# Modeling Educational Content: The cognitive approach of PALO Language[1]

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Abstract: *This paper presents a reference framework to describe educational material. It refers to PALO Language as a cognitive based approach to Educational Modeling Languages (EML). In accordance with recent trends for reusability and interoperability in Learning Technologies, EML constitutes an evolution of the current content-centered specifications of learning material, involving the description of learning processes and methods from a pedagogical and instructional perspective. PALO Language, thus, provides a layer of abstraction for the description of learning material, including the description of learning activities, structure and scheduling. The framework makes use of domain and pedagogical ontologies as a reusable and maintainable way to represent and store instructional content, and to provide a pedagogical level of abstraction in the authoring process.*

## 1. INTRODUCTION

The definition of formal specifications and representational frameworks in order to model educational material to provide reusability and achieve a reasonable level of abstraction is one of the main topics being currently researched in the field of Learning Technologies (LT).

Distance education and the emerging industry of e-Learning has faced, as far as the technological perspective is concerned, a lack of formal specifications and robust technologies to develop interoperable and reusable learning content for Learning Management Systems (LMS), that would

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allow to deal with the increasing demand for Distance Education and training (Murray 1999, Mizoguchi 2000). In this particular context, the current situation has progressed mainly due to research carried out by several standardization committees (i.e. IEEE, CEN/ISSS), some college researchers and Universities, as well as international consortiums (IMS, ADL) which have resulted in a collection of LT specifications, providing a first layer of abstraction between authoring and delivering processes.

On the other hand, from an instructional point of view, research based on the use of computer-based instruction has evolved to an increasing richness of learning environments (Cronje 2001, Moallem 2001, Bradley et al. 2002, Boyle 2002), involving different instructional approaches, pedagogical interactions and models that cannot be fully expressed or applied by just using actual formalisms. This is especially remarkable in the description of learning processes and activities.

As a result of such situation, a gap between the capacity of LT specifications to describe learning material, on one hand, and the current pedagogical needs on the other, has just appeared and it leads to a variety of implications derived from a lack of expressiveness and abstraction in the existing representational formalisms (Mizoguchi and Bourdeau 2000, Murray 1999, Maglajlic et al. 1998). Three main consequences should be pointed out: a) Firstly, current specifications do not provide authors of learning material with a pedagogical authoring layer based on instructional elements, originating –therefore- a tight dependence between the learning content and the final delivery format, mainly internet-based technology; b) secondly, specifications themselves are currently isolated representational frameworks, which provide a fragmented view of certain aspects of learning material; c) Thirdly, there is no room for cognitive approaches or instructional and pedagogical knowledge representations; to give an example, metadata specifications only provide a syntactic formalism and recommendation for vocabularies in some of the fields.

This paper roots in the emerging paradigm of educational modeling languages (Koper 2002, Wilson 2001) to develop a representational framework for learning content that could accomplish current requirements of learning technology standards. At the same time, it aims to combine them with knowledge modeling mechanisms in order to improve the description of learning content and processes, at a pedagogical level of abstraction (Rodriguez-Artacho 2000). We face the problem of extending the notion of learning content to overcome the current content-centered approach, at the present time shaped as an aggregation or sequence of learning objects (LO). It includes instructional processes and methods, providing, at the same time, a pedagogical level of abstraction -in the description- that facilitates the authoring process. In this respect, our objective is to propose a language based in a representational framework to describe larger units of educational material as a proposal of educational modeling language. Moreover, the aim is to enhance the actual view of learning objects as isolated components, providing a cognitive view of educational material structured in instructional ontologies. We will also focus on cognitive models of educational content, as richer representations involving semantically-linked themed knowledge bases and stressing the importance of ontological modeling in the design of educational systems (Breuker 1999, Mayorga et al. 1999, Scott 2001).

This paper has been given the following structured: Section 2 examines the current proposals for representing and creating learning material. Section 3 proposes a representational framework based on the paradigm of educational modeling languages. Section 4 describes PALO language and its authoring cycle of learning material. Finally, conclusions and further developments are presented in the final Section (Section 5).

## 2. ISSUES IN LEARNING CONTENT MODELLING

Before LT standards and specifications were developed, the authoring of learning material became deeply dependent on delivering technology, compromising maintenance, interoperability and interchangeability.

In recent years, there has been a great effort to correct the unbalanced situation between the development of learning content specifications and the design of LMS architectures by means of focusing on the following topics:

- Separation and formal specification of learning content and learning management systems.
- Structure learning material into reusable components.
- Provide a framework of interoperability between different LMS's as well as a standardized architecture.
- Create description formats to search and retrieve distributed and reusable learning material (metadata).

As a consequence, the interest in creating formal models to represent learning material has led to the creation of a set of initiatives and working groups (Robson 2000, Ritter et al. 1997, Collier et al. 2002) that have developed a variety of proposals to formalize different aspects of learning material, mainly content aggregation and packages, sequencing, repositories for learning content objects, all of them balloted as standards for Learning Technologies.

### LT Standards and the Learning Objects approach

Learning Technology standards are being developed by a variety of institutions and regular standardization forums. The majority of initiatives being carried out are related to related to the creation of specific standardization workgroups on Learning Technologies (LT) such as IEEE LTSC, CEN/ISSS LTWS, and ISO SG36, that helped in the coordination of standardization proposals. Moreover, some international initiatives such as IMS project have developed relevant e-Learning specifications to model learning content, sequencing, quizzes and repositories while others such as the ADL initiative in the U.S., developed its own proposal named SCORM, which consist of a learning-content packaging format, with additional sequencing extensions, that solves training demands of the DoD.

Parallel initial steps to create learning content as a separate component of LMSs were focused on the design of a repository of content structured in atomic reusable pieces of learning content, that could be searchable and retrievable by means of meta-description (Forte et al. 1997). Coincidentally, there has been the development of standardized Metadata specifications like LOM (Hodgings, 2000) and Dublin Core -among others- which developed learning objects metadata schemas and proposed guidelines for the creation of application profiles, with the main utility of serving as a catalogue system for learning objects.

The concept of learning object is, currently, the main issue being studied and researched in e-Learning and learning technologies (Gibbons 2000,Wiley 2001, Barrit 2000, Duval et al. 2001), although its definition and scope is, surprisingly not yet quite well delimited. Thus, early mentioned in (Reigeluth and Nelson, 1997) and used associated with metadata in the Ariadne Project (Forte et al. 1997), the best known definition is the one provided by the IEEE LTSC group. According to such definition, LO is 'an entity digital or non-digital which can be used, re-used or referenced during technology supported learning' (Hodgins, 2000). There are other approaches, which simplify the scope to 'any digital resource that can be reused to support learning' and criticize the lack of an specific instructional design paradigm based on them (Wiley 2001, Wiley 2000b), excluding non-digital resources, while other senses include pedagogical objectives as part of it (Nichani, 2002). Despite these differences, all definitions are focused on the notion of reusability, and they imply the attachment of metadata descriptors, in order to facilitate search and retrieval.

So far, researchers share the notion of LOs as a simple content 'brick' to build learning content by means of a process of aggregation. They are classified according to a hierarchy of aggregation levels, based on its size and on the pedagogical information attached, according to the granularity.

Notwithstanding the fact that most of the current research projects on LT are based on LO repositories, the main drawback of this model is the necessary trade-off between granularity, cataloguing effort and suitability to reuse (Merrill 2001, Wiley 2000a). Despite the fact that fewer granularity, the more suitable for reusing, it is also well known that it will be less likely to preserve its pedagogical context, without prejudice the effort needed to catalogue it. In fact, this might only be one of the drawbacks of a representational model that do not distinguish how to represent different kinds of instructional information and make it explicitly differenced from the learning content itself contained in the LO. Moreover, many critics to LOs are based on the inability to model in a flexible way the learning processes and methods of the learning material, and on the lack of a pedagogical context (Koper, 2001). It is also worth mentioning the difficulty of combining

–coherently- different LT specifications jointly with the use of LO's as components for building tailored educational material.

In connection with this idea, there are no pedagogical mechanisms left to authors when elaborating a course based on an aggregation of learning objects. Taken for granted that the suitable component will surely be found in our LO repository, some of its aspects (mainly methods, internal sequencing and structure) are embedded and hardwired in the LO itself. In this objects, activities and methods are not explicitly described. Although components are reusable, there is a lack of formalism to express structure, sequencing, and neither pedagogical uses of this content nor the learning processes involved on it.  The creation of large learning material with learning objects and packages of content as a succession of clip-arts, does not provide authors with a layer of abstraction that would allow them to create reusable learning material at an instructional level (Wiley 2001). Moreover,  this model is not rich enough to express a complex course, which, eventually, would include: (i) pedagogical features, (ii) meaningful structured parts and conditions for sequence, (iii) prerequisites and (iv) a variety of learning processes all of them  to be carried out  by teachers and learners (Koper 2001).

## Modeling learning content  and processes: the Educational Modeling Languages approach

A new representational framework has been developed under the generic definition of Educational Modeling Languages. In this respect, different approaches to said representational framework have been studied in the scope of the CEN/ISSS LT working group (Wilson 2001, Koper et al. 2002). These proposals aim to solve the representational problem of learning material, as they establish a layer of abstraction to describe learning material improving the model of content package as a collection of learning objects  (Rodriguez-Artacho  2002,  Suess  2000,  Koper  2001).

As it has been pointed out by (Wilson, 2001), EMLs and learning objects actually represent opposite approaches to the interoperability question. As far as learning objects approach is concerned interoperability for content is hampered by the contextual "baggage" of the object  only by stripping content of all its external referents (such as teaching methods, student roles, and activities) can an object be truly reusable.  EMLs, on the other hand take, as it has been mentioned before, an opposite approach. Assuming that units include large full lessons, practical, or courses and they include –in fact- all contextual information, then we shall conclude that components are truly shareable and reusable. Moreover EML's incorporate the definition of pedagogical aspects and learning processes that make interoperable courses or units of study, so they  provide appropriate instructional elements at its adequate abstraction level.

The advantages of such a definition framework of learning content are mainly contained/centered on the following ideas/topics:

- To define an abstract specification format to represent learning content that could higher the level of abstraction in the authoring process
- To provide abstract representational mechanisms to describe learning processes
- To provide a way to describe pedagogical behaviors, based on abstract representational mechanisms

Accordingly, our proposal extend current specifications and focuses on a broader variety of instructional information which are structured in a common representational framework specific for learning material.

## 3. A PROPOSAL FOR A REFERENCE FRAMEWORK TO DESCRIBE EDUCATIONAL MATERIAL

We hereby propose a classification that scaffolds heterogeneous information so it will allow to elaborate a learning material by means of a formal specification. In order to reach such an objective, the following considerations shall be taken into account, as assumptions

- Learning material is composed by pedagogical and instructional information that can be represented using an abstract information model and binding in an specification.
- The different elements of the specification are classified /grouped into categories called layers.
- As a formal specification, each element has an associated pedagogical meaning or operational semantics that require a process of interpretation or compilation by the LMS.

The representational framework rather than just being a model of aggregation or combination of learning objects, introduces instructional information associated to the formal specifications. This way, it is capable of turning the former view based on a plain package of content into a variety of components of instruction (processes, sequencing, prerequisites, scheduling, among others), plus educational content.

As a result, appears a classification of the different types of information that composes a learning material, scaffolded in a certain number of categories of elements or entities called layers. A layer expresses information about a certain kind of components, processes or functionalities, providing a coverage of a variety of aspects that are involved in describing learning activities to be carried out by a computer-supported learning environment.

| Layer | Functionality |
| --- | --- |
| Management Layer | LMS interoperability |
| Sequencing Layer | Scheduling, prerequisites, dependences |
| Structure Layer | Navigational model, Table of contents |
| Activity Layer | Activity, community, Roles, resources, tools |
| Content Layer<br>RIO, RLO's<br>Conceptual Domains<br>Multimedia Assets | Learning content, Learning Objects Ontology-based instructional Knowledge |

Table 1: Representational Framework of an Educational Modeling Language

Table 1 illustrates our proposed classification. On the left column each layer represents a categorized type of information related to any particular educative media. Entries on the right column (functionalities) explain the operational implications of the elements of the information models of each one of the layers. Next subsections describe each level of the representational framework.

## Layer 1: Content

Learning content at this level refers to, basically, any information contained in a given course, without any assumptions regarding its pedagogical use. Paradoxically, a layer called '*learning content*' seem to be redundant in the specification of learning material. However, the notion of learning objects, when considered as a plain self-contained piece of information for instructional purposes, poses a serious problem that needs to be solved. In our model, the former classification distinguishes more than one unique plain level of ‘*learning material*’, thus separating content from other aspects of the learning material, such as structure, learning activities, sequencing, scheduling or pedagogical model.

As a consequence, content level is only related to expositive information, from a technical point of view. This makes a distinction between (i) passive content, which can be simply delivered as it is, using any technology, and (ii) more complex learning material, such as learning processes or instructional functionalities, which need more than a simple delivery process and that require meaningful LMS's services. In this last case specification will correspond to upper levels on the hierarchy.

Additionally, the specific type of content will include –although is not limited to- learning objects. In particular, -as it will be mentioned/described in PALO- , we can also include references to conceptual domains and any other forms of knowledge organization based on learning ontologies. This repositories are structured into a knowledge domain with relationships between elements based on a pedagogical and instructional ontology, rather than containing isolated ‘*learning objects*’.

## Layer 2: Activities

The capability to specify learning processes is the main conceptual difference between educational modeling languages and the rest of the learning content specifications. This layer provides an abstraction level to define educative processes, embedded as part of the learning material.

Theoretical models for learning activities are related to learning theories. Consequently, they consider different conditions for learning and events of instruction (Moallen 2001). However, our aim, rather than providing a generic model, is to test abstract mechanisms in order to describe a learning task, stressing the importance of dialogues and feedback as well as carrying out work-based activities, discussion and a formative assessment (Cronj, 2001, Moallem 2001, Bradley 2002, Rodríguez-Artacho 2001).

## Layer 3: Structure

Instructional designers have long recognized the importance of analyzing a certain content of a given subject for the purpose of facilitating learning via the appropriate knowledge selection and organization (Merrill 2001).

In this layer, structure is described as a meaningful part of the learning material, allowing the LMS to associate -to them- pedagogical properties in terms of:

- Grouping components of layers 1 and 2 in a meaningful structure, providing an information model to implement some pedagogical mechanisms. (*i.e.* prerequisites, sequencing and scheduling)
- Associating partial assessment (some parts could be assessed separately from others)
- Providing a table of contents and a navigational model through the material

At the same time, this approach is different from current LT specifications such as Content Packaging format of IMS (IMS 2001) and SCORM (SCORM 2002) because, even though the former define a framework to package and structure learning content, no explicit semantic is associated to structure elements.

## Layer 4: Scheduling and sequencing

This level models the instructional workflow, pedagogical dependences, sequencing and time dependences between different parts of the learning material. Current specifications, such as IMS Simple Sequencing and SCORM also provide this feature of time restrictions and pedagogical dependencies associated to certain components of the learning environment.

Scheduling includes the following issues:

- Pedagogical prerequisites between the different parts of the components
- Deadlines, time constrains or any other schedule over the components
- Schedule to perform certain activities

This layer aims to integrate these features as part of a single specification, providing these mechanisms associated with parts of the learning material, rather than proposing an alternative information model to perform sequencing.

## Layer 5: Management

This level considers the information necessary to manage the description in order to provide interoperability with the LMS.

Management information is handled by the processing tool of the EML. It is later connected with the location of the domain knowledge repositories, resources or tools described in the specification, and metadata associated to any of the learning contents embedded in the course.

# 4. THE PALO LANGUAGE

PALO is an educational modeling language based on the former classification developed at LSI Department of UNED University.

PALO Language allows defining courses or units of study structured in modules. Each module includes (i) a declaration of the structure, (ii) activities to be undertaken by students and tutors and (iii) the scheduling of activities and content. Sequencing of modules is scheduled by mean of deadlines and dependences between modules, based on different types of prerequisites.

Table 2 summarizes the information model of PALO, that is to say, its location on the reference framework. Entities and attributes of each layer are detailed below.

| Layer | Entities | Attributes |
|---|---|---|
| Management Layer | management<br>objectsDB<br>taskDB<br>metadata | —<br>sgbd, location<br>sgbd, location<br>— |
| Sequencing Layer | none | Associated to MODULES<br>module-prerequisite<br>prerequisite-condition<br>deadline<br>Associated to TASKS<br>task-prerequisite |
| Structure Layer | course<br>module<br>part<br>subpart<br>essay | title<br>traceable<br>—id—<br>—id—<br>—id—<br>—id— |
| Activity Layer | task<br>essay<br>qualifier<br>simulation<br>tool | assessed<br>editor-type<br>type<br>weight<br>name<br>type |
| Content Layer<br>LO's<br>Conceptual Domains<br>Multimedia Assets | element<br>relation<br>glossary<br>as_is<br>hint | domain<br>name<br>category<br>—id—<br>—id—<br>format<br>— |

| | | |
|---|---|---|
| | | |

Table 2: PALO language entities and attributes

## Description levels in PALO

According to sections as described above, for each one of the different layers a subset of the language allows configuring properties in the components of the learning content at that specific layer. Therefore, Following sections will describe how different elements of the language are responsible for creating the specific layer. Thus, they trend to implement mechanisms of the language for each layer.

### Content layer

PALO has a content model based on a cognitive approach, which means that rather than encompassing a set of local or distributed "knowledge objects", PALO involves, instead, creating a course-specific repository of semantically linked material (Mayorga et al. 1999).

We agree with the hypothesis that the greatest impact on learning results from the representation and organization of the knowledge to be learned (Merrill 2001). In this respect, it is well known the importance of the use of conceptualizations in the process of learning (Breuker 1999, Mayorga 1999), and in the use of these classifications made by learning theories (Cronj, 2001, Bradley 2002, Henze 1997, Mayes 1995, Schank 1999).

However, in order to take advantage from these capabilities, it is necessary to, previously, create a course-specific repository of semantically linked material, based on an explicit conceptualization. In these conceptual models, some types and relations will be applicable for different subject matters, for instance, those relations producing taxonomies such as *part-of* or *class/subclass*, while others would be domain-specific. In order to provide flexibility to cope with different domains, our approach allows defining the type of entities and relations in a meta-level, using the same formalism: entities and relationships. In this meta-description, each specific domain model is generated as an instance of a generic model. Such a library of generic models (meta-descriptions) provides a variety of ontologies, -from simpler to richer ones-, in which a model can be selected whenever a new description for a particular domain needs to be made. Therefore, the type of objects, properties, and relationships to describe a domain can be changed and modified at the meta-level, facilitating not only the building process but also its maintenance (Verdejo 2000).

Figure 1 shows a simplified learning ontology taken from a generic scientific matter (actually used to create a course in logic and program verification). The ontology is represented using Entity-Relationship formalism. Entities are described by a category like *concepts*, *examples* and *explanations* in the field of study, and linked using the semantic relationships *illustrates* and *prerequisite*.

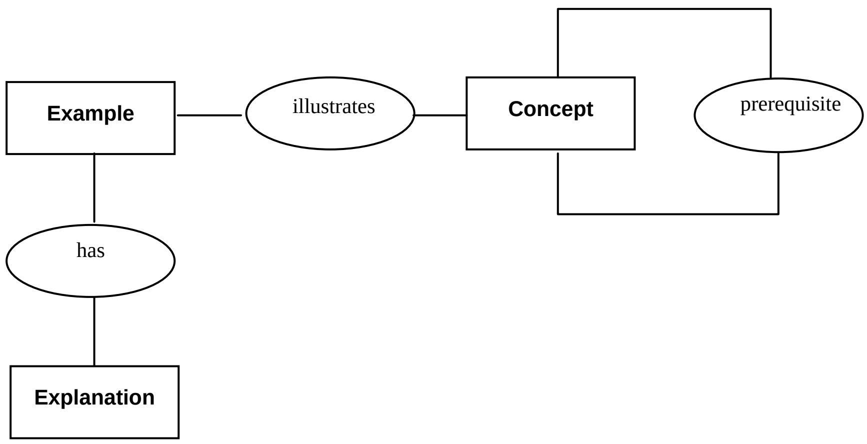


Figure 1: A basic learning ontology for a generic scientific matter

To illustrate PALO capabilities for retrieving educational content from an ontology-based conceptual domain, we can make use of tag `relation` in the context of the ontology of Figure 1. Assuming that we are creating a lesson related to concept X and that in some part of the learning material we would like to insert "*examples that <u>illustrate</u> concept **invariant***", we would compose the PALO fragment of Figure 2.

```
...
Here you can find more <relation
Name="Illustrates" Domain="Conceptual"
Subject="invariant"
Category="Example">examples</relation>
of the concept invariant.
...
```

Figure 2: Accessing domain knowledge using PALO

When PALO rendering process parses the `relation` tag, it retrieves from the knowledge base, all the *example* entities related to the concept "***invariant***" and builds the appropriate environment in the delivery format (i.e.a web page), which includes the sentence "Here you can find more examples of the concept invariant" where the term examples is rendered as a link to the corresponding list of examples.

These specific uses of a conceptual domain model facilitates authoring process of complex learning environments at a pedagogical and instructional level, and provide a higher level of abstraction in the description of course learning content. In the example of Figure 2 the `relation` tag can serve to retrieve elements from the knowledge domains according to a given pedagogical relationship (i.e. “easy” examples).

Single elements can be also retrieved on an individual basis (using `element` tag, as shown later in the activity section), or retrieve a collection of them, in alphabetical order, to create a glossary (`glossary` tag).

We focus on this last tag with another PALO example. In Figure 3 we describe ontology to represent chemical compounds and concepts. Based in this conceptualization, we can create a multiple nested glossary rooted in the “*compound*” entity using `glossary` tag.

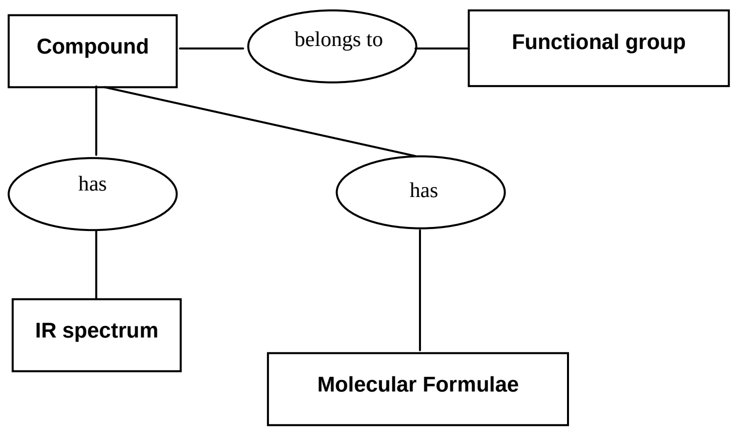


Figure 3: A chemistry-related ontology

Figure 4 shows the PALO fragment to create a glossary alphabetically ordered of compounds with their respective Infra-red spectrum, molecular formulae and associated functional groups. The resulting environment is shown in Figure 5.

```
<GLOSSARY CATEGORY="Compound" DOMAIN="Conceptual"
ATR-LABEL="Name"  ORDER="alphabetical">

        Glosario de compuestos

        <REFERENCE NAME="has" DOMAIN="Conceptual"
        CATEGORY="Spectrum" ATR-CONTENT="Name"
        LOCATION="antecedent">
        Ver Espectro
        </REFERENCE>

        <REFERENCE NAME="has" DOMAIN="Conceptual"
        CATEGORY="MolecularFormulae" ATR-
        CONTENT="Content" LOCATION="antecedent">
        Ver Formula molecular
        </REFERENCE>

        <REFERENCE NAME="belongs to" DOMAIN="Conceptual"
        CATEGORY="FunctionalGroup" ATR-CONTENT="Name"
        LOCATION="antecedent">
        Grupos Funcionales a los que pertenece
        </REFERENCE>
</GLOSSARY>
```

Figure 4: Creating a nested glossary

In all the cases, construction of this themed knowledge base is a core aspect of course development, and highlights the important role of learning ontologies to facilitate authoring learning material.

At the same time, ontologies can contain different multimedia components, as shown in Figure 5, where molecular formulae are rendered using a java applet, whilst spectrums are GIF files.

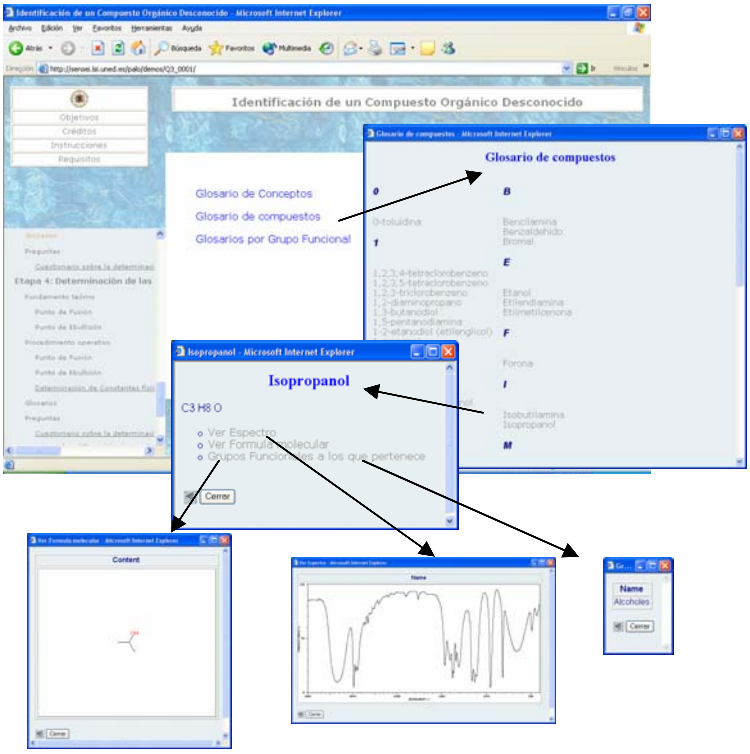

Figure 5: Nested glossary in a chemical-related learning environment

## Activity layer

Learning processes are defined using `task` tag. PALO can specify individual tasks involving two roles by default: student and teacher. Figure 6 shows a definition of an experimental essay to be carried out by learners in the UNED Engineering School (Verdejo et al. 2001).

```
<ESSAY NAME="Ensayo del Azufre A">
  Se toman en un tubo de ensayo 2 ml de
<ELEMENT DOMAIN="conceptual" NAME="d001"
CATEGORY="Concept" ATR-LABEL="Name" ATTRIB-
CONTENT="Content" FAQ="no">solución alcalina</ELEMENT>. Se
acidula con ácido acético, añadiéndose después una disolución
de acetato de plomo. Un precipitado negro de sulfuro de plomo,
indica la presencia de azufre.
<AS_IS TYPE="html">
  S <SUP>=</SUP>  + Pb  <SUP>++</SUP>   ---- <SUP>
  H  <SUP>+</SUP>  </SUP> ----> Pb S (Sólido Negro)  </AS_IS>
<TASK NAME="Q3_m2t01" TYPE="simulation" LABEL="Simular
Ensayo del azufre A" ASSESSED="yes">
  Simulación del ensayo del azufre A
  <SIMULATION NAME="simulation">Incoloro</SIMULATION>
  </TASK>
  <TASK NAME="Q3_m2t02" TYPE="text" LABEL="Comentar
Ensayo del azufre A" ASSESSED="yes">Comenta el resultado de
esta observación en la tarea adjunta. ¿Qué puedes
deducir?</TASK>    </ESSAY>
```

Figure 6: A PALO fragment with activity definitions

The essay includes two tasks in the PALO file fragment: task **Q3_m2t01** performs a simulation process (notice the value of `type` attribute of the task and that it contains a `simulation` element) and task **Q3_m2t02** defines a workspace with a text editor (`type` attribute value set to 'text') to comment the simulated chemical process.

An example of the use of the domain model using `element` tag, as shown in the previous section, is also provided, including the link to the retrieved element.

When rendering this PALO definition, two different workspaces are built up for each one of the roles. Figure 7 shows student view where he has to perform a simulated chemical reaction of a sulphur-based essay (A) and comment the results (B). The teacher's environment offer a group view of student tasks and a functionality to assess and feedback the students with a dialogue facility.

### Structure layer

PALO provide a hierarchy of Courses divided in modules, parts and subparts.

Each PALO description must only contain one Course which can be divided in one or more Modules. In PALO, the difference between tag `module,` on one hand and `part` and `subpart on the other, is that` a module is the unit that can be globally assessed, serving as a partial assessment of the course as a whole. Any of these elements can contain a combination of content and tasks as defined above.

Creating meaningful structure tags is useful (i) to organize a table of contents (like the one in the learning environment. See C in Figure 7) and (ii) to provide explicit dependencies between different parts of the specification, as shown in the next section.

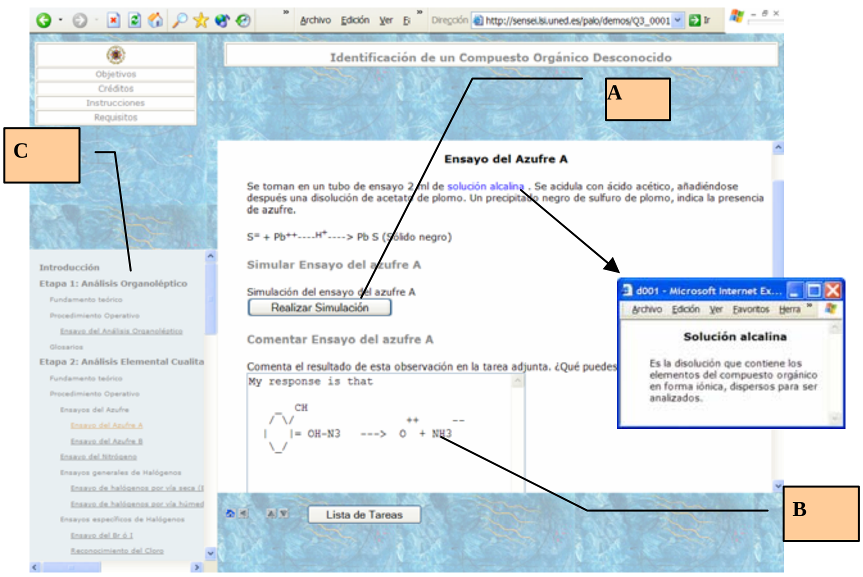


Figure 7: A PALO-based learning environment with task definitions (Student view)

## Sequencing layer

Scheduling and sequencing are provided by means of a set of attributes associated to structure and process levels.

Two mechanisms are, actually, implemented:

- Deadlines: Attribute `deadline` associated to a Module indicates that the corresponding tasks within the module have to be achieved before the deadline.

- Prerequisites: Attributes `module-prerequisite` and `prerequisite-condition are` associated to module. The first one controls the need to achieve the module indicated on the attribute before continuing with the next one. The second controls under what conditions (completed, assessed or passed) achieved in the module will allow going to the next one.

The rendering of these elements of the language results in the appropriate behavior of the learning environment, which will allow or disallow coursing a given module, if prerequisite conditions are not achieved.

**Management layer**

Management level in PALO describes location and type of the domain knowledge repositories.

Since this information depends on the LMS, it is not relevant going into details for this specific language. Currently, the most important issue in connection with this level is the fact that PALO provides elements to define the location (`location` attribute containing an URL) of the conceptual domains and to name the repositories (`sgbd`).

## Authoring cycle and learning experiences using PALO

Learning environments are generated by means of a compilation process of a PALO file. In the present binding, the PALO template is defined by means of a DTD file, from which a PALO file is generated.

The authoring process (Figure 8) is based on the creation of the learning material using PALO specification and a processing tool (a PALO parser).

The authoring process has three steps:

- Create or copy the ontology and instantiate it with a domain model of the content matter
- Create the learning material using PALO and, eventually, making use of the language features to access the former cognitive repositories
- Launch the PALO parser the corresponding web based learning environment

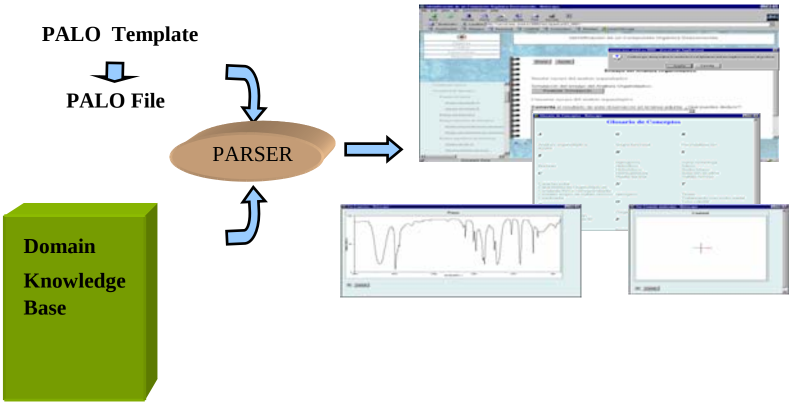


Figure 8: PALO authoring process

A desirable interoperability with an LMS should be provided by means of rendering processes in PALO compatible LMS's,. This would result in a facility to import and export learning environments among different e-Learning platforms, similar to some initiatives that had been taken by commercial e-Learning management systems like WebCT and others who have achieved to integrate IMS, SCORM, LOM and other learning technology specifications.

## 5. CONCLUSIONS

This paper describes a representational framework for learning material as well as its application to the definition of PALO language as an educational modeling language.

We have shown that PALO allows creating complex learning scenarios, which include the adoption of pedagogical models using a terminology close to the designers. The adoption of pedagogical theories by means of elements of the language shows that a more complex specification can provide easily with an extended variety of pedagogical interactions and models, and serve as an authoring reference framework of computer-based learning material.

Actual trends in learning technologies are focused on the creation of specifications to describe different aspects of learning material whilst the emerging paradigm of educational modeling languages enhances the application scope and provides pedagogical mechanisms to describe learning environments at a higher level of abstraction. At the same time, the use of instructional ontologies shows that we can create and maintain instructional knowledge bases separately from the authoring process of learning material, and reuse them in different courses or units of study.

Current research work is directed towards the definition of collaborative tasks based on the activity theory, in an enhanced specification of PALO called ‘Active Documents’ (Verdejo et al. 2002), which incorporates tools to parse documents on the fly, thus allowing a dynamic framework to develop adaptive material.

Finally, PALO language has been successfully used in the description of open courses at UNED University. It gives currently support to more than 1,500 students using a variety of material which includes 4 open courses, a didactic guide and self assessment environments for a program verification course of the degree on Computer Science.

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