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# Reusability and Interoperability of Adaptive Learning Objects Repositories

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***Abstract.** Learning objects repositories often keep their contents invisible from Internet-based search engines. By making them not “googleable”, some strategies must be drawn in order to provide a certain degree of external reusability of learning objects among repositories, which leads us to interoperability issues. This paper proposes a six-tiered architecture for learning objects repositories that intends to be general enough to support different pedagogical approaches, adaptation levels and interoperability with other repositories.*

## 1. Introduction

Design of hypermedia applications has been a point of interest for many researchers since hardware cost began to go down, at the same time that processing capacity of computers has been reaching a reasonable growing rate, leading to more powerful, cheaper machines. In addition to this, there is the WWW (World Wide Web) phenomenon, which is going to change all the way people face and use computers. Clearly, this fact is bound to more and more user-friendly GUIs (Graphical User Interfaces), whose routinely utilization is now completely spread around the world. Given this fertile scenario, it was expected that Internet-based hypermedia systems would begin to be developed specially for using on Computer-supported teaching/learning environments. Such recent expansion of ICTs (Information and Communication Technologies) usage on presence and distance learning has lead to the development of a new paradigmatic approach to the development of such applications, from the moment they have begun to be developed as aggregates of fine-grained learning objects. This poses a new issue to be addressed: how to store, classify and retrieve such learning objects in a proper way?

The definition used for learning objects considers them as any digital entity which can be used, reused or referenced during a technology-mediated learning process (wiley, 2000). Nowadays, this concept has become essential to the development of pedagogical content to be used in large scale educational projects to which are engaged a wide number of educational agents – students, teachers and faculty staff. Guaranteeing reusability of pedagogical content allows its use on different contexts. Therefore, a repository of learning objects that has a well-defined metadata structure can be used to customize learning processes.

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Development of learning objects repositories follows, in many senses, the same path all digital repositories must go through: data must be modeled in order to fit repositories structural requirements, relationships among such data shall be established and indexing/referencing strategies ought to be implemented. On the other hand, it must be considered that learning objects have some inherent characteristics that could not be bypassed, whose representations into repositories are equally needed and hard to be implemented. Most of these characteristics are related to the learning objectives of each learning object, and the hardness to represent them relies on the subjectivity of these objectives, since they could be related to so many different learning aspects which could vary from students' learning styles through pedagogical strategies. Besides, a learning objects repository would have not only to allow storage and retrieval of data, but also its sharing and reuse. Nowadays, a significant amount of learning objects repositories exist on the Internet, providing a very large range of elements to be retrieved, exposed and shared.

Recent researches on Learning Object have been contributing on the search of patterns for instructional content development, in order to make them adaptive, generic, portable and scalable enough to improve their potential for reusability. Besides, a wide range of virtual learning environments has been proposed to support these learning objects, with their properties and characteristics. Nonetheless, the great challenge still remains on how adaptive can a learning object be.

There are several levels of adaptation that can be reached, and these levels can be established regarding to a wide range of different aspects on teaching-learning processes, varying from the need of keeping track of students' evolution on building a specified piece of desired knowledge, until their learning styles, a multi-dimensional measure that are not only individual-dependant, but are also influenced by a range of factors so diverse as environment, inter-relational issues and psychological aspects related to how a student deal with certain sort of knowledge to be constructed, or skill to be developed.

The kind of architecture here presented can be empowered by applying it on collaborative systems, when a possible lack of an adequate implementation of some learning object would not be a fence to the learning process, since it would be reachable through collaboration. Even when the nature of a learning object makes it not adequate to promote the building of some sort of knowledge, collaboration can provide the means for supplement what lacks on learning object, helping to build new kinds of knowledge, and consequently acting to aid skills' development.

## **2. Learning Objects Repositories**

According to IMS (2003), digital repositories are defined as “any collection of resources that are accessible via a network without prior knowledge of the structure of the collection”. Repositories might hold actual assets or the meta-data that describe assets, not necessarily in the same repository. The term “digital repository” is preferred over “digital library” to stress the fact that many people could contribute with content to be shared among a community, with no “librarian” to keep track of all elements that are put in it – in spite of some opposite ideas about the role of real librarians on designing learning objects (Stockley and Laverty, 2003). Clearly, some reliability issues could be arisen, since in a scenario where no control is exerted over data is being put in a repository, unreliable elements could easily occur, which leads to the need for trusted digital repositories. RLG (2002) defines a trusted digital repository as “one whose

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mission is to provide reliable, long-term access to managed digital resources to its designated community, now and in the future”. NISO (2004) states: “the vast amount of information available makes it increasingly difficult for users to find trusted information - information that is reliably available for the long-term and is known to be authentic”.

Heery (2005) emphasizes that a digital repository is differentiated from other digital collections by the following characteristics:

- content is deposited in a repository, whether by the content creator, owner or third party on their behalf
- the repository architecture manages content as well as metadata
- the repository must be sustainable and trusted, well-supported and well-managed
- the repository offers a minimum set of basic services e.g. put, get, search, access control, besides some optional services that could be supported, like:
  - Enhanced access to resources
  - New modes of publication and peer review
  - Corporate information management
  - Data sharing and reuse
  - Preservation of digital resources

Hartwig and Herczeg (2003) also show that more abstract elements can exist in a repository, like objects representing not things, but processes. Despite digital repositories could be used for storage and retrieval of any digital material, Duncan (2003) points out the fact that digital repositories for learning objects are considerably more complex both in terms of what needs to be stored and how it may be delivered. Thus, a Learning Object Repository could be defined as a digital repository proper for store, referencing, discovery, delivery, sharing and reuse of learning objects.

According to Hatala et al. (2003), interoperability is one of the main issues in creating a networked system of repositories. Interoperability enables repositories to extend their collections by allowing them to discover new resources, as well as to provide additional resources related to its local collections. What is aimed is to provide interoperability among heterogeneous collections with a wide variety of data types and metadata standards, managed by large numbers of organizations, each with their own priorities: some of them established specifically for education, but most are not designed primarily for education.

According to Arms et al. (2002), interoperability requires agreements to cooperate at three levels: technical, content and organizational:

- **Technical** agreements cover all aspects that allow learning objects to be exchanged, including file formats, protocols, and so on.
- **Content** agreements cover the data and metadata, and include semantic agreements on the interpretation of the information.
- **Organizational** agreements cover the basic rules for access, authentication, rights, payment, and so on.

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Interoperability among learning objects repositories often relies on three techniques: federated searches, LOs harvesting through metadata and finally LO gathering (Massart and Dung, 2004; Goldrei et al., 2005; Arms et al., 2002).

Jacso (2004) defines federated searching as consisting of “transforming a query and broadcasting it to a group of disparate databases with the appropriate syntax, merging the results collected from the databases, presenting them in a succinct and unified format with minimal duplication, and allowing the library patron to sort the merged result set by various criteria”. Downes (2004) explains it better, saying that “when a person conducts a search, this search is sent to each repository in the network individually. Thus, if there are ten repositories in a federated search network, the search is conducted ten times, once on each repository, and the results are sent back to the searcher”. In a federation, a group of organizations agree that their services will conform to certain specifications (Arms et al., 2002). Recently, The Global Learning Objects Brokered Exchange (GLOBE) alliance has been established among Ariadne, EdNA Online (Australia), eduSourceCanada, MERLOT and NIME (Japan) to develop use cases, specifications, business rules and technologies that will enable federated searches across the repositories that the current GLOBE partners have developed over the last years.

Large learning objects federations are hard to be created and kept, besides the fact it is difficult to push some agreed standard to a predefined set of learning objects. Recent efforts have been done in order to create looser learning objects repositories based on metadata harvesting. Arms et al. (2002) states that. “the underlying concept is that the participants agree to take small efforts that enable some basic shared services, without being required to adopt a complete set of agreements”. Thus, each learning objects repository keeps its own metadata available in a simple interchangeable format, in order to be harvested by service providers and transformed into services such as reference linking, for instance. Metadata harvesting is not meant to completely substitute federated searching; its functionality is inherently not as complete as that provided by a federation of repositories. Though, for an organization is easier to participate of a pool of metadata harvesters than a federation.

Nonetheless, it is not always possible to establish a formal interoperability strategy among repositories. Even though, some minimal level of interoperability is possible by gathering openly accessible information using an Internet-based search engine. According to Arms et al. (2002), “because there is no cost to the collections, gathering can provide services that embrace large numbers of digital libraries, but the services are of poorer quality than can be achieved by partners who cooperate directly”.

IMS (2003) presents an architectural approach for interoperability among different repositories. IMS (2003) defines the four actors who potentially would utilize a repository, or a pool of interoperable repositories, as follows:

- **Learner:** is any person following a learning path through an e-learning application, with well-defined learning objectives. He/she can be actively engaged in a learning activity that would bring the need to discover resources that are required to complete a learning task. Once the Learner leaves the e-learning application, his/her primary role may change from a Learner to an Infoseeker.
- **Creator:** or author, is responsible for the authoring of learning elements at any level of granularity, from learning objects to learning paths and courses, through

an e-learning environment. A Creator may become an Infoseeker, discovering and accessing resources into the repository.

- **Infoseeker:** is defined as a person seeking to obtain information through the discovery of resources, not having to be under an e-learning system.
- **Agent:** is defined as an intelligent software application that carries out tasks directly on behalf of a Learner, Creator, or Infoseeker.

These roles are depicted in Figure 1, which shows the whole IMS proposal.

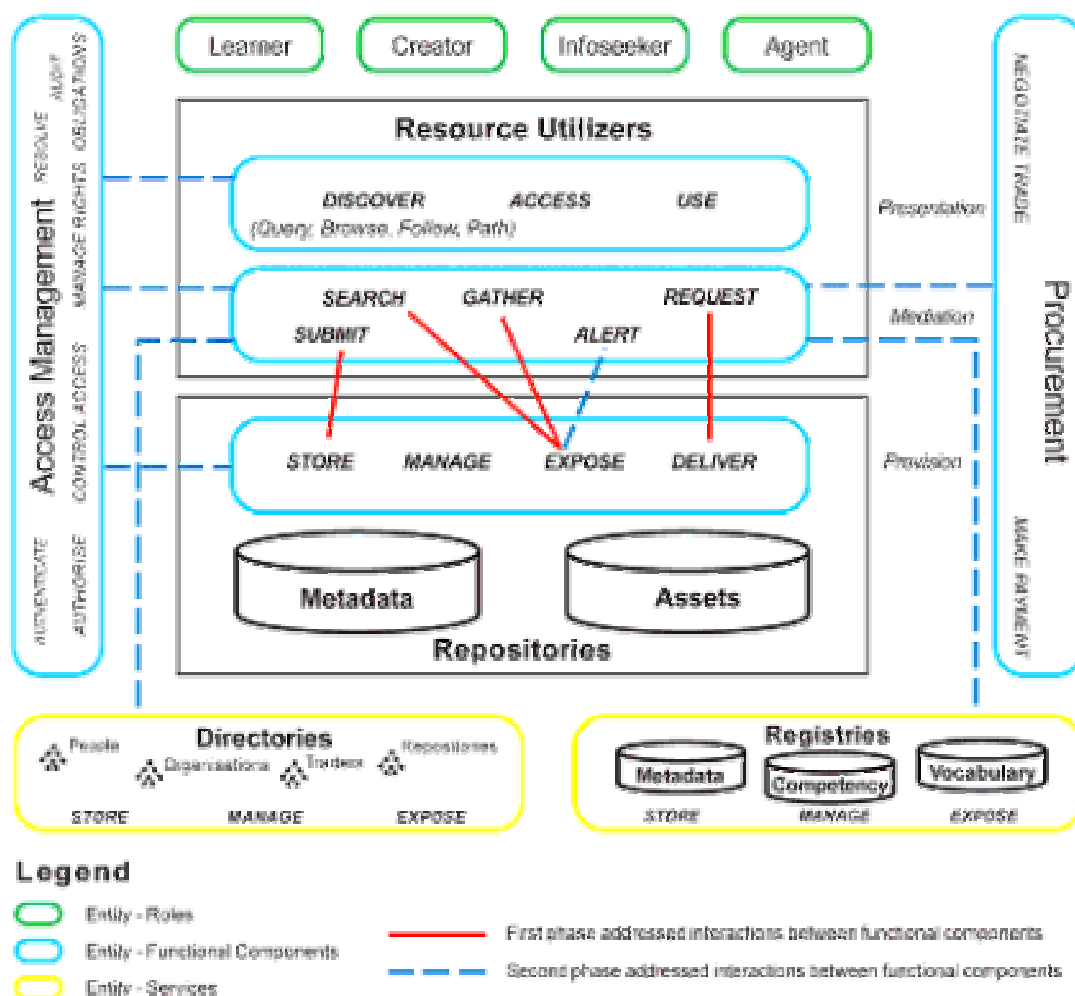


Figure 1 – IMS proposal for repositories interoperability architecture (IMS, 2003)

Figure 1 also shows the core functional interactions between the Mediation and Provision layers of the architecture. These core functions are (IMS, 2003):

- **Search/Expose:** defines the searching of the meta-data associated with content exposed by repositories.

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- **Gather/Expose:** defines the soliciting of meta-data exposed by repositories and the aggregation of the meta-data for use in subsequent searches, and the aggregations of the meta-data to create a new meta-data repository.
  - **Submit/Store:** refers to the way an object is moved to a repository from a given network-accessible location, and how the object will then be represented in that repository for access.
  - **Request/Deliver:** allows a resource user that has located a meta-data record via the Search or Alert function to request access to the learning object or other resource described by the meta-data.
  - **Alert/Expose:** could be a component of a digital repository or an intermediary aggregator service. Simple SMTP (Simple Mail Transfer Protocol) could provide this functionality

### 3. Inside a fully-interoperable repository of adaptive learning objects

Adaptive learning objects have been discussed at many different viewpoints, regarding since learner's adaptation through interoperability issues (Arapi, 2003; Brusilovsky, 2004). Figure 2, adapted from Silveira et al. (2004), presents an architectural proposal for learning objects repository supporting interoperability and adaptations.

This architecture is based in six inter-related but distinct layers:

- **Course Tier:** this tier is based on contents' sequencing by arranging references to learning objects inside Reusable Learning Objects Tier.
- **Reusable Learning Objects Tier:** this tier, represented in a deep view by Figure 3, is where learning objects actually rely on.
- **Presentation Tier:** this tier is responsible for dynamically build the optimal visualization for learning objects. It strongly depends on the following two tiers.
- **Learning Model Tier:** stores historical references about the relationship between learners and learning objects;
- **Learning Styles Tier:** describes customized profiles for each learner faced to different learning experiences, categorizing him/her into learning clusters according to his/her learning style.
- **Instructional Design Middle-Tier:** this tier is a transversal aspect that crosscuts the whole architecture, interfering in all process that is taken for each tier.

The whole concept of learning objects is essential for the development of resources for large-scale learning projects, involving a large number of students and syllabi related to formal or continued education. Figure 2 shows an inner view of learning objects inside a repository: they are inherently multi-granular, where coarse-grained learning objects might be aggregations of finer-grained ones.

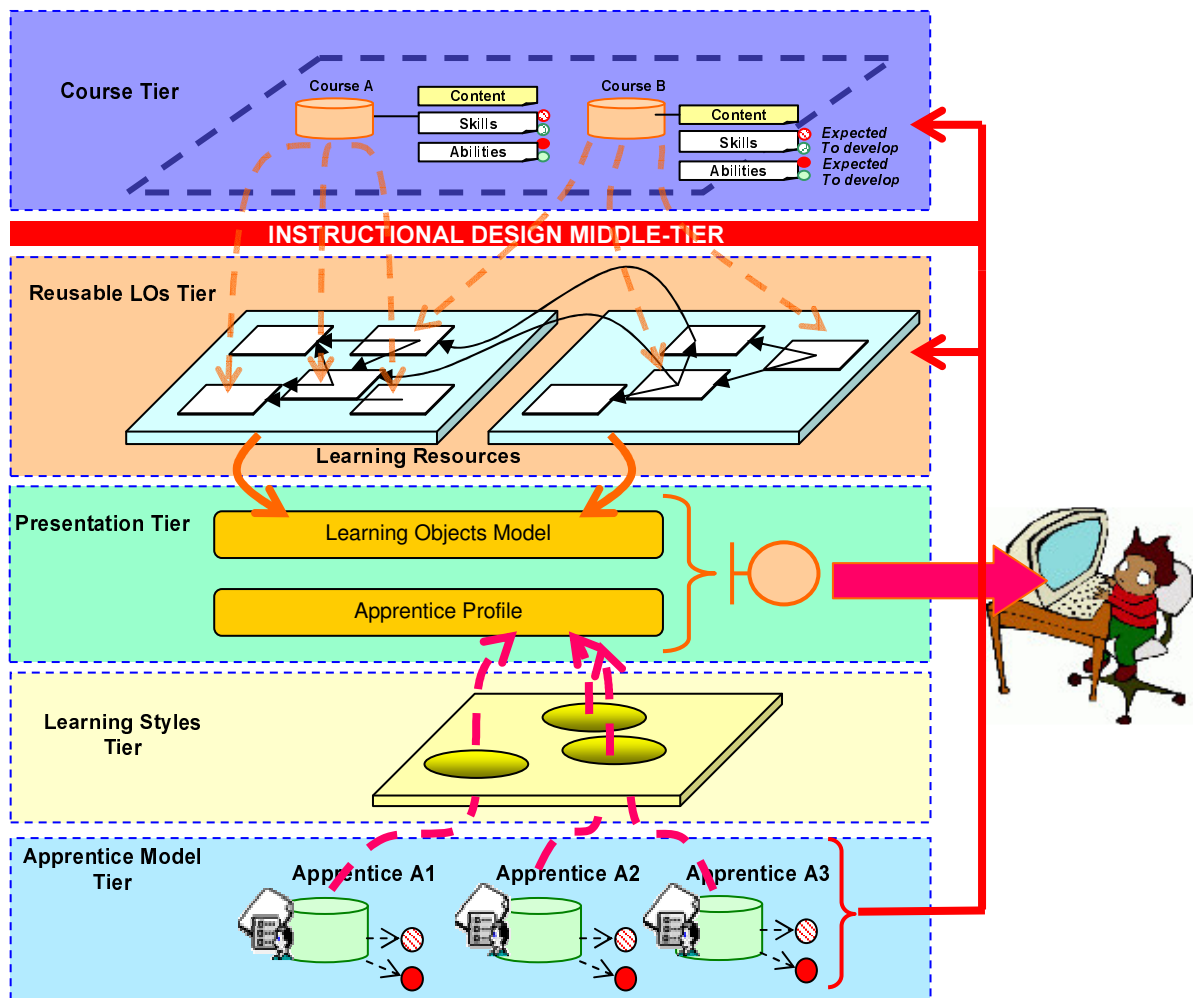


Figure 2 – Inner structure of a repository of fully-adaptive learning objects (Silveira et al., 2004)

The guarantee of reusability allows that a learning object – being granular enough, according to the use – could be used in different contexts. A learning objects repository with a well-defined inner structure and indexing and/or metadata strategy could be used to customize learning process according to learner's needs. LO granularity refers to the degree of detail or precision contained in a LO, as well as its size, decomposability and potential of reuse. Granularity can have several different dimensions, including time granularity and space. For some domains, it can be established the maximum degree of granularity of information in order to represent an atomic LO.

When dealing with learning objects reuse, a very important factor to be considered is related to the short-term effort that must be done in order to promote reusability beginning from some *ad hoc* reusability model, since more time and resources will be required to design, develop and assure the quality of LOs that are being to be reused. On the other hand, this effort is surely paid in a long-term basis by an increasingly rapid ability of developing high quality learning resources with decreasing maintenance effort.

Figure 3 shows an inner view of different granularity levels for LOs inside a repository.

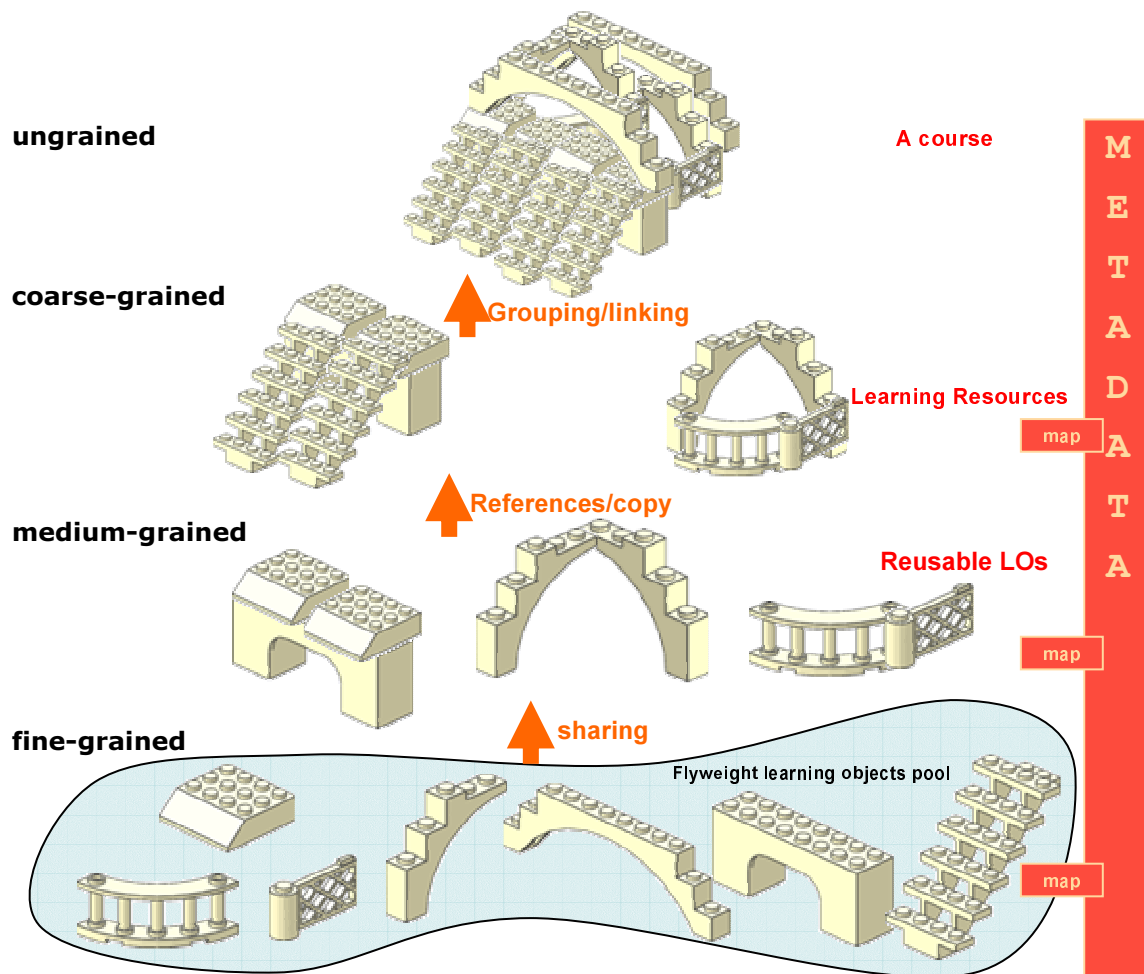


Figure 3 – Putting pieces together: different granularity levels for learning objects into a repository

The relationship among reusability and granularity of learning objects is straightforward, and it can be applied to a wide range of software reuse. Such relationship can be depicted in a simple but effective equation: the more granular a learning object is, the more reusable it becomes. Figure 4, adapted from Prieto-Díaz (1996), shows this relationship.

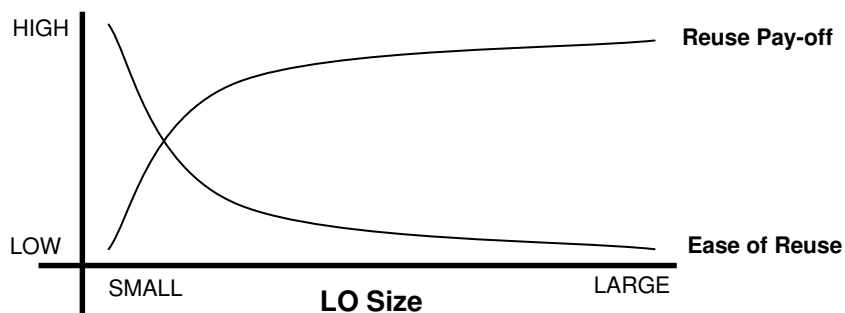


Figure 4 – Reuse versus LO size



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This relationship can be interpreted as follows: by having well-structured, fine-grained LOs, reusability can be achieved, allowing courses' planning and management to be done by combining shared LOs under some Instructional Design strategy.

Finer levels of granularity could be defensible regarding the fact that the smaller a LO is, the more likely it is to be able to be reused in different contexts. But the automation of the reuse process is not directly achieved by relying just on fine granularity.

Collis and Strijker (2003) affirm that "reuse is a personal practice". Gibbons et al. (2003) point out a very important issue on fine granularity and automated reusability: the more reusable a learning object is, the harder its use is to automate. Identically, the less reusable a learning object is, the easier its use is to automate. Nevertheless, if LOs are atomic enough in order to be arranged in different ways to compound a learning resource, adaptive intelligent strategies could be applied, thus allowing students to have different, personal instructional experiences. As a result, fine granularity must be combined with adaptive techniques in order to have all their benefits exposed.

### **3. Some Conclusions**

Learning could not be considered as being a raw process of knowledge gathering, nor could knowledge be labeled as an anamorphic agglomerate of factual information on a specific domain. Knowledge must be considered as something that is built from the interactions among learner and objects that represents learning objectives. From built knowledge, learners are able to develop new skills and abilities, which is the main goal of any teaching-learning process.

Every teaching-learning process must be driven by pedagogical strategies, which will define the way learning objects must be built and presented to learners, in order to properly fulfill learning requirements. So, the collections of learning objects used in any teaching-learning experience are fundamental on defining the bases of such process, since they are just the reflection of pedagogical strategies that were chosen. Here relies the importance of learning objects repositories.

A repository is much more than an aggregate of learning objects. Recent researches in Learning Object have been contributing on the search for standards that lead to the development of instructional elements that would be really adaptive, reusable, generic and scalable, as well as learning environments that would support these learning objects with all these characteristics. Regarding this, generic international standards have been created to guarantee interoperability among learning objects, their repositories and learning environments that make use of them.

Besides providing interoperability through metadata, by customizing repositories contents according to each particular learning experience, the architecture for repositories proposed in this paper would allow learning objects to adapt themselves to learners' historical background and learning styles, according to learning objectives. Thus, knowledge building process is improved, since relevance and significance of learning objects are strengthened inside a wider learning context.

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