The Educational Semantic Web and Associated Technologies for Adaptability in Adaptive Learning Systems

Ali. El Mezouary, Amal. Battou, Mohsine. Ben Ohoud, Chihab. Cherkaoui
Laboratoire IRF-SIC, Faculté des sciences Ibn Zohr,
Agadir, Maroc

ABSTRACT
The goal of this paper is to examine the issue of the semantic web and LO in ALS to assemble and generate, from a repository of LO, a course adapted to the needs, according to goals and preferences of a given learner. This objective is a part of the current work we undertake in the project ALS-PL (Adaptive Learning Systems for the Programming Language). What interest us more particularly in this paper is the question of the LOs and the granularity of the contents for a reuse and an efficient search. We are also interested in the impact of the semantics by taking into account educational standards, in order to elaborate a semantic model of the Los, and therefore an educational semantic Web.

General Terms
Semantic Web, Adaptive Learning System

Keywords
Educational semantic Web, Learning object, Standards, Ontologie, Semantic model of the teaching grains, ALS-PL.

1. INTRODUCTION
Among the problems often raised by the ALS systems, we can distinguish the following problems: first the modelling of the domain of learning, second the model of the learner, and third the process of searching for the numeric objects adapted to needs and to preferences of a particular learner. These problems are even more important when the objective is to answer the question of the re-use of the educational resources, called also learning objects (LO). The answer to this question is often sought by the standards of contents bound to learning environments like LOM [8] and SCORM [17]. These two standards propose particular solutions for the description and the representation of the LOs, generally reusable in platforms of the e-learning type.

For the ALS which adapt themselves to the learner, the semantic search of the contents establishes an essential and complex objective. Indeed, to make effective searches for LOs adapted to a given situation, it seems to us important to reach a very high level of semantisation. It is a question of improving the indexation of the LOs and their research. So, the intelligent machines and agents will have big opportunities to answer the requests which are posed on them.

In this paper we are particularly more interested in the question of the LOs and the granularity of the contents for a re-use and an efficient research. We are also interested in the impact of the semantic relations by taking into account norms and educational standards, so that we have elaborated a semantic model of the LOs for educational semantic Web. We will start at first by "demystifying" the concept of Educational Semantic Web, particularly the ontologie approach as a fundamental characteristic to reach an optimal research for the Los, and the importance of the granularity of the Los in the regeneration of the pedagogical contents, to allow the adaptability and the individualization necessary for the considered ALS. The second part we will present our own model of educational objects, in relation with the domain of aimed learning. Finally, the third part will present our own model of educational objects, in relation with the domain of aimed learning.

The aim of the remainder of this paper is structured as follows. We will start at first by "demystifying" the concept of Educational Semantic Web, presenting associated technologies and the LOs approach. The second part will appreciate the granularity, as a fundamental characteristic to reach an optimal search for the LOs and to allow the adaptability and the individualization necessary for the considered ALS. Finally, the third part will present the implementation and the architecture of ALS-PL system.

2. THE EDUCATIONAL SEMANTIC WEB AS A FOUNDATION
In this section, we briefly present the main paradigms and concepts which are the basis of our work, including the notion of the Educational Semantic Web, ontologies as a mechanism to represent knowledge, and the learning object paradigm for representing learning domains.

2.1 The Educational Semantic Web Concept
According to [15], the educational semantic web (ESW) is usually used to represent learning content in a semantic framework, enabling its interpretation and easy handling, both by humans and by computers and/or applications. The ESW is a very important initiative affecting education. It consists in adding a new semantic layer to the learning resources to facilitate their retrieval and reuse.

The ESW concerns two major actors and consumers of the Web: the students and the teachers. Each of these actors expressed a particular search need [4]. Teachers often need to look for resources tailored to specific learning situations, namely: preparing a new course, creating resources for e-learning, preparing exams, etc. Students conduct research to prepare their reviews, home works, improve their courses, writing papers, etc. These tasks of information retrieval are time and energy consuming. The traditional semantic web is too general to meet the demands of these actors. In addition, the semantic web must be aligned with changes in the world of education, both among learners and teachers. Indeed, most students are not the same as before. The new generations of students are 'consumers' who use technology from an early age: whether in the collaborative games, classroom, or elsewhere. These are learners who have preferences and are accustomed to technology: a virtual world with everything composed of media, without limitation or virtual space or time.

The ESW is therefore a Semantic Web with specific actors and with a purely educational requirement calling for adapted resources, implying therefore unique technologies.

The ESW can also easily support ALS and can consequently increase the performance of classical search mechanisms for these systems. Such evolving can be achieved by the simple integration of meta-data, by introducing standard markup languages such as XML, RDF, by using ontologies; with particular thanks to the OWL language, and by using specific educational standards like SCORM [17], LOM [8], etc.

2.2 The Ontologie Approach

Ontologie is a formal theory used to explicit knowledge. The primary objective of ontologies is to model knowledge. Indeed, they provide definitions of concepts and terms used to describe a domain, logical and semantic relations between concepts and terms and the constraints of their use. Practical descriptions on ontologies have shown their importance in several respects:

- Ontology involves the factorization of knowledge. Like the oriented object approach, knowledge are not repeated in each instance of a concept [6].
- Ontology provides a unifying framework to reduce, eliminate ambiguities and conceptual and terminological confusion [1].
- Ontology can significantly increase the performance of search engines. Through the semantics provided, ontology can address problems such as noise and silence of the traditional search engines [6].
- Ontology can support the sharing and reuse of knowledge [9]. Indeed, if a group of researchers want to create or extend ontology in a particular field, it can reuse existing ontologies and extending them.
- Ontology implements mechanisms of deductive reasoning, automatic classification, information retrieval, and ensure interoperability between systems.

2.3 The Learning Objects Technology

The "Learning Object" (LO) is a new term that emerges in the field of educational resources and learning, which does not escape to ambiguity. Most proposed definitions focus on the general principles governing the concept of LO such as: reusability, the learning intention and the independence of context.

Balatsoukas [12] gives a typical example of the Polsani's definition [13]. This author defines a LO as a unit of learning content, both independent and autonomous, which is predisposed to be reused in multiple learning contexts. Other authors such as Bibeau [20] considers a LO as the smallest information unit or the smallest tool of processing information (or software), used in an educational context, with an intention allowing learning through the technology support. Flamand & Gervais [19] identify three categories of LO. They distinguish objects with little media which is less complex and context-free (video speech of a president of a state radio interview, etc.), utilitarian objects (modeling software, etc.) and LOs consisting of basic elements of information (facts, ideas, concepts, principles, processes).

Finally, other approaches such as those of Downes [16] consider the size of a LO as important. Barron [18], in trying to consider this approach, suggests that five to nine information objects (text, image, video, photos, etc.) can be combined to form a LO. Other works of Mortimer [7] approach the size of a LO in terms of time. A LO takes no longer than 15 minutes to complete.

In addition to these theoretical conceptualizations and sometimes ambiguous, other definitions emerge from various works on standardization (SCORM, LOM, IMS, etc.). For IEEE Learning Technology Standards Committee for example, Learning Objects are defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning.

2.4 Impact of Granularity in the Semantic Structuring of Content

The granularity is a main characteristic of LOs as presented in [2], [7], [12], [13], [16], [18]. Most of authors were interested in assembling conditions to determine the type and level of granularity to consider. The LO granularity is related to the detail level contained in this LO, as well as its size, decomposability and reusability. Fine-levels of granularity are wanted since the smaller a LO is, the more probability it is to be reused in different contexts. How to decompose a LO differs from one model to another. So, the most used technique is the aggregation. According to [2], the LO granularity depends closely on the context where de granule will be inserted. Other authors such as [13] argue that granularity depends on the size of a LO. But size specified by this author can't be recorded in terms of bytes or execution time of the LO. The size here is the number of ideas that can transmit a LO. The LO must pass one or few ideas. In this case, the LO consists of several ideas, one of those ideas may be primary and the others are derived or depend directly on it. The "fine granularity" is then frees LO of any consideration related to the size such the time or the subjectivity of the designer.

The fine granularity can also annotate semantically different grains. These annotations increase the opportunities to find items adapted to a specific situation. Moreover, the granularity combined with indexing plays an important role in facilitating adaptability. Indeed, instead of adding metadata to large blocks of educational content, small size granules are indexed, which enlarges the space search. This will also destroy the silence of research, which may be due to an insufficient granularity. The adaptability consists to search between those grains and choose those that are appropriate to a given situation.

In the following, we propose a presentation of a semantic model of educational contents in relation to new developments bound to the learning objects.

3. CONCEPTION OF A CONTENT SEMANTIC MODEL

In this section we present a semantic model of content we have conceived. This model is presented with a UML class diagram. We furthermore underline the importance of semantic relations and meta-data to facilitate the search mechanism. A part of the diagram class that was instantiated to process the concepts of the "C" programming language, is also discussed in this section.

3.1 A Semantic Model of Learning Objects

To reach the necessary semantics for the LOs, we propose a semantic model of content which consisted of two complementary levels (Figure 1): The structural level and the semantic level.

The Structural Level: Corresponds to the structural organization of content. In this level, we distinguish three basic and important classes: the class Document, the class Fragment and the class Concept. Each of these classes is associated with other classes by relationships of specialization, composition or ontological relationships. A document can be generated from a set of Fragments (introduction, definition, example, exercise, paragraph, remark, evaluation, synthesis, or illustration). Each of these fragments is described by multimedia bricks: text, image, sound, video, simulation, animation, etc. We note that each fragment can reach an educational objective related to a concept.

The Semantic Level: Consists of various meta-data which allows describing the various educational grains on one hand and on the other hand the semantic relations between classes constituting the model. The meta-data also describe the multimedia bricks. Here, and to describe fragments we used some descriptors of the part Education of the standard LOM (Learning Object Metadata) [8]. A fragment is so described by descriptors such as: the type (exercise, example, definition, etc.) The type of interactivity (activate, transmissive, collaborative, communicative, undefined), the level of difficulty (easy, average, difficult), the estimated time, the list of the multimedia bricks, the context of use (here one or a combination of concepts). Finally, other attributes part of the general description of a fragment has been introduced such as ID, title, author, language and keywords. Besides, every multimedia brick is described by the other descriptors such as: size, format and physical location.

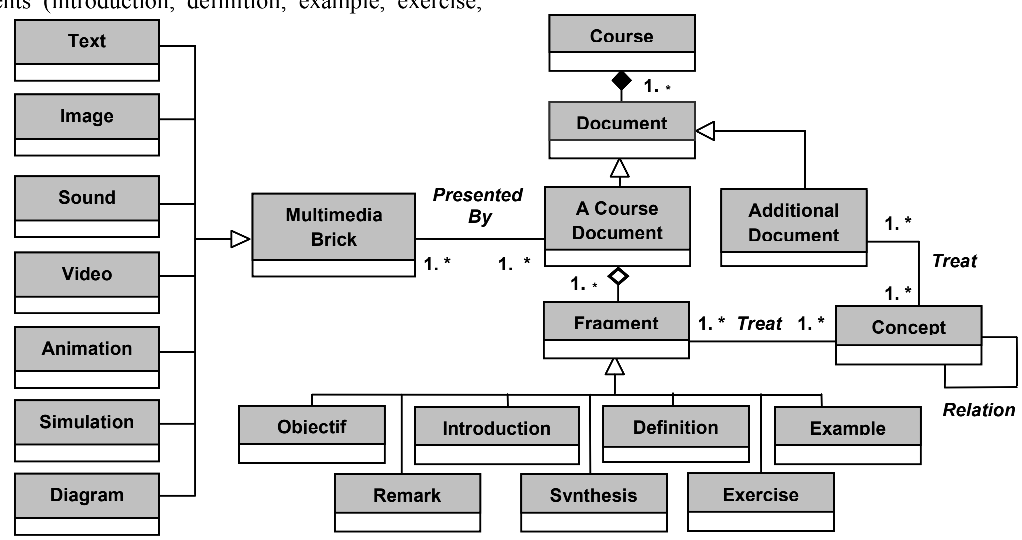

Figure 1: The Semantic Model of the Grains of LOs.

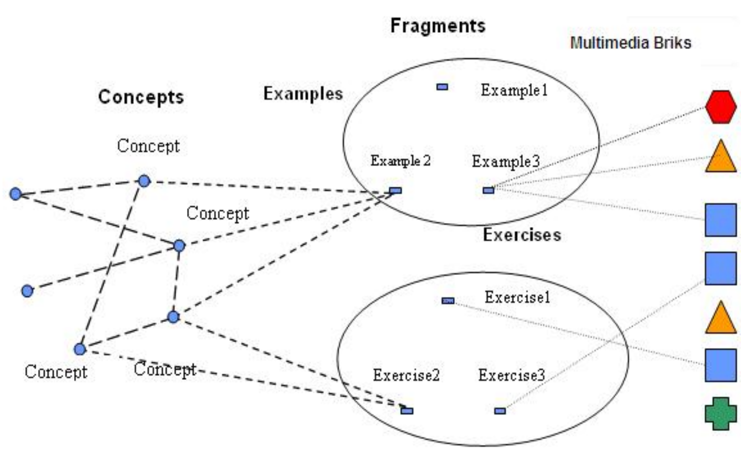

Figure 2: Representation of the Learning Domain (inspired by work of Brusilovsky [14]).

3.2 Contribution of the semantic in the research of LO

The semantic search integrating educational standards is important for ALS systems. It provides educational features for searching in a database indexed by descriptors coming from standards such as LOM. For example, it is necessary for each learning object to specify exactly how that learning object is related to concepts in a particular domain, and the kinds of learning outcomes that are possible in that domain, i.e., an ontology of concepts in a domain [10]. With this kind of knowledge, an agent can compare the course structure developed by a course designer with the learning object based on a common understanding of how they relate to each other. This allows the agent to determine which learning objects are "right" for a particular course. Of course, it is important that the course designer use the same concept ontology in specifying the course structure.

In the case of a conventional search, considering such a query seeking the concept of "iterative statement". The result is formed by the LOs which containing at least one LOM descriptor contains this expression. But, if for example a LO is indexed with one of the following terms: "loop", "while", "for" or "do while"; the system does not infer that this LO also treats the iterative statements. This comes from the fact that the semantic content is represented inadequately because it is often limited to traditional keywords. Furthermore, the links and relations as the composition [11], the order of learning concepts, the similarity relationship and the dependencies of prerequisite between concepts must be mentioned to enable not only the retrieval of LOs but also to facilitate their reuse.

To ensure the semantics, it is necessary to use both meta-data related to standards, the semantic relationships and fine-grained content. Work in this area requires the development of appropriately scaled ontologies as shown in Figure 6.

3.3 The Model of Learning: Case of the Programming in the "C" Language

The model of the domain which we propose represents an ontologie of the domain of the "C" programming. Such ontology represents a graph of concepts and relations between concepts (Figure 3). The concepts are the knowledge which must be acquired by the learner. Every concept is connected with fragments and pointing towards multimedia bricks.

The relations between the concepts can be of various types. The relation of prerequisite will indicate for example that the learning of a concept A is subjected to the control of the concept B which precedes it. The composition means that the description a concept is made by means of the description of its constituents. The union of all the constituents forms a generic concept. The generalization expresses that a concept represents a generic concept and his successors disgrace. Figure 3 shows an example of the domain of computer programming, including the three first level of knowledge or concepts, with relationships of a pre-requisite, composition and generalization.

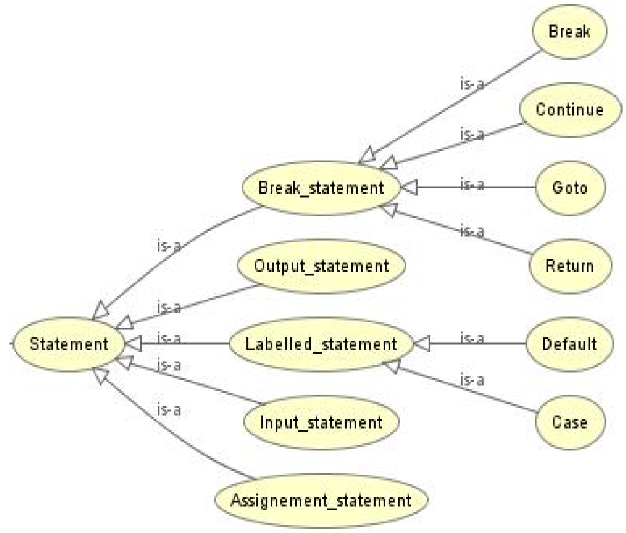

Figure 3: A Part of Graph of Learning Concepts for "C" Programming

Reading and interpretation of the model is done in depth. Thus, the concept "***Statement***" is a generalization of five types of statements: "***Input_statement***", "***Output_statement***", "***Assignement_statement***", "***Lebel_statement***" and a "***Break_statement***". A control instruction is either a conditional statement or a repetition again it is a generalization. The assignment consists of the concepts of variables, operator and expression, it is a composition relationship.

4. IMPLEMENTATION AND ALS-PL ARCHITECTURE

In this section we illustrate some functionalities of our system **ALS-PL** which is under development and finishing.

Actually, the architecture ALS-PL implements the LOs infrastructure, the domain concept structure and the learner model interface (Figure 4).

This architecture is structured in two levels: The editing and the Run Time levels. The editing level offers teaching and authoring services. The learning objects infrastructure enables the authors of editing, viewing and the searching LOs. The second level allows the system to generate content adapted to a learner. We note that the system allows multiple connection types according to the nature of learner.

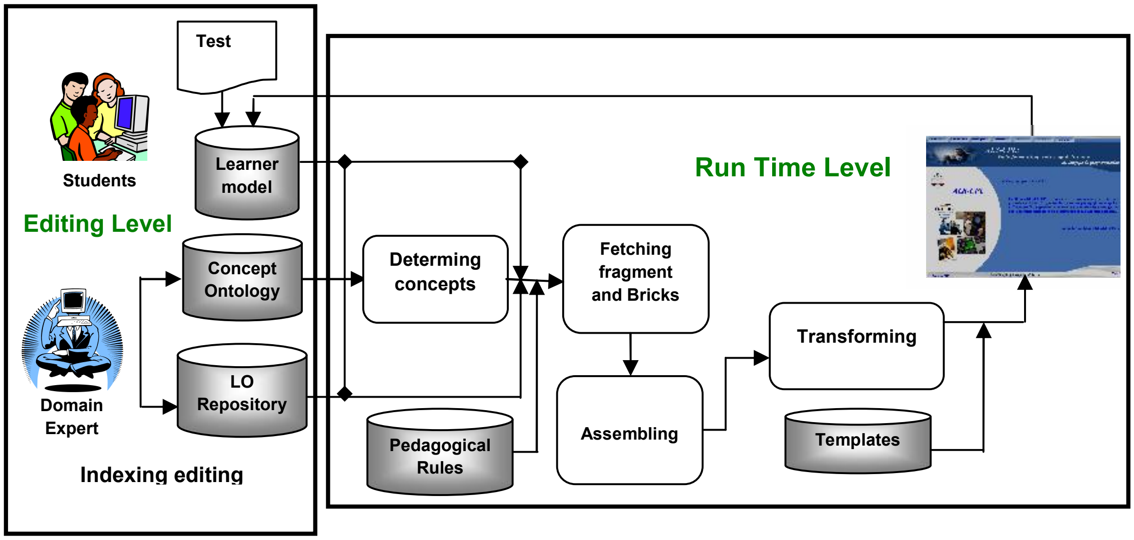

Figure 4: Architecture of the System ALS-PL.

We note that in this paper we are interested by the first level. We will detail the tree components: the LO repository, the concept ontology and the learner model.

4.1 The LOs Infrastructure Component

This component of our architecture as presenting at the Editing Level (Figure 5) consists of an editor of LOs and reflects the semantic model presented above. This component uses PHP code to load an exiting LO to be edited. It also allows the creation of a no existing LO. To assure the reuse of the LOs, it is necessary to qualify them by exploiting meta-data and the necessary descriptors so important to characterize each OP. We have used descriptors coming from standard LOM.

The open multimedia bricks and concepts (Learning goal) can be associated to the LO. Other items for indexing LOs are added in this step. As output, an XML file is generated.

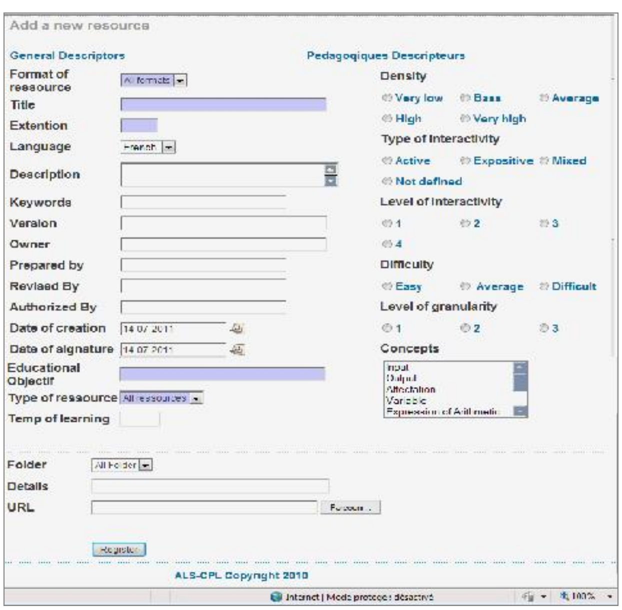

Figure 5: Creating or Editing a Learning Object.

4.2 The Concept Structure Component

The concept structure component is made as an ontology with the PROTEGE2000 editor. This tool provides ontology and metadata engineering capabilities coupled with basic document management facilities.

The concept structure is composed of set of concepts and relations between them as we have presented before (Cf. III.C). These relations express for example that some concepts are more abstract than others, or more specific, etc. The learning objects are linked with concepts by the view expressing that a concept can be achieved by a unique concept (Figure 1, Figure 2). We note that the learner model contains also the concepts already knows by a learner (initialized with a pre-test). The evaluation of the learner of each concept is done by a numerical calculation.

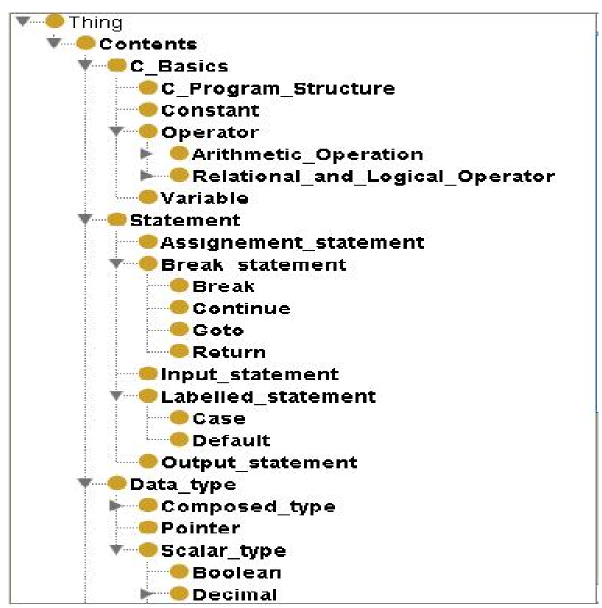

Figure 6: Editing Concepts and the Learning Model with Protégé.

4.3 The Editing of the Learner Modeling Profile

To be able to exploit the system, the learner has to become identified through the authentication screen (Figure 7). We note that this component allows a new student to be registered by recording its initial profile and individual preferences.

The model that we propose here is a model of the overlay type [3], [5]. It includes particularly the learner preferences and background knowledge. This learner model includes several parts of information and of knowledge. The first part as presented (Figure 7) corresponds to the generic profile of the learner. It includes personal information (first name, name, password, etc.). The second part and the most important one is composed by three sub-parts (Figure 8). Indeed, the learner model is structured as follows:

- The level of using the information technology and the internet tools (beginner, intermediate, Expert)
- The level concerning the programming languages (beginner, intermediate, Expert)
- The background knowledge composed of a set of programming concepts (variables, decision-making code, loop structures, procedures and functions, data bases, etc.).

The thirst part relates the preferences of the learner. This part is also vital and often neglected by the ALS community. For us, this part can be summarized in three sub-parts:

- Preferences relating to adaptive presentation of contents: it contains (1) Multimedia preferences (sound, image, video, applet, animation, etc.), (2) Textual navigation (we asked if the student prefer reading on a screen), and (3) some elements of the psychological profile (visual, auditory and kinesthetic styles);
- Preferences concerning the nature of the contents: as expressed before, our content model is relevant from the LOM standard. Thus, different types of learning objects as proposed to the student to choice his preferences. The student may have alternative and favorite elements of the course: exercises, examples, illustrations, explanations, simulations, glossary, etc.;
- Preferences about pedagogical tools: offers choices of some of the aspects coming from the socio-constructivism approach like the collaborative learning (forum, chat, etc.).

The initialization of these items is followed at the first session after logging. In the case of a new Login (new inscription), the system shows a continuation of screens to register the information relative to the learner (Figure 7, Figure 8).

We will note that the evolution of the background knowledge of learning during one or more sessions is induced by evaluations (exercises proposed to the student). Moreover, each concept has a level of knowledge of the learner (Read, Acquired, uncompleted, etc).

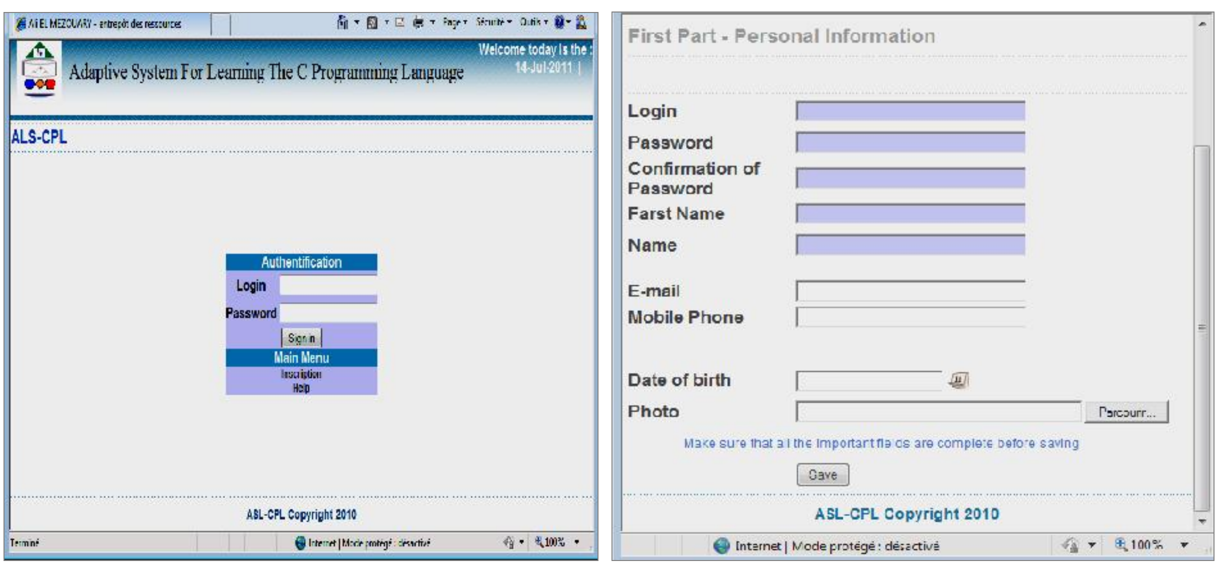

Figure 7: Login and Editing Personal Information in ALS-CPL

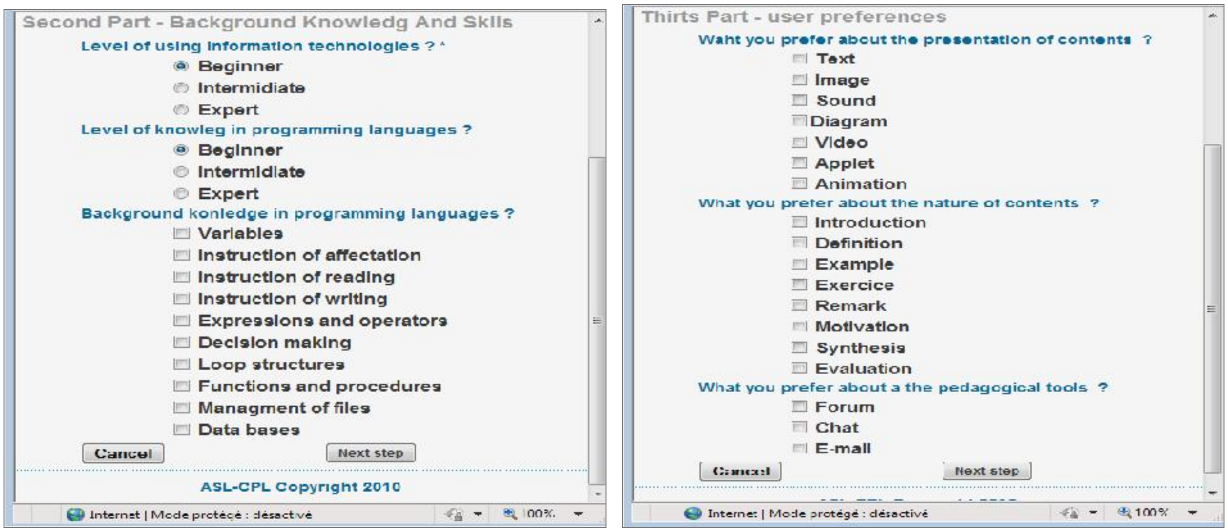

Figure 8: Editing Background Knowledge and Preferences of a Learner.

5. CONCLUSION

In this paper, we have proposed a granular model of LO for the adaptability and the re-use of the learning contents. This model of content is designed respecting to the various characteristics of the stated granularity. The first advantage of this model is its hierarchical structure in the form of "grains" of contents which respect the specifications of the existing standards (LOM, SCORM, etc.). Another advantage lies in the fact that the same fragment or a multimedia brick could easily be re-used in several documents or then directly in another context of learning. We can also note that the model suggested is open. It can indeed employ the proprietary format of the contents, or import it from the web. Moreover, the granularity combined with indexing plays an important role in facilitating the search mechanism and adaptability. Indeed, instead of adding metadata to large blocks of educational content, small size granules are indexed, which enlarges the search space. This will also destroy the silence of search, which may be due to an insufficient granularity.

As a second point, we have showed an architecture capable of integrating the LOs infrastructure, the domain concept structure and the learner model interface. Different interfaces are presented.

It is clear that several issues remain to be addressed to arrive at the expected system. Our work continues along these lines to try to finish a first functional prototype which will be tested and validated.

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