AN EVALUATION OF E-LEARNING TECHNOLOGIES AND TRENDS: ESTABLISHING AN OBJECT-ORIENTED APPROACH TO LEARNING OBJECT DESIGN AND DEVELOPMENT

CHRYSOSTOMOS P. CHRYSOSTOMOU, GEORGE A. PAPADOPOULOS
Department of Computer Science
University of Cyprus
P.O. Box 20537, CY-1678
NICOSIA – CYPRUS
chrisc@cs.ucy.ac.cy, george@cs.ucy.ac.cy

Abstract: E-learning is a technology that plays an important role in modern education and training. Its great importance lies in the fact that it makes learning content readily available at any place at any time. Until recently e-learning was usually achieved by providing complete on-line courses. This approach has proven to be inflexible, time consuming and expensive. A solution to these problems is given by the Learning Object (LO) technology. The LOs are small self-contained chunks of learning content that can be stored, searched, retrieved and assembled in order to provide just in time learning. This paper examines and evaluates current work, systems, technologies and trends relating to LOs. The main aim of this paper is to identify the aspects of the LO technology to which further research would be most pertinent and valuable. The paper concludes by identifying the need for a methodology and tools for designing and developing LOs based on the Object-Oriented model for software engineering and finally lays down the route for further work that will lead to the establishment of such a methodology and the implementation of the relevant tools.

Keywords: e-learning, learning object, metadata, instructional design, object-oriented learning objects.

1 Introduction

E-learning is currently implemented in most of the higher education institutions around the world. Some of the most well known e-learning platforms include *BlackBoard*[1] and *WebCT*[2]. Other similar systems exist that are used not only by academic institutions but other industries as well. Their purpose is to facilitate capturing, editing and distribution of knowledge in a well-structured and suitable way. Such systems include: *CourseKeeper*[3], *Multibook*[4], *Atutor*[5] and more. A list of such systems is provided by the IMS Global Learning Consortium Inc. [1], an organisation that deals with specifications for interoperable learning technologies. More systems can also be found through the e-learning centre (http://www.e-learningcentre.co.uk).

Up until recently most of the e-learning systems tended to facilitate the distribution of structured on-line courses [3,19,25,26]. Quite often this distribution was achieved by supplying links to courses through web portals. *"The instructional content and the structure of these courses don't provide the learning experience suited to each student individually. It is difficult for many students to follow a long continuous course that doesn't allow him [sic] to find the exact chunk of material he wants in order to solve a specific problem"* [3]. In order to counteract these problems, the technology of *Learning Objects* (LOs) has been developed.

The term *'learning object'* was originally coined by Wayne Hodgins in 1994. The definition of a LO is still rather vague, as different organisations view LOs differently in terms of "size, terminology and focus" [4,5]. The Institute of Electrical and Electronic Engineers (IEEE), for example, defines a learning object as: *"…any entity, digital or non-digital, which can be used, reused or referenced during technology-supported learning"* [2].

According to Longmire [26] *"the object approach can satisfy both immediate learning needs…and current and future learning needs that are not course-based"*. Longmire also mentions a number of arguments supporting the creation of content as LOs, including: Flexibility, Ease of update, Search and content management, Customization, Interoperability and more.

Apparently LOs, are commonly accepted as the technology dominating current and future e-learning developments. A closer examination of contemporary research and development reveals that there are a variety of technologies and trends that are often linked to LOs and they form the main pool of research efforts in the area of e-learning.

In section two e-learning related technologies and trends are briefly discussed and their potential as

[1] http://www.blackboard.com
[2] http://www.webct.com
[3] http://www.coursekeeper.com
[4] http://www.multibook.de
[5] http://www.atutor.ca

research subjects is evaluated, leading to the identification of the need of a LO design methodology. Section three looks into the application of Object-Oriented (OO) techniques for the design and development of LOs, as this has been shaped through the work that has been done in this area in the last few years and a methodology for OO LO design is being proposed. The paper will conclude by outlining the work that will follow in order to fully implement and support the proposed methodology.

2 E-learning technologies and trends

2.1 An outline of the technologies

In this section the major technologies that relate to e-learning are being described. The purpose of these descriptions is to provide a basic understanding of each technology and demonstrate its contribution to the advancement of e-learning.

2.1.1 Learning Objects

IEEE defines a LO *as "any entity, digital or non-digital, which can be used, reused or referenced during technology-supported learning"* [2]. Other definitions have also been provided by organisations and writers, which differ from each other in order to serve the varied purposes towards which LOs are being used. Polsani [5] attempts to evaluate some of those definitions and tries to specify a new definition that incorporates the main characteristics that a LO should have: *re-usability* and *interoperability*. Polsani's definition states: *"A Learning Object is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts"*.

Writers often tend to resemble LOs with LEGO™ blocks [2,3,6,7], which have got the ability to be connected to each other independently of their individual attributes (size, shape, colour etc.), because of their uniformly shaped pins. However, when it comes to LOs *"…not all Learning Blocks can and should be combined together…"* [3]. For this reason each LO is accompanied by a set of data (*metadata*) that provide the necessary information to define the content of each LO, the way that it can be used, its special requirements etc.

Apart from the definition and the structure of a LO, another matter of dispute is the size (or *granularity*) of the LO. The basic idea behind this technology is the use of small chunks of information so that they can flexibly be reused to form learning material. This is very similar to the way that objects are used in Object-Oriented Software Engineering [7,8,9,19,25]. The term Aggregated Learning Object is used to refer to different levels of granularity. A good example of the granularity levels of learning content is the model used by AutoDesk (Fig. 1).

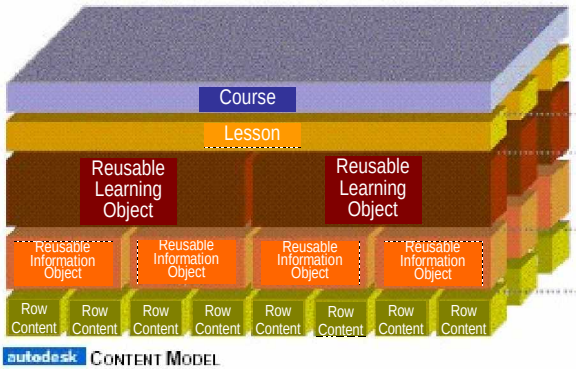

Fig. 1: The AutoDesk LO granularity levels (from [9]).

Finally according to Longmire [26] the ideal reusable LO should have the following attributes:

- Modular, free-standing and transportable among applications and environments;
- Non sequential;
- Have a single learning objective;
- Accessible to broad audiences;
- Coherent and unitary within a predetermined schema so that a limited number of meta-tags can capture the main idea or essence of the content;
- Not embedded within formatting.

2.1.2 Metadata

One of the most important attributes of a LO is its metadata. Metadata can be defined as *"the means to fully describe and identify every piece of e-Learning content so that you can efficiently find, select, retrieve, combine, use/re-use, and target it for appropriate use"* [9].

According to a MASIE Center report [9] metadata are used in e-Learning for the following purposes:

- *Categorization:* To organize LOs into categories.
- *Taxonomies*: The organization of categories into ordered-groups of relationships (e.g. hierarchical structures)
- *Re-use*: The reusability of learning content increases as the content becomes smaller and its metadata more structured.
- *Dynamic assemblies*: The metadata can be used to enable the dynamic assembly of LOs.

The IEEE's LTSC (Learning Technologies Standards Committee) has done extensive work on metadata and has developed the first metadata standard, the IEEE 1484.12.1 Standard for Learning Object Metadata (*LOM*) [10], which defines the metadata that should accompany each LO.

2.1.3 Standards

Standards refer to a set of commonly agreed and accredited specifications according to which

products are built. For example all the electrical devices use a standardised power outlet that can fit on any standard wall plug. This enables consumers to buy electrical products from a variety of suppliers, without having to worry whether they will be compatible with their home's electrical installation. *"Likewise, common standards for things such as, content meta-data, content packaging, content sequencing, question and test interoperability, learner profiles, run-time interaction, etc., are requisite for the success of the knowledge economy and for the future of learning"* [9].

According to the MASIE Center e-Learning consortium [9], the adoption of standards helps to ensure the following e-Learning qualities:

- *Interoperability* – Ability of different systems to work together;
- *Re-usability* – Ability to reuse learning content;
- *Manageability* – Tracking of the appropriate information regarding user and content;
- *Accessibility* – Enabling the learner to access the appropriate content at the appropriate time;
- *Durability* – Enable the e-Learning system to adapt to technological changes and not become obsolete.

A number of organisations have done considerable work in the development of standards for e-Learning. Some of the most important ones include:

- *IEEE LTSC (Learning Technology Standards Committee)* (http://ltsc.ieee.org) - Working towards the development of technical standards, recommended practices and guides.
- *IMS (Instructional Management System) Global Learning Consortium* (http://www.imsproject.org) – A consortium that focuses in developing metadata XML Bindings and Content Packaging for interoperability.
- *AICC (Aviation Industry Computer-based training Committee)* (http://www.aicc.org) - Promoting information, guidelines and standards that result in the cost-effective implementation of e-learning.
- *DCMI (Dublin Core Metadata Initiative)* (http://dublincore.org) - An open forum dedicated to the development of interoperable metadata standards.
- *ADL (Advanced Distributed Learning)* Initiative of the US DoD (Department of Defence) has done some extraordinary work in the area of e-Learning standards, bringing together the work of the earlier mentioned organisations into a common and usable "reference model", now known as SCORM (Sharable Content Object reference Model).

SCORM was first released in January 2000. According to the SCORM overview in the ADL Web Site: *"SCORM defines a Web-based learning 'Content Aggregation Model' and 'Run-time Environment' for LOs…It is built upon the work of the AICC, IMS, IEEE, ARIADNE and others to create one unified 'reference model' of interrelated technical specifications and guidelines designed to meet DoD's high-level requirements for Web-based learning content"* [11].

2.1.4 Wireless delivery and Mobile systems

IEEE refers to the term M-Education *as "a new conceptual paradigm in the use of mobile and wireless technologies for education"*. In the WELCOME project [12], Mobile Education has been defined as *"any service or facility that supplies a learner with general electronic information and educational content that aids in the acquisition of knowledge regardless of location and time"*. The above definitions would embrace devices such as laptop and palmtop computers, PDAs and even mobile phones. From these definitions we can deduce that there are a variety of environments and methods that can be used in the activities of mobile education, (or m-learning as it is more popularly known). Such environments and methods would mainly include:

- PCs, laptops, PDAs and other computer systems linked through a *W-LAN*;
- Laptops, PDAs and other handheld computational devices working *off-line with occasional synchronisation* (off-line mobile systems with synchronization);
- Laptops, PDAs, mobile phones and other handheld computational devices that can offer *wireless connectivity* (on-line mobile systems).

The main advantages and disadvantages for the above methods are summarized in the table below:

Advantages	**Disadvantages**
W-LAN	
Fast connection. A lot of memory. Large screens. Multimedia capabilities.	Limited portability. Special equipment needed (W-LAN cards, transmitters).
Off-line systems with synchronization	
High portability. Synchronization is fast. No or limited special equipment needed.	Information updated occasionally. Small screens. Relatively small memory. Relatively slow processing.
On-line mobile systems	
High portability. Up-to-date information. No or limited special equipment needed.	Usually low connection speeds. Small screens. Relatively small memory. Relatively slow processing.

Table 1: Advantages and disadvantages of mobile systems.

A number of projects are working towards the resolution of the disadvantages of mobile devices in order to provide efficient m-learning. Such projects include:

- MOBILearn (http://www.mobilearn.org/)
- WELCOME [12]
- X-Learn [13]

2.1.5 Web Services

Web-services are *"Web-based applications that dynamically interact with other Web applications using open standards that include XML, UDDI and SOAP"* [14]. Microsoft's .NET and Sun's Sun ONE (J2EE) are the major development platforms that support Web Services. The main aim of Web Services is to *"provide a standard means of communication among different software applications, running on a variety of platforms and/or frameworks"* [15]. A Web Service is essentially made up of two parts:

- A Service, which is an implementation of a software module i.e. a software object such as a java class;
- The Service description in WSDL, which contains the details of the service's interface and implementation e.g. data types, operations, network location etc.

Once a Web Service is developed it has to be registered with a UDDI (Universal Description, Discovery and Integration), which is a technology that publishes the characteristics of Web Services (i.e. the service description), so that they can be found by potential clients. The communication means between the Web Services and the Client Applications is provided by the SOAP (Simple Object Access Protocol), which uses existing protocols such as HTTP and TCP/IP for transportation of the Web Service over the Internet. This framework of technologies and protocols that are used to describe, publish, discover and deliver Web Services over the Internet is known as Web Services Framework or Web Services Protocol Stack [16].

Writers [15] argue that Web Services are capable for implementing an interoperable e-Learning system for three main reasons:

- Information exchanged between e-Learning systems all have XML bindings;
- Web Services are platform and language independent;
- As Web Services can be used through the same model over private intranet or public internet, then the network technology need not affect the e-Learning developer and consumer.

2.2 Evaluation of technologies and trends

In 2.1 the main technologies and trends relating to e-learning have been described. In addition to the above recent reports [17,18] are proposing some more subjects that seem to form some of the most recent trends in the area of e-learning. These include:

- Dynamic assembly of LOs;
- Smart learning objects (automatic metadata update, context sensitivity – semantic web);
- Activity-based learning;
- Peer-to-peer learning;
- Learning Relationship Management systems.

For the purpose of defining a route for further work, the technologies and trends have been examined and evaluated in terms of their applicability towards a set of objectives. Such objectives include:

- Relation with the discipline of Computer Science;
- Relation with e-Learning and LOs;
- The innovation involved;
- The significance of the possible outcomes;
- The feasibility of a possible project in the given area of research;
- Personal research interests.

Following this evaluation and a number of discussions the decision was made to aim the concentration of further work towards a methodology that aims in promoting the genuine reusability and sharing of LOs. As Freisen [21] states: *"It might be argued that if educational objects represent anything truly novel in educational technology, it is that curriculum and teaching resources can be not just reused, but shared and exchanged by a community."* It has been decided that it will be attempted to apply Object Oriented (OO) techniques, to the design and development of LOs. The OO approach was selected because of its successful application in the area of Software Engineering (SWE) and the similarity of LOs with objects of OO Programming (OOP). It is expected that the successful implementation of such a methodology will have a significant impact on the way that LOs are currently designed and developed. The originality and the feasibility of the implementation will be initially assessed through additional literature survey, concentrating on passed approaches to apply OOP theories and methods to the design and development of LOs.

3 Object-oriented LO design and development

In this section the basic concepts and benefits of OO design are outlined to provide the necessary understanding of the theory of object orientation. Arguments are then made to prove the need for

adopting such an approach to LO design, supported by an evolutionary review of the related literature. Finally a brief description of the proposed methodology is given.

3.1 Object Orientation

Software applications were originally written as single files containing sequential code. However, creating and maintaining a large application as a single file of code is quite cumbersome. The need to break these programs down to smaller and more manageable parts aroused. The development of the Object-Oriented Programming (OOP) methods and languages caused a complete paradigm shift, in the area of SWE. The idea behind OOP was to break a program down into small and independent parts. Each part could be developed independently of any other part and then it could be combined with other parts in order to form a larger application. In OOP there are a number of basic constructs and concepts that are used in order to develop an Object-Oriented program. These include:

- *Class:* A small independent program that can be combined with other similar programs in order to provide a larger application. A class is made up of attributes and methods (*encapsulation*);
- *Attribute:* Usually a simple data element that is part of a class. It is usually a variable or a constant;
- *Method*: Small independent part of a class's code. Similar to the notion of a function or a procedure in linear programming;
- *Object*: A class acts only as a template and consequently in order to be used in a program an instance of this class has to be created. This instance is called an object. Any number of objects can be instantiated by a single class;
- *Inheritance*: Ability to create a new class (*subclass*) from an existing class (*superclass*). The subclass will inherit all of the characteristics of the superclass (attributes and methods). The subclass can *extend* the superclass by defining its own attributes and methods;
- *Aggregation***:** The ability to join a number of instances of one class in order to create a new class (e.g. if *square* is a class, then joining 64 instances of this class will give a new class called *chess board*).

The main benefits that OOP has offered to SWE include:

- Less complexity in the development of large applications (consequently faster, easier and cost effective development);
- Easier error detection;
- Easier update of applications;
- Ability to extend software applications;
- The efficient creation of new classes from existing ones (*inheritance*);
- The ability to store and reuse classes whenever they are needed (*reusability*).

3.2 The need for modularization in e-learning

Similarly to SWE, one of the biggest problems of e-learning is the inflexibility of large on-line courses. Such courses are very costly and time consuming to produce, they are difficult to be used by learners (especially when only a limited part of the course is needed), they do not offer any chance for reuse in a context different than the one they have been created for and consequently they are inappropriate for sharing between disciplines and institutions. In addition, statistics [22] show estimates of $50 000 and 1 500 hours for the creation of an on-line university course. LOs are expected to tackle these problems.

The concept of LOs seems to be quite similar to the concept of OOP that has caused such a dramatic change to the ways we develop software. OOP principles are now well established, documented and widely accepted. OO design methodologies (i.e. UML - http://www.uml.org/) have been created to enable the structured analysis and design of OO systems and OO programming languages (i.e. C++, Java) have been developed to enable the development of such systems. The concepts and tools for OOP and design are being used extensively and successfully for a long time now, becoming the de facto standard for the development of all of the applications that logically lend themselves to object orientation. LOs are also widely accepted as a concept that can cause a dramatic change in the field of e-learning. However, LOs are not yet considered to be well established. Sosteric and Hesemeier (2002) for example argue that *"while learning objects may be revolutionary in the long term, in the short term, definitional problems and conceptual confusion undermine our ability to understand and critically evaluate the emerging field"* [4]. They also go on to argue that in the literature there is an inability *to "map the features of OOP programming [sic] objects to learning objects"*. For the sake of this argument it would be useful to examine the work that has been done around the linkage of object orientation and LOs.

3.3 The evolution of the OO LO

One of the first attempts to use OO techniques for the design, development and use of LOs was done by Robby Robson of Oregon State University in 1999. Robson views learning resources as *"objects in an object-oriented model"* [22] that have methods (such as rendering and assessment methods) and properties

(such as content and relationships to other resources) and he declares the aspiration to give the power available for SWE to web authoring and instructional design software.

Through a couple of self-initiated projects (Probability Park [22, 23] and Math 544 [22]), Robson concludes that an object-oriented web authoring tool should allow its user to define and modify LOs using a 'learning object wizard', it should also allow the definition of other objects as properties of a different object and to choose the ways in which objects should be rendered. He finally suggests that an object-oriented approach to instructional design will resolve the problem of interdependence of content with instructional design and will provide extensibility of LOs through the inheritance of properties.

In 1999 a major shift towards the LOs approach was also done by one of the major systems development enterprises – Cisco. Cisco's Reusable Information Object Strategy [20] provides guidelines for designing developing and using Reusable Learning Objects (RLOs). James Erb (Cisco Small Medium Business Center) a year after, identifies the connection between LOs and the objects of OOP:

"Like their counterparts in Object Oriented Programming (OOP), learning objects are designed for combination and reuse" [24].

Another writer that realises the importance of OO SWE for the development of LOs is Stephen Downes. In 2001 Downes [25] also identifies the inefficiencies of on-line courses and proposes to use SWE techniques for the development of LOs, in order to avoid creating all content from scratch every time it is needed and allow for content to be applied to larger audiences. Downes claims that *"The heart -- and essence -- of a learning object economy is the merging of these two concepts, of viewing reusable learning materials as reusable subroutines and applications" [25].* He then concentrates on the method that object-oriented design uses to construct *object prototypes*, referring to the idea of constructing a class (prototype) acting as a template from which objects may be created stressing out the importance of inheritance. Downes also refers to SCORM that describes the object hierarchy in a course, which lends itself nicely to an object-oriented representation. Finally, in terms of development language, the writer considers XML as an appropriate language for implementing object-oriented LOs. XML, according to the writer, can provide an object hierarchy where each object may contain other objects and may be assigned any number of properties.

Later on (2003), Polsani [5], identifies reusability, accompanied by accessibility and interoperability, as the major "functional requirements" of LOs, and he argues that reusability is what accords value to a LO. He also finds a connection between OOP and LOs because, as he argues, *"the functional requirements of LOs are similar to the benefits derived from the object characteristics in object-oriented programming"*. The writer goes on to suggest that LOs should be created with a high level of abstraction, in order to provide independence from usage scenarios and the ability to join other LOs in a variety of contexts. In his conclusions, Polsani suggests as an immediate necessity the "r*eengineering of the design and development process of LOs in a multidisciplinary and cooperative model of development to create knowledge that is appropriate for the emergent network society"*.

In the same year (2003) Mohan and Brooks [7] point out the limitations of LOs, taking into consideration current standardization efforts. As a major limitation, the writers identify the inefficiency of LOs to provide information regarding their relationships with other LOs. Embracing the theories initiated by Robson and Downes, the writers attempt to examine the true nature of LOs and they conclude that: *"From a computer science perspective, there is much to gain by treating learning objects as object-oriented software artifacts. Object-oriented technology can be used to take learning objects out of their current static form and imbue them with behaviours that allow them to contribute more meaningfully to an instructional situation" [7].*

Based on their above deductions, the writers proceed to propose the notion of the *"Object-Oriented Learning Object"* (OOLO), which does not deviate greatly from what Robson proposed in 1999. According to their suggestions, there is a *Learning Object* superclass from which all learning objects are derived. All the learning objects will then:

- Have *properties to metadata* instances;
- Have *properties to other objects* (e.g. version object, context object, combination object etc.);
- Have *methods* (e.g. query methods, version control methods, insertion, deletion etc.);
- Support *aggregation* relationships to allow hierarchies of LOs to be created out of simple LOs;
- *Support inheritance* for producing new LOs out of existing ones;
- Not have '*using' relationships* because they reduce reusability due to coupling between LOs.

The writers also suggest that *"Instructional design Patterns can be formalized and applied to build objects that use proven methods of conveying meaning"* [8]. Finally, Mohan and Brooks express their beliefs on the future of the object-oriented learning object: *"We believe that the object-oriented approach can go a long way towards achieving the vision currently being promoted for learning objects.*

Learning objects with object-oriented features provide a solid foundation for the effective reuse of learning resources on the Web" [7].
Other writers have also suggested object-oriented methodologies that could be applied to the development of LOs. In the International Conference of Advanced Learning Technologies (ICALT) in Athens (http://lttf.ieee.org/icalt2003/ - 2003), Ben Daniel and Honggang Wu from the Department of Computer Science of the University of Saskatchewan (Canada), presented a poster [27] describing an XML based language for the development of LOs (LOML) based on the object-oriented inheritance model. Most writers consider XML to be the most appropriate language for the development of LOs. XMLs suitability for this purpose is based on the flexibility and extensibility of the language. Recently (2004) Downes who earlier (2001) proposed some OO design techniques for LOs [25], is "*returning to the idea of 'object oriented' learning objects"* [19] and an extension of XML the o:XML (object-oriented XML). o:XML (http://www.o-xml.org), is a mark-up language, but it is also an OO programming language that can be used to develop OO XML based LOs.

3.4 OO LO design methodology

From the above examination it has been revealed that in the last few years writers have been examining the possibilities of applying OO techniques to the design and development of LOs. Their work includes theories and ideas of how this could be achieved, however up until now we have no solidly defined method for designing and developing LOs by applying OO techniques. Drawing on the work of Polsani (need for reengineering the design and development process for LOs), Robson and Downes (LOs should be created as classes of OOP with methods and attributes and abilities of object instantiation, inheritance and extensibility), Daniel and Wu (XML language, based on an OO inheritance model) and others, it is deduced that a solid OO design methodology for LOs would have a lot to offer to LO based e-learning.
The methodology should be developed following the model of OO software design that has been proven to work efficiently and added great quality to software design and development. The proposed methodology should use a *superclass* of a LO from which all LOs should be instantiated. Subclasses could exist to add specific functionality to different kinds of LOs (i.e. content_object, assessment_object etc.). Sub-sub-classes could be used for even more specific objects (i.e. types of content_object: text_content_object, animation_content_object etc.). The classes should include all the necessary attributes (metadata) based on SCORM specifications and also methods to enable the appropriate use of the LOs. Additional metadata may need to be added if current specifications do not cover all necessary attributes. An appropriate language (such as XML or o:XML) should be used for the creation of the classes.
Figure 2 demonstrates some example classes as part of a hierarchy based on an OO inheritance model. Each class includes some example attributes and methods.

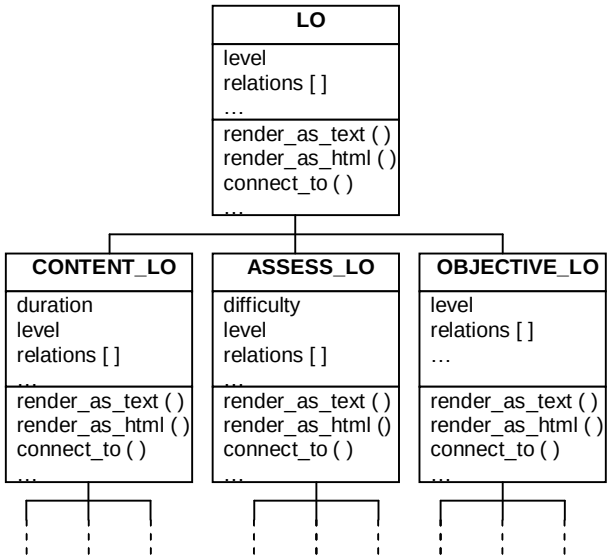

Fig. 2: An example of the hierarchy of LO classes.

4 Conclusions and future work

In this paper we have examined the major technologies, trends and research activities that relate to e-learning and are revolving around the technology of LOs, a technology that is currently playing an important role in the advancement of e-learning. From this examination we have deduced that the area of reusability of LOs is one with great potentials for further research and development. Our research has also shown that there is a need for reengineering the design and development processes for LOs. Further research has shown that OO techniques may be of great use in reengineering these processes with genuine reusability as the main aim. We are then suggesting an OO approach to LO design, borrowing theories from OOP.
This paper constitutes the fundamental idea for the development of the methodology that has been suggested and briefly described earlier. Further work will follow for the detail specification and the development of an OO methodology for LO design and development as well as the creation of relevant tools. Follow up work is expected to include:

- Deeper examination of OO design techniques and LO specifications and standards (e.g. SCORM, LOM, LO structure etc.), aiming in combining the two into

completing the methodology that has been initiated through this paper;

- Research and application of other technologies and theories that may make the methodology more efficient and effective (i.e. design patterns);
- The establishment of a language (probably XML based) to enable the creation of LOs based on the proposed methodology;
- The development of an authoring tool that will enable the creation of LOs by combining the above objectives.

References:

[1] **IMS**. *IMS Global Learning consortium.* http://www.imsglobal.org/direct/getproducts.cfm

[2] **Heng, S.** *Learning Objects-Where next?* http://citeseer.nj.nec.com/556932.html

[3] *Learning Objects – Does Size Matter?* http://www.springerlink.com/

[4] **Sosteric M., Hesemeier S. (2002).** *When is a Learning Object not an Object* http://www.irrodl.org/content/v3.2/soc-hes.html

[5] **Polsani, R. P. (2003).** *Use and Abuse of Reusable Learning Objects.* Journal of Digital Information, Volume 3, Issue 4, Article No. 164, http://jodi.ecs.soton.ac.uk/Articles/v03/i04/Polsani

[6] **Wiley, A. D**. *Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy.* http://www.reusability.org/read/chapters/wiley.doc

[7] **Mohan P., Brooks C. (2003).** *Engineering a Future for Web-Based Learning Objects.* http://www.cs.usask.ca/~cab938/icwe2003_mohan_brooks.pdf

[8] **Mohan P., Brooks C.** *Learning Objects on the Semantic Web.* http://www.cs.usask.ca/~cab938/9

[9] **The MASIE Center e-Learning consortium**. *Making sense of learning Specifications & Standards: A Decision Maker's guide to their Adoption.* The MASIE center. New York. 2002. http://www.masie.com/masie/default.cfm?page=standards

[10] **IEEE LTSC**. *Draft Standard for LOM* http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf

[11] **ADL**. *SCORM Overview.* 2003. http://www.adlnet.org/index.cfm?fuseaction=scrmabt.

[12] **Lehner, Nosekabel, Lehmann.** *Wireless E-Learning and Communication Environment: WELCOME at the University of Regensburg.* http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS//Vol-61/paper2.pdf

[13] **De Meo et. al.** *X-Learn: an XML-Based, Multi-agent System for Supporting "User-Device" Adaptive E-learning.* Springer Verlag, 2003.

[14] **TechWeb Encyclopedia**. *Web Services.* http://www.techweb.com/encyclopedia

[15] **Liu, Saddik, Georganas. (2003)** *An implemementable architecture for an e-learning system.* University of Ottawa. Canada.

[16] **W3C.** *The Web Services Framework.* http://www.w3.org/2002/ws/

[17] **Kelly Blinco, et. al. (2004)** *Trends and Issues in E-learning Infrastructure Development.* DEST (Australia), JISC-CETIS (UK). http://www.educationau.edu.au/papers/Altilab04-Trends-Issues.pdf

[18] **Eklund, Kay, Lynch. (2003)** E-*learning: emerging issues and key trends. A discussion paper Dr John Eklund.* Australian Flexible Learning Framework. http://www.flexiblelearning.net.au/research/2003/elearning250903final.pdf

[19] **Stephen Downes. (2004)** *Object Oriented Learning Object.* http://www.downes.ca/files/1

[20] **CISCO. (1999)** *Cisco Systems Reusable Information Object Strategy* http://www.cisco.com/warp/public/779/ibs/solutions/learning/whitepapers/el_cisco_rio.pdf.

[21] **Friesen, N. (2001)** *What are educational objects?* Interactive Learning Environments, Vol. 9, No. 3, Dec 2001. Online: http://www.careo.org/documents/objects.html

[22] **Robson, R.** *Object-oriented Instructional Design and Web-based Authoring.* The journal of Interactive Learning Research. http://www.eduworks.net/robby/papers/objectoriented.pdf

[23] **Robson, R. (1999).** *Probability Park: A Database-backed On-line Professional Development Environment Targeting Standards-based School Reform* http://www.eduworks.net/robby/papers/probpark.pdf

[24] **Erb, J. 2000.** *Object Oriented Education.* Cisco Small Medium Business Center. http://www.cisco.com/warp/public/779/smbiz/netsolutions/articles/education/

[25] **Downes Stephen. (2001)** *Learning Objects: Resources for Distance Education Worldwide.* International Review of research in Open and Distance Learning. http://www.irrodl.org/content/v2.1/downes.html

[26] **Longmire, W.** *A primer on learning objects.* http://www.learningcircuits.org/2000/mar2000/Longmire.htm