UDC 371.64/69

The collaborative development of didactic materials

Carmen Padrón[1], Juanma Dodero[1], Paloma Díaz[1] and Ignacio Aedo[2]

DEI Laboratory. Computer Science Department.
Universidad Carlos III de Madrid, Spain.
[1]{clpadron, jmdodero,pdp}@inf.uc3m.es, [2] aedo@ia.inf.uc3m.es

Abstract: In this paper we present an analysis of the development process of technology-supported didactic material. Such analysis considers didactic materials as the conjunction of contents and instructional design used to guide learning and teaching processes. And we examine why several features such as reusability, semantic interoperability and collaboration support must be ensured from the earlier stages of the material creation process. For those reasons didactic material development is not a trivial task and demands of a development methodology support and a high-quality authoring environment. We describe how the MD2 research project provides an integrated solution for creation of didactic materials that take into account those rationales. The MD2 solution is based on two approaches: first, the definition of a method for the collaborative creation of didactic materials and second, the elaboration of a quality evaluation framework for a priori testing of educational products. We also present CASLO a collaborative authoring tool used to facilitate these endeavors.

1. Introduction

The educational process consists of a set of teaching and learning processes and materials with the goals of acquiring some knowledge or training. There are four important aspects to take into consideration when analysing the educational process. Those aspects are: the actors of the process, their objectives, the didactic or instructional materials, and the administrative and support infrastructure [28].

Actors can be differentiated in two categories: learners (i.e. students or apprentices) and pedagogical or academic staff (i.e. instructors, tutors, pedagogical advisors, etc.). Their objectives are complementary: learners' objectives are related to the achievement of some knowledge, competences or skills, following the guidelines defined for the lesson or course in which they are enrolled. Meanwhile, academic staff is devoted to compose didactic materials, manage their contents, and establish pedagogical mechanisms to guide learners through the learning process.

Didactic materials are any kind of aid that assist those actors to achieve their objectives during the entire learning process [28]. There are two types of didactic materials according to the actors of the educational process: teaching materials and learning materials. Learning materials are those assets or resources that support learners during the process of learning (e.g., books, games, worksheets, etc.). On the other hand, teaching materials provide academic staff with resources to guide and support the learning process of students.

The administrative and support infrastructure for the educational process comprises all those services related to management of the learning process. In the case of students, some of those services are course offerings, admissions, enrollment, lesson schedules, tests and examinations, examination results, etc. For academic staff those services are mainly related to organization of courses, their structure, schedule and timing according to selected curriculum or educational program, among others.

The rapid development and deployment of Information and Communication Technologies (ICT) advances have strong influences in all areas of modern society. Education is not an exception. New technologies provide the means to integrate teaching and learning into every facet of each person's life, they promote life-long education and increase the globalisation of education [21]. ICT advances provide the educational process with communication tools that help to overcome issues related to the geographical localisation of its participants and the synchronization of their activities [28]. The introduction of ICT advances in education has been named with the term e-Learning. e-Learning is defined as any learning, training or education that is facilitated by the use of well-known and proven computer technologies, especially Internet and network-related technology [18].

Thanks to e-Learning an important evolutionary step has been taken in the educational area with the digitizing of traditional didactic materials. Digitizing improves learning materials communication and presentation capabilities since contents can be represented with demonstrations, simulations and animations using interactive and multimedia techniques [28]. Thus, learners' comprehension of represented information (or knowledge) is also improved. Other advantages of e-Learning worthy to be mentioned are the enhancement of flexibility in the use of didactic materials and their accessibility, their support for diverse pedagogical methodologies, the optimisation of resources, the improvement of learners' individual work, the enrichment of their relations with the academic staff, and the improvement of other learners' attitudes such as responsibility and collaborative work will [46].

But e-Learning is not simply a matter of digitizing traditional materials, it also involves new approaches that must take into account pedagogical, technological and organizational features to form a well-designed educational process [27]. For that reason, we analyse and propose some solutions to the development of technology supported didactic material in this paper. The paper is structured as follows: In section 2, we make a brief analysis of different variants of technology-supported didactic materials, stressing their added values to the learning and teaching process. We also present a description of the technological context, which includes the different perspectives to be considered in the development and deployment of any technology-supported educational process, the technological disciplines involved on each perspective and the role of technical standards and specifications. In Section 3 relevant research approaches to the collaborative creation of didactic materials are analysed according to the previous elements. In section 4, we present a solution for collaborative creation of didactic materials that is based on the experiences from the MD2 project. A description of CASLO, a support tool for the creation method, is presented in Section 5. And finally, some conclusions and future works are outlined in Section 6.

2. Learning technology-supported materials: contents and processes

First efforts to integrate ICT in the educational process had as result the development of a number of didactic materials with different degrees of instructional value and development costs. Generally the instructional value and the cost of development of didactic materials are directly proportionate [5].

The instructional value and development cost of learning materials have evolved during last years. A simple example of technology-supported didactic material is the web page of a course. In this case the instructional value is low, since teachers use the web page as a simple and unidirectional communication mechanism to let students know information about the course. The cost of development of a course web page has decreased thanks to the great availability of hypermedia and web authoring tools.

Nevertheless, when a website for didactic materials of various and related subjects is built up, the development cost is increased. Because it is necessary to collect, compose and maintain the appropriate conceptual and navigational relations among the elements contained in those web pages. The instructional value is also increased with respect to a simple web page because learners are provided with related resources that help them to enhance their mental associations used to store and retrieve information between new concepts being learnt and the knowledge they already have [15].

The following step in complexity and development cost is achieved when communication tools like forums, email, chat systems or videoconferences are also introduced. From the instructional point of view, those tools improve the communication with the teachers and between learning peers as well.

A step further is taken with the use of interactive activities and simulations that illustrate and facilitate the comprehension of the most important concepts involved in a course. A greater instructional value is present in those didactic materials that smoothly integrate all aforementioned resources. For those cases the development cost is also increased if that integration intends to be scalable, robust, secure, usable and compliant with interoperability standards.

But we think that digitalizing materials is not enough since didactic materials are more than contents, they also include an instructional design that guides the teaching and learning process. That is why if we want to analyse how ICT advances have influenced the way didactic materials are developed and deployed, we need to detail the set of perspectives, technological disciplines and specifications that are involved in the development and deployment of didactic materials. All those facts form what we call the context of technology-supported materials that is represented in Figure 1.

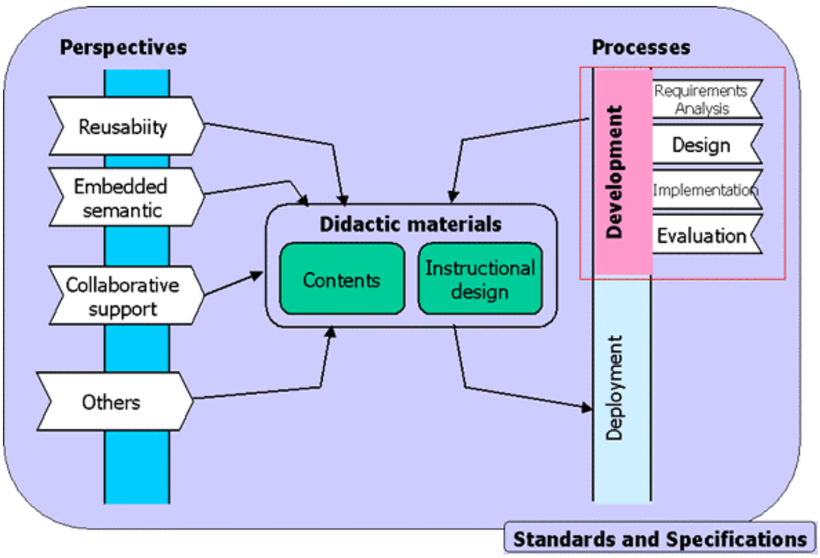

Fig. 1. The context of technology supported didactic materials

The context of technology-supported didactic materials is an analysis framework that considers technology-supported didactic materials as the conjunction of contents and learning/teaching processes ruled by an instructional design.

The educational process can be seen as two-part process: development and deployment. The first one is related to the analysis of educational requirements, design and planning, implementation and configuration, and a priori evaluation of all activities and resources that will be used by actors during the deployment of the educational process. Didactic materials are directly involved in both processes. They are resulting products from the development process and they are used as supporting and guiding resources during the deployment of teaching and learning activities. In this paper we focus on the analysis of didactic material development process according to the set of perspectives depicted in Figure 1.

2.1. Perspectives on the development of didactic materials

There is a number of perspectives needed to take into consideration when we are concerned with the development or creation of didactic materials. Those views ensure desirable features of didactic materials for the deployment of any educational process. We can summarize them in the following features:

- Reusability
- Embedded or associated semantic character
- Collaboration support
- And others such as quality and usability.

We detailedly explain each one of these perspectives in the following subsections.

Reusability and the semantic interoperability

The reusability character of didactic materials is based on their capability to be used in different learning situations or in diverse knowledge domains. The reusability and the embedded or associated semantic character are closely related features. Reusability can be achieved if didactic materials have embedded or associated some kind of semantic information. It means that designers and developers of didactic materials should include semantic information related to the use, format, learning objectives, learning audience, knowledge domain, among others within the design of such materials. Thus, other designers or developers with similar needs can retrieve and compare that semantic information with their current requirements in order to decide if they reuse that didactic material.

Reusability can be achieved thanks to use of common vocabularies that describe the learning materials, such as metadata and Ontologies, tools to perform annotations, and the technological infrastructure used to store and retrieve materials. Repositories and search engines are those infrastructures that allow the storage, management and retrieval of didactic materials based on their metadata annotation. There are available different types of repositories: centralized vs. distributed, with use free of charge or by subscriptions payment. Some examples of repositories are Merlot [40], Careo [8] or LionShare [31].

On the other hand, the IEEE Learning Object Metadata (LOM) specifications [32] provide developers with a set of metadata, which are classified in several categories (i.e. General, Lifecycle, Rights, Relation, Technical, Educational, and Classification). Those categories help to describe different features of any didactic material, allowing their sharing, management, exchange, selection and localization, in such a way they can be reused in different learning contexts or knowledge domains.

Though metadata can provide such descriptive information, they are not enough to obtain the desired semantic interoperable to achieve reusability. It is also required to annotate didactic materials. Actually, the annotation task is tough and often considered as optional during the development. Thus, didactic materials usually are poorly annotated or lack of annotations at all. For that reason, a way is needed to automatically or semi-automatically carry out annotations during the development and to achieve an appropriate semantic interpretation of metadata. Fortunately, Ontologies and software applications such as agents and Web services can be used to solve those matters.

Ontologies afford means to represent a portion of our mental model about a specific domain [13] in a computer-usable and machine-understandable way (e.g. software agents, sophisticated search engines or web services) that facilitates the automated processing of elements from that domain. Thus, software agents or web services can use Ontologies with the aim of make feasible and easier the semantic annotation during the development of didactic materials.

Ontologies in Education

Ontologies define formal and real-world semantics for information, in order to make it machine-suitable for processing content with meaning [19]. They also provide a correlation between the information model and the real world domain they represent, supplying a vocabulary (i.e. a language of types and terms that has a corresponding formal semantics) and allowing to express the entities and relationships of a conceptual model for a general or particular domain.

The research on educational ontologies is not scarce. Outstanding examples are Murray's proposal [42] and Mizoguchi's approach [41]. Special mention deserves the proposal of educational ontology made by Leidig [29], which defines a model based on conceptual graphs of didactic concepts, a set of relations, and a number of patterns. Patterns describe typical uses of concepts and relations between them. The ontology also includes rules that define constraints between conceptual graphs and transform didactic knowledge into a navigational plan between didactic materials. Additionally, a taxonomic organization of didactic concepts based on various dimensions is provided.

Educational ontologies provide elements needed to create templates, wizards and consistency-checking tools that help authors during the development of didactic materials [29]. They provide an appropriate semantic interpretation for search engines to localize and retrieve didactic materials from distributed repositories. They also facilitate the automated and configuration of learning processes as long as the conceptual model contains relationships between tasks, competences and knowledge. Ontologies can also provide the common vocabulary needed for a proper communication among participants during the collaborative development of didactic materials.

Collaboration support

Another important perspective to keep in mind during the development of didactic materials is collaboration. If we consider the multidisciplinary character of the didactic material design and the nature and learning requirements of knowledge that is enclosed in any didactic material can change along time, it is unlikely that a single academic or subject specialist can completely generate the whole learning material. Therefore, a group of specialized actors (i.e. content providers or authors, teachers, tutors, media, system and instructional designers, pedagogical advisors and even students) should be involved in the development of didactic materials. These roles provide the development process with diverse ideas and positions on how the materials should be composed and created. Their ideas represent their expert knowledge on different disciplines, and constitute different views of the process (e.g. artistic, instructional, psychological and specific domain-related knowledge). Thus, collaborative support is needed for the development, whereby participants' ideas are exchanged, evaluated, negotiated and as result of such negotiation, didactic material is composed or created.

Other essential aspect for an adequate collaboration support is a common language and semantic interpretation among participants needed for a proper communication that can be provided by Ontologies. There is also need for a coordination mechanism of the different activities, actors and the management of task interdependencies. Finally, it is important to control and trace all the activities involved in the collaboration process.

Other perspectives

There are other features, such as quality and usability, which should be also considered during the development of didactic materials.

According to the overall definition of quality provided by Taguishi [58], the quality of a didactic material can be defined as "the degree in which the characteristics of the material can cover the felt o pre-felt needs of users during a period of time". The quality of didactic materials must be analysed from two points of view: the material as a product itself, and the development process.

From the point of view of the product, to facilitate the measurement of user satisfaction, formal specifications of the user needs, the required attributes of the didactic material and some analytical tools must be provided. From the point of view of the process, we need to analyse the protocols that guide how didactic materials are built, and how these can improve efficiency and reduce costs. Some initiatives that stress on the definition of a quality framework of didactic materials are the Essen Learning Model [48] and the Australian Flexible Learning Framework [33].

On the other hand, the usability of didactic materials is a feature closely related to quality. According to the definition of Rosson and Carroll [52], the usability of the didactic material is based on its capability for: easy use (if there are different ways to exchange information with the target audience); easy learn (if it has a consistent and coherent design to ensure that new users can easily understand how to work with the material), and effective support for users' goals and tasks. Thus, usability evaluations are essential during the development of didactic materials [51], since they assure that didactic materials will effectively support the educational process and the achievement of its goals.

2.2. The role of e-Learning standards and specifications

The perspectives previously described for the development of didactic materials should take into account current learning technology standards and specifications. They provide a common means to make materials interoperable among heterogeneous systems, accessible, and flexible enough to perform composition, integration, management and personalization.

Several organizations and initiatives on learning technology standardization (e.g. IEEE-LTSC [38], IMS-GLC, [25]; ADL, [1]) have provided essential specifications, which can be summarized in the following:

- Learning objects and metadata (e.g. IMS-LRMDI [32]) to classify materials.

- Learning objectives and competences (e.g. IMS-RDCE [26]) to express the required abilities or skills to achieve during the learning process.
- Learner information profiles (e.g. IMS LIP [35]) to exchange learner information between different learning management systems.
- The instruments of evaluation of learning performance (e.g. IMS QTI [17]).
- Interoperability and packaging of content resources (e.g. IMS-CPIM [23]; SCORM [56]) to allow their exchange between different systems
- Integration of learning management systems (IMS Enterprise, IMS Enterprise Services).

On the other hand, the IMS Learning Design Specification (IMSLD [30]) has become an integrative layer to many of those specifications and provides an enhanced level of interoperability. IMS LD defines a way to describe any kind of didactic technique that can be applied to the organizational structure, development and deployment of an educational process. In short, the specification defines a learning design as a description of a method that enables learners to attain certain learning objectives by performing certain learning activities in a certain sequence within the context of a certain learning environment.

Two important definitions are derived from such specifications: learning objects as contents versus units of learning as instructional designs. According to IEEE LTSC [39] a learning object (LO) can be defined as any entity, digital or non-digital, which can be used, re-used, or referenced during technology-supported learning. On the other hand, the concept of unit of learning (UoL) is derived from the IMS LD specification (IMSLD [30]) as the diverse group of prescribed activities based on a given set of contents (in the form of LO) that allow learners to obtain certain learning objectives (acquisition of knowledge, skills, competences and/or attitudes). A unit of learning also includes assessments, services, and support facilities provided by teachers, trainers and other staff members.

Once described the elements and rationales behind the development of didactic materials, we will analyse how these are considered by diverse research and development efforts that are concerned with the collaborative creation of didactic materials.

3. Collaborative development of didactic materials

In this section we will briefly analyse some related work to the collaborative development of didactic material. The analysis is based on the view of didactic materials as the conjunction of learning contents and processes, and according to the perspectives described above.

Some authors provide approaches for developing didactic materials that ensure reusability from the multimedia perspective [4]. They introduce the concept of learning module to represent didactic materials as contents supported by multimedia techniques. Learning modules can be adapted to the goals, tasks, interests and other features of users to support reusability. However, although they clearly outline the development process of reusable learning modules, a development methodology is not provided, and scarce attention is paid to the to the instructional design of didactic materials and to the collaborative aspects of the development.

Other works are focused on the collaborative nature of the creation and define a conceptual model for the collaborative development of software [11]. Such a model resumes and generalizes positive aspects from theoretical models and theories to support collaborative applications [12, 59], but the attention is paid to technological aspects of educational software instead of general and multifold view of didactic materials.

The collaboration support is seamlessly integrated into the development process of the EdukaLibre project [20], which provides a software platform to support the collaborative creation of free educational resources. The collaborative development of educational materials is approached from a novel point of view, i.e. exploring how the common practices of the open source software community can be translated to the educational content domain. The result is a web-based application that provides the common functionalities available in version control systems, but specifically targeted to develop educational documents. The users of the system can choose from a wide set of editing tools, and the system provides automatic conversions to many end-user open formats (e.g. PDF, HTML, OpenOffice, etc.). Nevertheless, the instructional design component is not considered in the approach, since the subject of development are documents and content-based resources.

Other authoring tools work on IMS and SCORM specifications, such as the Reusable E-Learning Object Authoring and Delivery tool (RELOAD [50]). RELOAD is designed for authoring and packaging SCORM sharable content objects [56] and IMS LD learning designs. Although all the units of learning created by the RELOAD tool can be shared on online educational object repositories, collaborative authoring is not intended in RELOAD, and its approach is neither based on any development methodology.

Meanwhile, the Learning Activity Management System (LAMS) [14] represents didactic materials as reusable sequences of learning activities, based on pedagogical templates, which is very similar to IMS LD units of learning concept. Such pedagogical templates can be modified and reused by authors. This is easily achieved by means of a simple drag-and-drop interface, which makes explicit the teaching and learning processes as a series of discrete activities. LAMS includes environments for authoring and adaptation of learning sequences, user administration, student run-time delivery of learning sequences, teacher run-time monitoring of student sequences, and collaborative support tools for learning sequences. LAMS is currently focused on the process and content dimensions for reusing and adapting didactic materials, but it does not provide the development methodology. Future versions are expected to be conformant to IMS LD.

The annotation of learning materials is another relevant task to be considered in the collaborative development process. Some tools like RELOAD provide facilities for annotating learning materials with LOM metadata. Aloha is another similar annotation tool, which is also capable of processing IMS Vocabulary Definition Exchange (IMS VDEX) files [37]. Aloha defines the metadata workflow as the process involved in the creation of a metadata record, which is a first step towards collaboration facilities. Each user only annotates those sections related to her expertise domain, and the whole process is the result of integrating annotations from all users.

Works related to collaborative and semantic annotation are also profuse in other fields, which can be harnessed by the e-learning development tools. For instance, the Annotea project provides an RDF-based editing and browsing collaborative annotation tool of Web resources, called Amaya, developed as a supporting prototype of the W3C Semantic Web specifications [3]. The annotation metadata can be stored either locally or in annotation servers and any client capable of understanding such metadata can use them. Collaboration in Amaya consists in the opportunity to view other users´ annotations on a Web resource.

There are also approaches to support collaborative ontology development. Among them, APECKS [60] is designed for domain experts use to foster and support debate about domain ontologies. It does not enforce consistency or correctness of ontologies, but it allows coexisting different conceptualizations of a shared domain. WebOnto [17] supports argumentations between users on the ontology design. The strength of WebOnto approach lies in the advanced support for communication. Ontosaurus [54] combines support for collaboration, reasoning, and consistency checking. But due to the limitations of HTTP-based applications, users cannot be alerted about simultaneous changes on the ontology. By contrast, OntoEdit [62] is an ontology-engineering environment that combines a development methodology with capabilities for collaboration and a sophisticated concurrency control based on fine-grain locks of the ontology structure.

All the described features of the related works have been taken into account in the MD2 project but viewed from the analysis framework of section 2. The MD2 approach considers didactic materials as the conjunction of contents and learning/teaching processes, on the basis of learning technology specifications, and subject to collaborative development.

4. MD2: Collaborative development of learning material

As we have shown, the development of didactic material is not a trivial task. It requires training the developer, as well as the support of a development methodology and a powerful authoring environment. Authoring environments and tools are key factors for reducing the development cost of learning materials. Such rationales are behind the research project called MD2, which is the Spanish acronym standing for *Development Method of Didactic Materials (and their automation)*. The goal of MD2 is to provide an integrated solution to the creation of learning materials by means of the following approaches:

1. The definition of a method for the collaborative creation of didactic materials that aims ensuring the reusability nature of learning materials, improving efficiency and reducing conflicts and coordination issues. Such a method is the basis for a set of tools that will systematically guide and assist developers during the entire development process.
2. The elaboration of a quality evaluation framework for a priori testing of educational products in several dimensions —i.e. usability, educational utility, interoperability, etc. [53]

The theoretical endeavors of MD2 are tested in practice on a distributed software platform, whose architecture is depicted in Figure 2. The main component is the collaborative development tool, which is divided in several functional modules. The first two modules are related to the edition and annotation of learning contents and designs. The collaboration support is provided by another module, which is based on a distributed collaboration server. Another function of the tool is to provide access to the evaluation framework and facilities, based upon the collaboration server as well. Since such facilities are planned to be used in two phases, the corresponding modules have been included: first, for the quality assessment of materials during the development and before they are completely created; and second, for the analysis of the performance of materials after they have been deployed on a given learning setting.

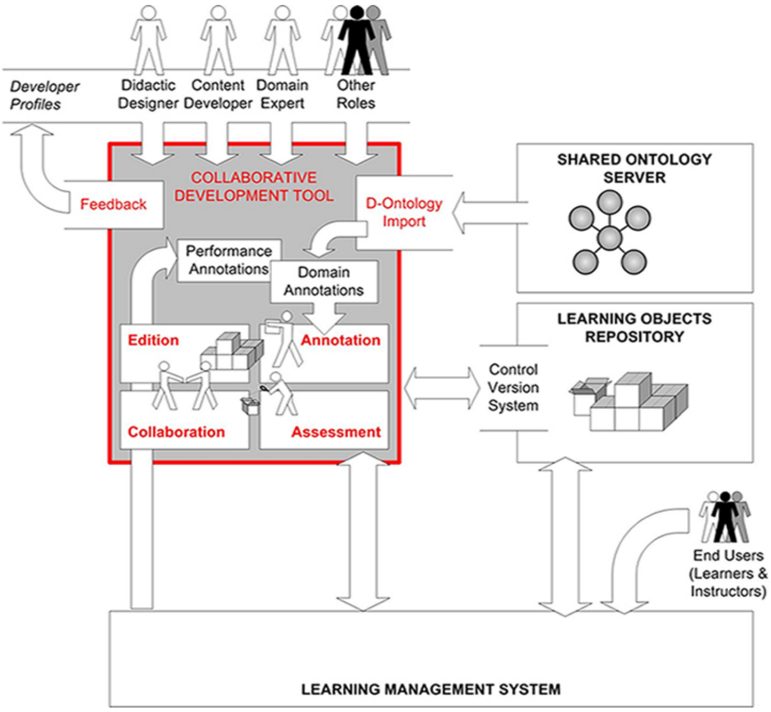

Fig. 2. General architecture of MD2 platform

The rest of the components depicted in the Figure 2 are external subsystems (e.g. learning management system, learning object repository, and shared ontology server) which interact with the main tool through a web services-based architecture [46].

The core of the MD2 environment is the edition and annotation tool that is based on a development method. The development method is supported by the collaborative realization of ontology annotations on learning materials, on the basis of a model-driven instructional design approach. The model-driven instructional design method consists in the composition of the final materials through an iterative process of merging and transforming a number of independent models (i.e. pedagogical, technical, subject-specific domain, and presentation). Such models support elaborated semantic descriptions of the contents, processes, and services that compose the material:

- The technical model describes the compliance with technical standards and specifications, in order to ensure interoperability, technical reusability, and flexibility for composition, indexing and storage capabilities.

- The subject-specific domain model describes the characteristics of the subject or discipline enclosed in the didactic material contents. It considers the material simply as the holder of specific knowledge on the discipline that constitutes the learning target, including features such as completeness, coherence, durability, etc.
- The pedagogical model describes the kind of pedagogical method, the behavioral or constructive features of learning, the cognitive level of learning objectives, the effort required to run the material, etc.
- The presentation model focuses on usability issues, i.e. how well users respond to the presentation of the didactic material, related to time on task, accuracy, recall, and emotional response.

The procedure used to merge models has a desirable order according to the interdependencies exposed by each pair of them. The process should start with the subject-specific domain models, since they are the basis on which the educational process is focused. The following merge can be made either with the technological or the pedagogical model, depending on development constraints or priorities. And the last merge is made with the presentation model, because usability solutions depend on the available technology and the desired pedagogical achievement. Nevertheless, if the usability model has implications on pedagogical issues; some eventual iteration should be performed back.

Within the MD2 project, didactic materials reusability and quality are based on a proper, common consent use of metadata annotations. Although these could be made according to LOM, they would not be expressive enough to represent elements from each one of the previous models. Therefore, we have improved the reusability of didactic materials through the use of more specialized annotations, based on domain ontologies, which must be adapted to the context of learning materials. This is carried out through the domain annotation module of the MD2 platform.

The collaboration module provides the collaboration mechanisms required by other modules during the development of any didactic material. In the MD2 method and tool, any action on editing or annotating some material can be proposed, compared, evaluated, negotiated, and finally carried out automatically into the learning material. As well, the rationales for such actions revert as performance annotations to the learning material, in such a way that they can be taken in consideration for further design situations. For example, if a given lesson is considered as semantically too dense (i.e. includes many complex concepts) and it is split in two parts, that rationale is annotated within the resulting lessons. By that way, another instructional designer can re-construct the original lesson if he considers that semantic density is not an issue for her aims.

Once introduced the main features of the MD2 platform, next we describe CASLO, which is a web service-based server and a client tool for the collaborative annotation of didactic materials. The purpose is to illustrate how web services are used to integrate the different modules of the MD2 project [46].

5. CASLO: Integration of learning web services

The Collaborative Annotation Service for Learning Objects (CASLO) [45] has been developed from previous experiences with CARLOS [44], a multi-agent based collaborative authoring tool. CASLO has been conceived to provide a general-purpose environment for collaborative annotation of XML files. The access to collaborative annotation services is made through a client application, which is used to propose, negotiate, and assess annotations on manifest files that describe didactic materials.

CASLO consists of a back-end collaboration server and a front-end client tool, which are combined to perform annotations on didactic materials as depicted in Figure 3. A web service collaboration gateway links the collaboration provider and the front-end tool. Over this gateway, SOAP [55] messages are exchanged to carry annotation proposals and evaluations between the client and the server. The client knows the collaboration primitives of the server through WSDL-based descriptions [64], which can be readily integrated in the normal operations of the authoring environment. Such descriptions are retrieved from an UDDI repository [43].

Collaboration is provided by pluggable coordination protocols and evaluation strategies, as well as auxiliary services like version control, notifications and tracing. The current implementation uses a two-phase consolidation protocol to control the timing of interactions and which proposals are subject to peer evaluation before being consolidated into the manifest file [16]. Nevertheless, it is easy to replace the collaboration protocol with another implementation if would be required. Once proposals have passed through the collaboration protocol, they are automatically translated in changes to the manifest file along with the resulting rationales from evaluations.

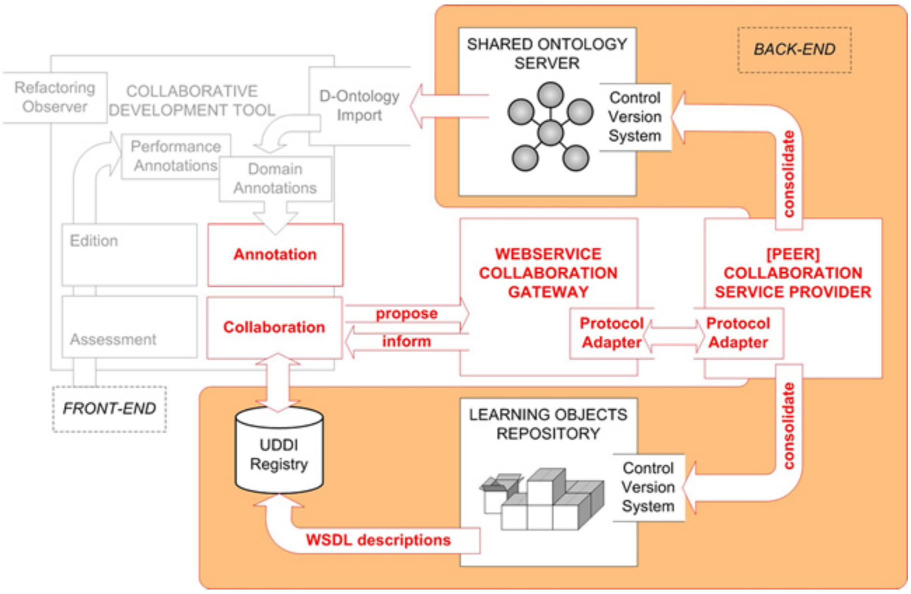

Figure 3. CASLO service-oriented architecture

6. Conclusions and future work

In this work we analyzed the development process of technology-supported didactic materials. Didactic materials are herein considered as the conjunction of contents and instructional design used to guide learning and teaching processes. We describe how several features, such as reusability, semantic interoperability, and collaboration support, must be ensured from the earlier stages of the material creation process. We analyze how these and related issues can be approached by means of ontologies, collaborative work, and web services.

From that analysis we concluded that didactic material development is not a trivial task and requires the support of a development methodology and a high-quality authoring environment. These rationales are considered in the MD2 research project. The method aims for the reusability of didactic materials [49], based on the fact that content creation and the learning design are conceived as different but convergent views of instructional design that require collaboration. The method prescribes that all design rationales must be stored along with the products to be available for instructional designers in similar design situations. Finally, we described CASLO, a collaborative authoring tool used to facilitate these issues.

There is still work to completely achieve MD2 project aims; at the time of this writing we are working in the development of more tools of toolkit based on the collaborative creation method.

7. Acknowledgements

The work described in this paper is supported by MD2 project (TIC2003-03654), which is funded by the Ministry of Science and Technology, Spain. The IEEE Technical Committee on Learning Technologies awarded CASLO as 2004 IEEE TCLT Small Scale Research Project.

References

1. Advanced Distributed Learning Initiative. Available at *http://www.adlnet.org/*.
2. Aloha project. Available at http://aloha2.netera.ca/
3. Annotea Project Available at http://www.w3.org/2001/Annotea/
4. Ateyeh, K.; Mülle, J., Lockemann, P. C. (2000) Modular Development of Multimedia Courseware WISE 2000, Proceedings of First International Conference on Web Information Systems Engineering Volume 2, June 2000, Hong Kong, China.
5. Bersin & Associates (2003) "Blended Learning: what Works?"
6. Bengamin S. Bloom, Bertram B. Mesia, and David R. Krathwohl (1964). Taxonomy of Educational Objectives (two vols: The Affective Domain & The Cognitive Domain). New York. David McKay.
7. Barrows H. (1985)"How to Design a Problem-based Curriculum for Preclinical Years". Springer, New York.
8. CAREO -Campus Alberta Repository for Educational Objects available at *http://careo.ucalgary.ca/*
9. CARLOS Project, available at http://sourceforge.net/projects/carlos/ and *http://caslo.dei.inf.uc3m.es*
10. Cooper J. (1996)"Cooperative Learning and College Teaching Newsletter", Dominguez Hills, California State University, 6(2).
11. De Antonio, A., Villalobos, M. (2003) "An environment for software development based on distributed collaborative model" Proceedings of 5th International Conference on Enterprise Information Systems ICEIS 2003, Angers, France
12. De Farias, C., Ferreira, L, Van Sindern, M, (2000) "A Conceptual Model for the development of CSCW systems". Proceedings of 5th International Conference on the Design of Cooperative Systems COOP´2000 Amsterdam, the Netherlands, 2000 IOS Press, pp 189-204

13. Daconta, M., Obrst, L., Smith, K. (2003). The Semantic Web. A Guide to the Future of XML, Web Services, and Knowledge Management. Wiley Publishing, Inc., Indianapolis, Indiana.
14. Daziel, J .(2003) "Implementing Learning Desing: The Learning Activity Management System (LAMS)" In Proceedings of ASCILITE Conference
15. Díaz P., Catenazzi N., Aedo I (1996) "De la multimedia a la hypermedia". Editorial RA-MA.
16. Dodero, J. M.; Aedo, I.; Díaz, P. (2002) A Multi-agent Architecture and Protocol for Knowledge Production. A Case-study for Participative Development of Learning Objects, In Proc. of the Informing Science 2002 Conference, Cork, Ireland, 2002, pp. 357-370.
17. J. Domingue. (1998) Tadzebao and WebOnto: Discussing, browsing, and editing ontologies on the web. In Proceedings of the 11th Knowledge Acquisition for Knowledge-Based Systems Workshop, April 18th-23rd. Banff, Canada, 1998.
18. Fallon C. and Brown S. (2003) e-Learning Standards: A guide to Purchasing, Developing and Deploying Standards-conformant e-Learning. CRC Press LLC, USA
19. Fensel, D. (2003) Ontologies: A silver bullet for knowledge management and electronic commerce, 2nd edition Springer, 2003.
20. Gonzalez-Barahona, J. M., Tebb, C., Dimitrova, V., Chaparro, D., Romera, T. (2005) Transferring Libre Software Development Practices to the Production of Educational Resources: the EdukaLibre Project
21. Hummel, H., Manderveld, J., Tattersall, C. and Koper, R. (2004) "Educational modelling language and learning design: new opportunities for instructional reusability and personalised learning", Int. J. Learning Technology, Vol. 1, No. 1, pp.111–126.
22. W3C, Web Services Architecture, Working Draft. Retrieved from *http://www.w3.org/TR/ws-arch*.
23. IMS-CPIM (2001). IMS Content Packaging Information Model. Version 1.1.2 final specification, Retrieved from http://www.imsproject.org/content/packaging/cpv1p1p2/imscp_infov1p1p2.html.
24. IMS-CPXB (2001). IMS Content Packaging XML Binding. Version 1.1.2 final specification, Retrieved from http://www.imsproject.org/content/packaging/cpv1p1p2/imscp_bindv1p1p2.html.
25. IMS-GLC (2002). IMS Global Learning Consortium, Inc, *http://www.imsproject.org/aboutims.cfm*.
26. IMS-RDCE (2002). IMS Reusable Definition of Competency or Educational Objective - Information Model Version 1.0 final specification, Retrieved from http://www.imsglobal.org/competencies/rdceov1p0/imsrdceo_infov1p0.html
27. Jochems, W., van Merrienboer, J., Koper, R. (eds) (2004) Integrated e-Learning: implications for pedagogy, technology and organization. Routledge Farmer, London.

28. Koper, R. (2000) From change to renewal Educational technology foundations of electronic learning Environments retrieved from DSpace OUNL site *http://hdl.handle.net/1820/38*
29. Leidig, T. (2001) L3—towards an open learning environment, Journal on Educational Resources in Computing (JERIC) Volume 1, Issue 1es (March 2001), 7 Retrieved in July 2005 from *http://doi.acm.org/10.1145/376697.376702*
30. IMS –LD (2003) IMS Learning Design XML Binding. Version 1.0 - final specification. Retrieved from *http://www.imsglobal/learningdesign/ldvlp0/imsld_binclvlp0.html*
31. LionShare P2P project available at *http://lionshare.its.psu.edu/main/*
32. LOM -IMS-LRMDI (2004). IMS Learning Resource Meta-data Information. Version 1.3.1 - final specification, *Retrieved from http://www.imsglobal.org/metadata/mdv1p3pd/imsmd_bestv1p3pd.html*
33. Lowerinson, G., Gallan, G., Boyd, G. (2003) ”Learning objects in Distance Education: Addressing issues of Quality, Learner Control and Accessibility” in the Proceedings of CADE-ACED conference. St. Johns
34. IMS Meta-data Best Practice Guide for IEEE 1484.12.1-2002 Standard for Learning Object Metadata Version 1.3 retrieved from http://www.imsglobal.org/metadata/mdv1p3pd/imsmd_bestv1p3pd.html
35. IMS_LIPS (2001) Learner Information Package Specification Version 1.1 –final specification Retrieved from *http://www.imsglobal.org/profiles/lipinfo01.html*
36. [IMS_LIP XML(2001) IMS Learner Information Packaging XML Binding Version 1.1. Retrieved from *http://www.imsglobal.org/profiles/lipbind01.htm*
37. IMS Global Learning Consortium Vocabulary Definition Exchange Specification Retrieved May, 2004 from *http://www.imsglobal.org/vdex/index.cfm*
38. IEEE-LTSC (2002). IEEE Learning Technology Standards Committee (LTSC), Available at *http://grouper.ieee.org/groups/ltsc/index.html.*
39. LTSC “Learning object definition”. LTSC Learning Technology Standards Committee of the Institute of Electrical and Electronics Engineers (IEEE). Retrieved October 2002 from LTSC Web site http://ltsc.ieee.org/
40. MERLOT Multimedia Educational Resource for Learning and Online Teaching. Available at *www.merlot.org/*
41. Mitzoguichi, R., Sinitsa, K. E Ikeda, M (1996) Task Ontology Design for Intelligent Educational/Training Systems. Workshop on Architectures for Designing Cost-Effective and Reusable ITSs, Montreal, Canada p 1-21
42. Murray T. (1996) “Special Purpose Ontologies and the Representation of Pedagogical Knowledge”. International Conference for the Learning Sciences (ICLS-96). Evaston, Charlottesville(USA)
43. OASIS UDDI Technical Committee, Universal Description, Discovery an Integration of Web Services (UDDI) 2.0, Specification. Retrieved from *http://www.oasis-open.org/committees/uddi-spec/doc/tcspecs.htm*
44. Padrón, C., Dodero, J.M., Díaz, P., Aedo, I., and Fernández, C. (2003) “CARLOS: A Collaborative Authoring Tool for Reusable Learning Ob-

jects". In proceedings of the 14th International Workshop on Database and Expert Systems Applications, IEEE Computer Society, September, 2003, pp. 269-273.
45. Padrón, C. L, Dodero, J. M., Lanchas, J. (2005) "CASLO: Collaborative Annotation Service for Learning Objects". IEEE TCLT Learning Technology newsletter ISSN 1438-0625, Vol 7 2/2005, pp 2-6. Retrieved from *http://lttf.ieee.org/learn_tech/index.html*
46. Padrón, C. L., Torres, J., Dodero, J. M., Díaz, P., Aedo, I. (2004) "Learning Web Services Composition and Learner Communities Support for the Deployment of Complex Learning Processes" In proceedings of the 4th Int. Conf. on Advanced Learning Technologies (ICALT), Joensuu, Finland, August 2004
47. Parr W. and Smith M. (1998) "Developing case-based business statistics courses", The American Statistician 52(4): 330—337, 1998.
48. Pawlowski, J.M. (2000) The Essen Learning Model: A multi-level development model. In Staff and Education Development International 4-2000.
49. Polsani, P. (2003). Use and abuse of reusable learning objects. Journal of Digital Information, 3 (4), 10 p. Available: *http://jodi.ecs.soton.ac.uk/Articles/v03/i04/Polsani/.*
50. RELOAD (2005) Reusable E-Learning Object Authoring and Delivery Retrieved from *http://www.cetis.ac.uk/members/x4l/articles/reload*
51. Rubin, J. (1994) Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests. Wiley,
52. Rosson, M. B. and Carroll, J. M. (2002) Usability engineering. Morgan Kauffmann Pub
53. Sarasa, A., and Dodero, J. M. (2004) "Towards a Model of Quality for Learning Objects" [to be published] in proceedings of the 4th Int. Conf. on Advanced Learning Technologies (ICALT), Joensuu, Finland, August 2004.
54. Swartout, B., Patil, R., Knight, K. and Russ, T. (1996) "Toward Distributed Use of Large-Scale Ontologies". in Proceedings of the 10th Knowledge Acquisition Workshop, Banff, Alberta, Canada, November 1996.
55. Simple Object Access Protocol (SOAP) 2.0, Specification. Retrieved from *http://www.w3.org/TR/soap12-part0*
56. SCORM (2004). Sharable Content Object Reference Model (SCORM), http://www.adlnet.org/scorm/history/2004/documents.cfm
57. Swartout, B., Patil, R., Knight, K. and Russ, T. (1996) Toward distributed use of large-scale ontologies. In Proceedings of the 10th Knowledge Acquisition Workshop (KAW'96), Banff, Canada, November 1996.
58. Tagushi (1998). Tagushi Methods A hands-on approach to quality engineering. AddisonWisley, 1998
59. Teege, G. (1996). Object-Oriented Activity Support: A Model for Integrated CSCW Systems, CSCW Journal Bd. 5 Nr. 1, S. 93--124. Retrieved from *http://citeseer.ist.psu.edu/53722.html*

60. Tennison and N. Shadbolt. (1998) APECKS: A tool to support living ontologies. In Proceedings of the 11th Knowledge Acquisition Workshop (KAW'98), Banff, Canada, April 1998.
61. Thomas J. (2000) "A review of research on project-based learning", Autodesk Inc., 2000
62. Sure, Y., Erdmann, M., Angele, J., Staab, S., Studer, R. and Wenke, D. (2002) Ontoedit: Collaborative ontology development for the semantic web. In Proceedings of the 1st International Semantic Web Conference (ISWC2002) .Retrieved from *http://citeseer.ist.psu.edu/sure02ontoedit.html*
63. W3C, Web Services Architecture, Working Draft. Retrieved from http://www.w3.org/TR/ws-arch
64. W3C, Web Services Description (WSDL) 2.0, Specification. Retrieved from http://www.w3.org/TR/wsdl12/
65. Wiley, D. A. (2002) "Connecting Learning Objects to Instructional Design Theory: A Definition, a Metaphor, and a Taxonomy", in D. A. Wiley (ed.), The Instructional Use of Learning Objects, Agency for Instructional Technology and Association for Educational Communications and Technology, 3-23, 2002.