range rdf:resource="&rdf_;Learning_Object"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;isUsedIn"
 rdfs:label="isUsedIn">
```

```
<rdfs:range rdf:resource="&rdf_;Learning_Object"/>
<rdfs:domain rdf:resource="&rdf_;Learning_Object"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;primaryResource"
 rdfs:label="primaryResource">
<rdfs:range rdf:resource="&rdf_;Learning_Object"/>
<rdfs:domain rdf:resource="&rdf_;Learning_Object"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;requires"
 rdfs:label="requires">
<rdfs:range rdf:resource="&rdf_;Learning_Object"/>
<rdfs:domain rdf:resource="&rdf_;Learning_Object"/>
</rdf:Property>
</rdf:RDF>
```