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A Taxonomy for Definitions and Applications of LOs: A Meta-analysis of ICALT papers

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ABSTRACT

This paper presents an analysis of papers delivered at the ICALT 2004 conference, in order to understand the current research issues relating to Learning Objects (LOs). The major research results are summarized, and the papers are classified according to the definition of LO used and the approach taken (technical, pragmatic or pedagogic). The technologies employed, and the features present in the papers, are analyzed.

Keywords

Advanced learning technologies, Learning objects, Taxonomy

Introduction

At the 4th International Conference on Advanced Learning Technology (ICALT 2004) held in Joensuu (Finland) 259 research papers were delivered: 130 full papers, 75 short papers and 54 posters. Many of these papers concern Learning Objects (LOs), either as a central theme, or as part of the research results presented, and an initial inspection of those papers reveals that a variety of definitions are used for an LO, together with many different technical and pedagogic approaches to the *application* of LOs.

One of the reasons for the lack of a clear definition for an LO may be that they are still evolving (Polsani, 2004), and Polsani further suggests that "*we could consider the LOs as a contemporary form of organizing knowledge and information like other historically evolved forms such as mythology, narrative poems, books and others*". Another reason could be found in the IEEE definition of LO: *"Learning Objects are any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology-supported learning."* (IEEE, n.d.). This means that a LO may be a book, a web document, a traditional classroom lesson (events referenced during technology supported learning) as well as a videoconferencing lesson.

This is the starting point of this work, which aims at identifying a taxonomy of all research papers published in ICALT proceedings that focus on the Learning Objects topic, in order to understand how the various definitions of LOs, and approaches to their application, inform research currently underway into the topic.

An initial quantitative analysis, summarised in table 1, reveals that 6 (out of 46) sessions and a total of 26 (10%) papers *explicitly* relate to LOs. However, not all papers concerning the organisation and distribution of learning resources were scheduled in these sessions, and a more selective analysis identifies 33 papers (approximately 14%) that have an explicit reference to LOs in the title and elsewhere in the text. To perform a more detailed analysis of those papers that *implicitly* discuss LOs, we used a larger set of keywords related to LOs, as shown by the conceptual map in figure 1, and this identified 54 papers, approximately one fifth of the total. In addition, the distribution of papers shown in table 1 raised some questions: why is the number of short papers and posters, with implicit references to LOs, greater than the long ones, and why is the situation for the explicit references the opposite? One of the possible answers could be that while the long papers report completed research on a particular topic, and the authors evidence this in the title. The short papers and the posters, however, are work in progress reports, and the details of the material are concealed in the text.

Table 1 The classification of papers

	Long	Short	Poster	Total
Explicit in title	11%	9%	4%	9%
Explicit elsewhere	6%	3%	2%	5%
Implicit	2%	19%	22%	11%
Not related	80%	69%	72%	75%

This quantitative analysis gives us a starting point to understand the e-learning research trend, and qualitative analyses can provide us with more detail.

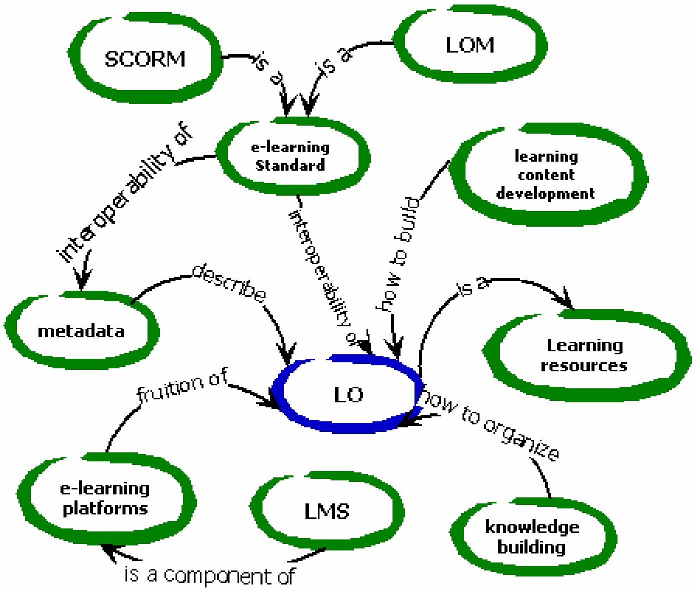

Figure 1. The conceptual map of keywords related to LOs

A focus of much of the research work is the problem of "pedagogic neutrality" of current e-learning standards (Friesen, 2004). A popular solution to this problem seems to be *ontologies*. Many researchers claim that using ontologies to describe both the knowledge domain and metadata is a very powerful method to enhance the pedagogic strength of e-learning environments, and beyond simple enhancement of the description of learning resources, it is also necessary in order to improve the functionality of Learning Management Systems (LMSs).

Other papers propose architectures for building LMSs that could supply more personalised learning paths to the student and at the same time more powerful functionalities to support the teacher in building their own courses. In order to better understand in which direction the research on LOs is going, we analysed the ICALT proceedings to make a classification of all papers related to the LOs. In order to achieve this goal it is necessary to define a taxonomy appropriate for performing a classification.

The Leaning Objects taxonomy

LOs is a topic in e-learning research which involves skills of several professionals, including teachers, computer scientists, pedagogues, and instructional designers and implementers. Thus a good starting point could be the different points of view that the different professional skills have: **pedagogic** (pedagogues), **pragmatic** (teachers and instructional designers) or technical (computer scientists and implementers of instruction).

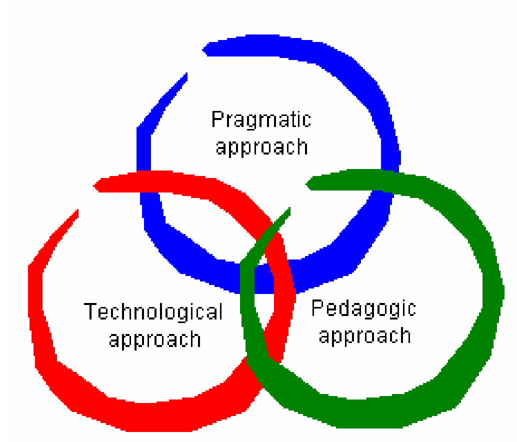

Figure 2: the graphical representation for the taxonomy

Specifically:

- A *pedagogic* approach means that researchers build tools, or supply frameworks, models or languages that enable them to take into account pedagogic aspects of e-learning.
- A *pragmatic* approach means that researchers give solutions to different problems in using LOs and LMSs in a practical way rather than using rules and principles.
- A *technical* approach means that researchers seek and supply solutions for building LOs and learning environments suggesting which technological support is the most suitable for solving a particular problem.

Of course the approaches used are not always clearly classifiable as one of them, rather the solution is often a combination of different viewpoints as shown in figure 2 where the intersections are the common points of view.

This kind of taxonomy is useful not only to classify the LO applications, but also to evaluate the evolution of the "LO" term, if other definitions have been supplied, and in which context they can be used.

The evolution of the "Learning Object" term

Most papers that mention LOs use the IEEE definition (IEEE, n.d.) to explain what a LO is, although they often claim that this definition is rather vague. Most of these works then give more accurate definitions, which typically add that an LO is an entity that should be *accessible*, *reusable* and *interoperable*.

An interesting definition, which derives from a *pragmatic* point of view, is where the LO is conceived as a **medium for enabling the dialogue between abstraction and application (**Klobas et al., 2004). This definition emerges from a study about the pedagogic approach for teaching in engineering and business. From a pedagogic point of view the problem of teaching in engineering and business requires two different approaches: the first emphasizes the abstraction which can be applied in many different situations, while the second emphasizes problem solving in specific situations. The authors' goal is to build LOs that simulate the operation of networks with a very high degree of accuracy.

The computer scientists' point of view is very interesting too. Von Breven discusses how it is possible to define new types of LO, that he calls eLOs, using the OO paradigm (von Breven, 2004). The starting point of his research is that *"awareness of the context is crucial to design e-learning artifacts, since information required to complete a task can be dynamically inferred from its environment"*. In this case, LOs become objects that include not only the didactic content of an e-learning course, but also information about the context in which they will be used. Therefore, the notion of *subject domain* of a system becomes very important, and is defined by the author as *"the union of the subject domains of all messages that cross its external interface. To find out what the subject domain of a system is, it is necessary to identify which the entities, the events and the messages sent and received by the system are"*. As result of analysis of an e-learning environment von Breven has defined 3 types of eLO: Structural (SeLOs), Conceptual (CeLOs) and Granular (GeLOs). SeLOs contain messages and events about the structure of a CBL course; CeLOs are objects responsible for course adaptability, interoperability and reusability; and GeLOs contain messages and events that mainly talk about congregating granular or atomic database entities (e.g. video, text, or audio).

Software engineering methods can be used to define a formal model to describe not only the design and the implementation of educational systems but also the design of LOs. Frosch-Wilke defines a LO as *"a package of correlated objects"*, and using an OO language, such as UML, describes a model with respect to the LOM standard (Frosch-Wilke, 2004). This information model can easily be extended by using methods that can be implemented as functions of a learning system.

In order to integrate ontology and Semantic Web technologies into e-learning environments it is necessary to represent LO metadata in ontological databases, and Sicilia *et al.* define LOs as *"information bearing things that contain digitally coded information readable by a computer"* (Sicilia et al., 2004). In this case, the LOs are seen as purely digital entities. Mapping between the LO metadata model and their ontological knowledge base has been easy, even if some LOM elements require the definition of additional elements.

Applications for Learning Objects

A similar discussion could be made for the applications of LOs. It is interesting to classify the large number of applications of LOs according to this taxonomy to identify current research trends. In order to find out this kind of information, we compare the different approaches (technological, pedagogic and pragmatic) used to solve common problems.

Building LOs and LO repositories

The growing interest in LO topics has caused researchers to build repositories of LOs, each with a specific goal. An example is PILO (Practitioner Inquiry Learning Object) that collects multimedia web-based resources for teachers (Nichols, 2004). The goal of this repository is to supply a database (*technological approach*) in which school teachers and researchers can find learning material for training themselves in conducting classroom inquiry. A larger project is CeLeBraTe (Context e-Learning with Broadband Technologies) that aims at supplying support for a European Learning Network (ELN) of virtual learning environments in which it is possible to store and to share learning resources (van Assche and Massart, 2004). The idea is that all ELN members can store metadata in a central repository, or in a local one, and a federated searching system will allow retrieval of information that matches the searching criteria. However, since teachers and students usually have some difficulty in interpreting results of a simple text-based search, the authors propose to use the LOM standard in order to guide the searching activities and explain how it is used in their federated search engine. A more effective solution could be to define a model for producing effective LOs in order to help the searching engines to be more productive (Griffiths et al., 2004). The paper goes in this direction (*pedagogic approach*) and uses two frameworks, the Cisco's model and the UDRIPS ones, in order to create LOs from existing course material. This work tries to join the two frameworks in order to produce a pedagogically sound model for creating supportive educational materials. On the other hand, Kazi supplies his own framework to develop reusable content SCORM-compliant (Kazi, 2004). The starting technical points are the common aspects between an Intelligent Tutoring System (ITS) and a Web-based Intelligent Learning Environment (WILE).

Rokou and Rokos supply a more pragmatic and pedagogic strategy for building LOs, and identify one of the major problems as being LO granularity, a topic in which not many researchers are interested (Rokou and Rokos, 2004). The paper supplies an interesting LO granularity classification based on their educational content: micro levels, content independent of context; combined information objects, content with minimal added context; and frameworks representing macro level scaffolding, content contextualized by the implementation of specific instructional approaches. This type of classification is useful for tools that aim at automatic definition of learning paths.

Evaluation of Learning Objects

In order to build good quality LOs, it is necessary to know how we could evaluate their quality and which factors we should consider to decide the quality of an LO. One pedagogic and technical solution to this problem has been given where a model is proposed for evaluating LOs that considers four factors: content design, the design of the delivery system, the presentation interface and the learning outcomes (Daniel and Mohan, 2004). The authors claim that in order to evaluate LOs all aspects related to their “electronic” nature and their “educational” ones should be taken into consideration. The same approach has been used by Pitkänen and Silander, who take classic usability models as starting points (Pitkänen and Silander, 2004). In this case, the authors propose criteria for evaluating the pedagogic reusability of LOs in terms of content, pedagogic and technical features. Therefore, in their point of view for building LOs all these three features that should guarantee the maximum degree of reusability should be taken into consideration. A more pedagogic approach uses a mathematical model for evaluating e-learning contents built by using LOM specifications (Ueno, 2004). The content analysis method is based on two factors: the complexity of the content and the ease of understanding.

Reusability of LOs

One of the major problems in reusing learning materials is that details are not always given concerning the learning scenario in which a particular didactic content has been used. Busetti et al. supply a pragmatic solution in which teachers’ experiences can be embedded in LOs (Busetti et al., 2004). Unfortunately, the authors do not supply details on the implementation. A more technical solution involving Web Services can be used to provide an intelligent means for dynamically re-purposing reusable LOs for new instructional scenarios, in which the Learning Content Management System (LCMS) is able to interact with a content package and to make more timely decisions allowing the adaptation of learning content to the different learning scenarios (Fraser and Mohan, 2004).

Liao and Yang propose a workflow framework to compose pervasive LOs as another technical solution for building reusable e-learning material using LOs (Liao and Yang, 2004). The description is made using the Grid Services Flow Language (GSFL), and the idea is that several LO services collaborate using GSCL and share information about their content.

A more pedagogic solution is supplied by the Sridharan et al. (2004), who stress that, to enhance the effectiveness of the learning environment, it is necessary not only to facilitate access to the relevant knowledge, as proposed in the previous works, but also to provide access to semantic interrelationships between the knowledge chunks and the contextual information for each of them. Ontology plays a pivotal role, because it can facilitate the creation of both, but current knowledge management frameworks do not support its integration in learning environment. Their research, therefore, aims at defining a new framework (including an architecture for implementation) where the processes required for managing the knowledge are classified as follows: knowledge creation, knowledge extraction, knowledge classification, knowledge retrieval and knowledge sharing and reuse.

The solution adopted by Bouzeghoub et al. (2004) is between the pedagogic and the technical approach, and contains an RDF implementation of a description model which allows reuse and assembling of LOs. The model they provide is a 3-level model: the domain level enables representation of the structure of concepts in the knowledge domain, the user model keeps track of learners’ profiles and the LO level describes the content of each LO with respect to the defined domain model. They propose the use of SeRQL language for seeking in the three models the appropriated LO for the learner. A similar approach has been used by Bennacer et al. (2004), who supply a more formal and comprehensive content description of LOs in order to make the metadata less ambiguous. In this case the authors give more attention to the relationships between the learning resources since they are the most relevant for retrieval activities. For this reason the relations are classified as either structural or pedagogic. Using this classification and the OWL Query Language they are able to find relevant answers to queries and to guide a learner in his/her learning process. Doan et al. (2004) use the same solution and give a real example of it. The same problem, ambiguity of metadata, is addressed by Sánchez and Sicilia (2004) in a more technical way using the OO paradigm to improve the meaning of the LOM Relation category. The basic idea of this work is to try to find out the semantic LO relationships and re-write them from a computer science point of view using the OO paradigm and the UML language. Moreover, Simões et al. (2004) argue that the LOM metadata model is not practical for describing course material such as bibliography, FAQ or evaluation rules. The research proposes, using a mixed approach between the pedagogic and the pragmatic, a new category, named Environmental, which enables these kinds of information to be described. Elsewhere, there are proposals to extend the metadata model in order to describe the context (Motelet and Baloian, 2004). A (more technical) solution is the definition of a Media Vocabulary Markup Language (MVML), useful for describing the context of any media resource (Verhaart and Kinshuk, 2004), and a (more pedagogic) approach proposes the integration of IMS LD and LOM specifications, which allows a description of the whole structure of a unit of courseware, from basic LOs to high-level organisation (Motelet and Baloian, 2004).

The proposal of Gašević et al. (2004) aims at improving LO reusability using a mixed approach between the pragmatic and technical. Again, the semantic web seems to be the best means to enable pedagogic agents to be more intelligent. This is possible using two kinds of ontologies: one that describes the LO metadata and the other that describes the LO content. In this way a Web-learning environment could be able to help a teacher to find more appropriate LOs. An author accesses and retrieves available LOs in the repository using the domain ontology. After the appropriate LO is found, it can be incorporated it into the course instructional model (built using the EML language). Moreover, the system could provide a teacher with a tool that allows the teacher to mark the parts of the course found to be interesting for the course and to create a new LO with its own ontology-based content. Yang et al. (2004a) use the same approach, in which the authors present a system for authoring learning material using the domain ontologies and an existing Content Repository Management System. The content creator can select the outline which will guide the search engine to import existing LOs and then can personalise the outline (adding or deleting nodes) and then create their own SCORM content package.

Personalized learning

Another problem in e-learning environments discussed at the conference is the customization of learning paths. Current LMSs are still not adaptive systems, in other words they are not able to supply different didactic content to different types of learners. An interesting solution to this has been proposed from a computer science point of view (Karampiperis and Sampson, 2004). Using ontology, the authors define a methodology to organize the knowledge space in a directed acyclic graph (DAG) and discover the optimum learning path using a shortest path algorithm in a DAG graph. Alternatively, the ontology could be used in combination with multiagent software technologies (Keleberda et al., 2004).

During the process of personalizing learning paths, when we choose which LO to present to the student, it is necessary to be aware that the knowledge quality of a learning process is as important as the time it takes to acquire that knowledge. Then, in order to supply the optimal learning path to a learner, Berri et al. (2004) propose a model of time-dependent learning. Its goal is to optimize the volume of knowledge of interest while satisfying the learners' time constraints (pedagogic and technical approach). The algorithm decides which embedded LOs and links satisfy the content and the time requirements of learning.

A more pedagogic solution uses the IMS LD specification in order to represent the students' curriculum (Rasseneur et al., 2004). The goal is to supply the student with more helpful and appropriated content according to his/her curriculum. The system draws the student's curriculum and the didactic content, using the LD specification, and gives the student the chance to choose their own tasks. In this way the student becomes an actor in their own learning process. A similar solution, but from a more technical point of view, presents a curricula planner and user modeler, based on concept maps, that is fully integrated in a LMS (Giovannella and Selva, 2004). The tool enables the student to define their own curriculum map using a graphical approach. The system, then, examines the curriculum, and if no problem is found it is approved. It could be used by the student, as a starting point to access the content in the LMS, by the system for building the user's model.

Nevertheless, in order to supply personalized learning paths, it could be useful to extend current LMSs fostering the adaptive techniques used by instructors in traditional teaching. A proposed adaptive LMS architecture allows teachers to organize materials and provide presentation strategies of content tailored to their learners (Armani, 2004). The same problem in can be solved by IVA, a pedagogically biased LMS (Laanpere et al., 2004). The conceptual model is based on Jonassen's suggestions concerning the three cornerstones for constructivist learning environments: Context, Construction and Collaboration. In the LMS the interface uses the 3C model that is divided into three sections: Bookshelf (context area), in which teachers store didactic material and all information related; Webtop (construction area), the learner´s personal workbench; and Workshops (collaboration area), in which all discussions take place. An alternative approach is to use the Learning in Process (LIP) methodology as a solution for the problem of contextualization of learning (Schmidt, 2004). Using this methodology a prototype system has been implemented, in which the ontology has been used to enhance the metadata imperfection. The proposed system helps to establish a quality-controlled training process, allows a high LO reuse, and is an easy-to-use tool for building learning material.

Luís et al. claim that the large use of e-learning platforms is producing an effective loss of face-to-face contact between actors' learning process (Luís et al., 2004). In order to improve learning efficiency and overcome the lack of face-to-face contact, the authors provide a 3-level data model for tracking and monitoring students' progress in an e-learning platform. The three levels are the following: data acquisition, data analysis and knowledge generation. This model necessitates the inclusion of a data warehousing system in an e-learning platform that should transform large amounts of useless data in an intelligent monitoring system and, as side effect, it should reduce the lack of face-to-face contact.

Architecture for building Learning Management Systems

As previously mentioned, in order to enhance the e-learning environment we have to consider not only the problem related to LOs and their structure but also the problem of implementing more adaptive LMSs. Some of the ICALT articles focus on this problem and try to define and supply architectures for innovative e-learning-systems. For example an interesting CAI system prototype provides a solution for the problem that SCO usually cannot be presented without an LMS, in which the system functionality is split into server-side and client-side components (Watanabe et al., 2004). The server provides the courseware information to the LMS client and manages the student's score and learning time. The client keeps track of all learner interaction activities and sends the data to the server only when IT is needed, for example when the learner finishes assigned learning tasks. The prototype includes the possibility for the teacher to understand the students' achievement level and which are his/her weak points. The LMS shows to the teacher the SP-chart created from the student's score and learning time. Ronchetti and Saini describe an architecture for supporting knowledge management in an LMS and making e-learning process more effective (Ronchetti and Saini, 2004). The problem is that all current LMSs provide administrative functions in order to manage courses and learning materials in general, but "they would be much better if they had a notion of their content". Therefore an LMS could suggest related material to an author or automatically interconnect the elements that compose different courses. To build a more "intelligent" LMS the authors supply a knowledge architecture, enhanced by semantic metadata, and three tools: a knowledge navigator, an automatic link generator and an automatic metadata generator. In this case, as well other works mentioned above, the ontology has an important role, because it enables navigation through the knowledge domain, classification of the learning materials, the creation of a richer net of hyperlinks, and personalization of the learning paths. Of course, the process is not totally automatic, and some of these activities must be validated by a human.

Another problem in building a distance learning system is that communication tools in LMSs are not usually well integrated into learning activities, in either a pedagogic or technical sense. LO and metadata concepts are used in order to propose two models of forum which could be useful for linking the discussion activities with the learning ones (George, 2004). In other words this solution tries to build a bridge between (constructivist) pedagogy and the technology (how to use an LOM to organize the discussion in order to make it more effective). Wen and Jesshope (2004) highlight a similar problem: students that use an LMS can select some existing learning activities (such us forum, chat, notice board, …) but they are unable to define personal learning activities or change the content of existing ones. The authors describe a schema-driven methodology to design a general LMS in order to drive and control business processes including activities in distance learning.

The large number of proposals for system architectures in this field is in part due to the lack of standards for building e-learning system. In recent years, much effort on the part of e-learning communities has been focused on developing standards for learning resources rather than for e-learning systems. This is the starting point of a discussion as to how different layering strategies could be used to guarantee a high level of reusability and interoperability and a suggestion as to how two of these (responsibility-based and reuse-based) could be applied to e-learning systems (Paris, 2004). The conclusion is that "a reuse-based layering strategy should be a key consideration in the future development of standards for open architectural framework".

Authoring tools for LOs

Vigorous development of e-learning standards make the production of learning resources more difficult than in the past, and for this reason some researchers are building authoring tools that provide support to novice authors of e-learning material. For example, VOSSAT (Visualized Online Simple Sequencing Authoring Tool) is a tool for editing existing SCORM-compliant content packages (Yang et al., 2004b). The basic idea of is to encourage teachers to reuse LOs by choosing one from a repository and giving the sequence specifications.

Building reusable didactic material means that the author should also be able to design and implement metadata. However, even if the metadata contain fundamental information in order to enhance the use, search and re-use of LOs, they are very difficult to write. A technical solution is eMAP, a tool which assists inexperienced educational authors in this task (Chatzinotas and Sampson, 2004). In addition, since there are different metadata specifications, eMAP allows the easy designing of an application profile using one or more educational metadata standards.

Metadata and LO for other technologies

The increasing use of communication technologies in learning and instruction fields has contributed to interest in distance learning. Mobile technology seems to offer new possibilities for improving the effectiveness of distance learning. The problem in this case is: how could we adapt the learning content to mobile devices? A proposed describing a learning content development system for m-learning is based on a framework which divides learning content into five layers using the OO paradigm: material database, primitive content, compound content, learning-flow content and learning unit (Juang et al., 2004). This classification improves the flexibility of the content and facilitates the content adaptation in a mobile device. The paper also describes a system architecture that aims to support the teacher in building content for their "mobile" lessons. Another tool for supporting teacher in this new task starts from the premise that teachers usually prepare lesson plans (Chen, 2004). In particular when they use wireless technology it is important to provide an easy method for building instructional plans. The authors describe an instructional plan metadata and the specifications of an instructional plan package, which contains the metadata and the content material.

Digital TV is a new technology that is spreading quickly in the field of distance learning, and it is necessary for e-learning systems and applications to take advantages of digital TV and e-learning experiences. This is the technical approach of Frantzi et al. (2004), in which the TV-anytime and SCORM specifications are compared. The correspondence between single video segments and SCO is obvious, in both cases they are the lowest level of granularity, and they could be restructured and re-purposed to generate alternative navigation modes. Using this correspondence, the authors have built an application that is able to transform the video segments into SCOs.

Results

This paper proposes a taxonomy for classifying the applications and the definitions of LOs that have been given during the last edition of ICALT, in order to find out in which direction e-learning research may be moving.

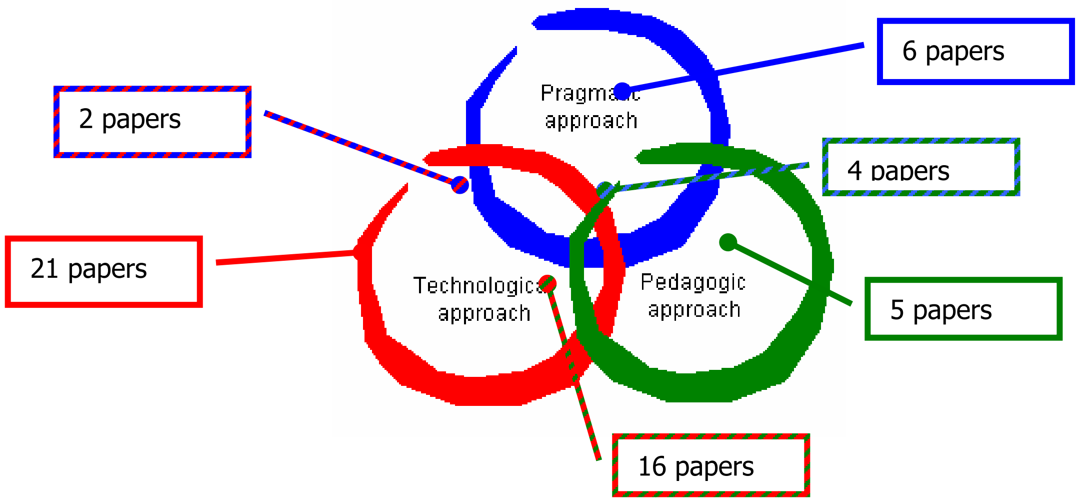

Figure 5: the graphic representation of papers distribution in the taxonomy

As a result of our analysis we can modify the starting figure of our taxonomy (figure 2) according to the number of papers that are situated in each set and in each intersection between them. As we can see, the majority of papers are situated in the red circle (technological approach) and in the intersection between the red and the green circles (technological and pedagogic approaches). This is an expected result since the conference is a computer science conference, and if we analyzed the papers of a pedagogic conference on the LO topic it is likely that we would find the opposite situation. An unexpected result is that there are no papers in the center, which represents the union point of all viewpoints necessary to define an e-learning environment, even though we might expect that taking into consideration all three approaches should be a successful strategy.

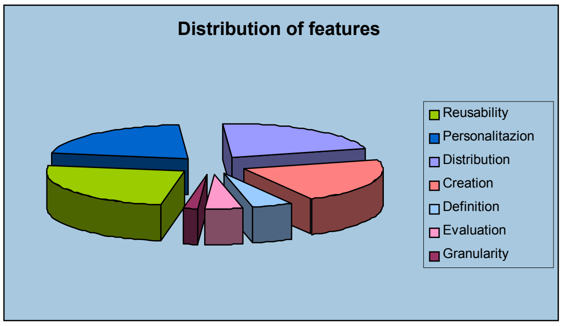

Figure 3: Distribution of features in the papers

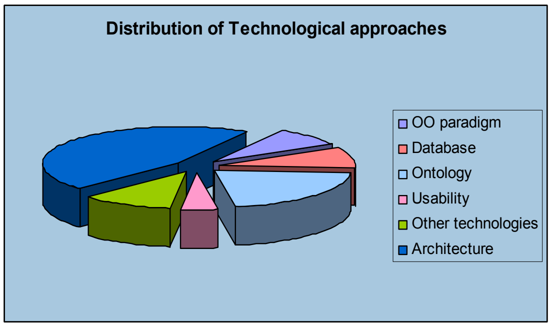

Figure 4: Distribution of technological approaches in the papers

In the context of this taxonomy we can examine closer the distribution of papers classified as technological approaches, and the distribution of features that the papers analyzed take into consideration.

In particular, figure 3 shows the distribution of all papers based on the type of problem or feature they focus on. As we can see, there is a balance between personalization, distribution, creation and reusability of LOs. There is considerable overlap between these four categories, and the most populated are the personalization and the reusability ones, since the other two are closely related to them. These results underline that a current trend is to supply more personalized learning paths and more re-usable didactic materials, in order to reduce the differences between face-to-face and distance learning. Another unexpected result is the poor consideration of LO granularity. Defining how much information a LO should contain is one of the most important problems because, as universally stated, it affects personalization processes as well reusability ones.

On the other hand, figure 4 shows how technical papers are distributed amongst different informatics approaches according to following criteria:

- OO paradigm: papers that describe LOs and applications from a OO point of view
- Database: papers using a database approach to manage LOs and LO repositories
- Ontology: papers using the ontology approach to describe LOs and applications
- Usability: papers using usability guidelines to design LOs and their applications
- Other Technologies: papers using other technology (for example, the GRID system) to design and implement LOs and applications
- Architecture: papers giving details about system architecture or framework to support system development

The majority of papers are focused on proposals for architectures, and in this category papers describe not only LMS architectures but also frameworks useful for designing more powerful LMSs and e-learning tools, such as LO and metadata authoring tools.

One of the findings of this analysis is that the pedagogic neutrality of current standards is a common problem, and this has been approached using ontology and the semantic web (the second biggest category in figure 3). Even though different authors have used different approaches (technical, pragmatic or pedagogic), they all agree that ontology could fill this gap, since it enables not only the representation of the organization of knowledge items in a particular domain, but also the semantic relations between the items themselves. This kind of knowledge representation is useful to allow an LMS to retrieve the best LO for a particular learner and therefore make the LMS a more adaptive system. An unexpected result is the low number of papers that address the adaptation of database techniques to the LO field.

Conclusion

Much recent research in educational technology research area has been focusing on LOs, a topic where different professional skills are involved, including those of teachers, computer scientists, pedagogues, designers and implementers of instruction. Thus a good starting point could be the different point of view that the different professional skills have: pedagogic (pedagogues), pragmatic (teachers and designers of instruction) or technical (computer scientists and implementers of instruction). Following this analysis we can conclude that there is not a solution better than the others, because each one considers a particular aspect of the complex domain of e-learning environments.

Future work will include analyses of other conference and journal papers, in order to better understand the trend of research on this topic, together with the development of a formal method suitable for paper classification in this taxonomy as a tool for automating the process.

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