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An Ontology Oriented Approach on eLearning: Integrating Semantics for Adaptive eLearning Systems

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An Ontology-Oriented approach on E-learning: Integrating Semantics for Adaptive E-learning Systems

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Abstract

In the last decade the evolution on educational technologies forced an extraordinary interest in new methods for delivering learning content to learners. The role of technology has often been overestimated causing a myopic consideration of the critical issues in e-learning. This paper provides an initial discussion of the role of ontologies in the context of e-learning. The overall objective is to emphasize the importance of analysing a phenomenon and reveal the descriptive conceptualizations that affect the employment of technology. Ontology as a term has an intrinsic holistic character and from this point of view is quite interesting to investigate ways of understanding the phenomenon of e-learning from several perspectives. An initial clarification of term ontology is presented and the main issues are used for the description of the developmental process of the e-learning ontology entitled Mutli-Dimensional Dynamic Learning (MDL). The final conclusion balances conceptualizations and technological formulations by drilling down abstract concepts to data declarations and thus machine-readable semantics.

Keywords

Ontologies, E-learning, Semantic Web, Adaptive E-learning Systems, Knowledge Management

1. Introduction

Mizoguchi (1995) summarized the merits of ontology as following: Ontology provides a common vocabulary, and an explication of what has been often left implicit. According to Mizoguchi, the systematization of knowledge and the standardization consitutes the backbone of knowledge within a knowledge-based system. He also pointed out that a meta-model functionality specifies the concepts and relations among them, which are used as the main building blocks.

Ontology engineering has contributed several interesting aspects to modelling. Usually research on ontologies focuses on upper-level i.e. the equivalent of the meta-level in modeling. Maedche and Staab (2001) stressed that ontologies could be considered as "metadata schemas providing a controlled vocabulary of concepts".

An interesting clarification of the philosophical term ontology is provided by Guarino and Giareta (1995). They summarized several common definitions of ontology and they tried to elaborate further the main consideration that ontology is a specification of a conceptualization. The clarification of Guarino & Giareta is depicted in figure 1 and presents ontology as:

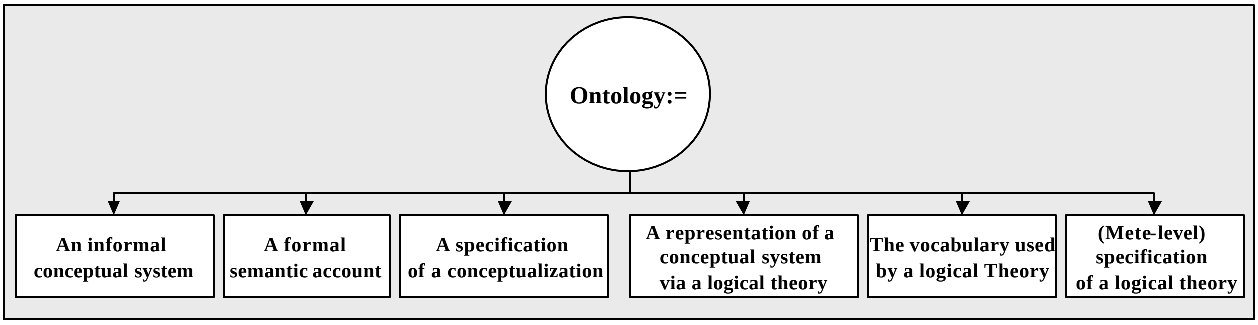

Figure 1. A basic clarification of ontology

- A philosophical discipline
- An informal conceptual system
- A formal semantic account
- A specification of a "conceptualization"
- As a representation of a conceptual system via a logical theory
  - characterized by specific formal properties
  - characterized only by its specific purposes
- As the vocabulary used by a logical theory
- As a (meta-level) specification of a logical theory

The above clarification sets the background for discussing ontologies in the context of e-learning. In the course of developing ontology for e-learning we can gain significant wisdom if we try to understand the deeper meanings of its definition.

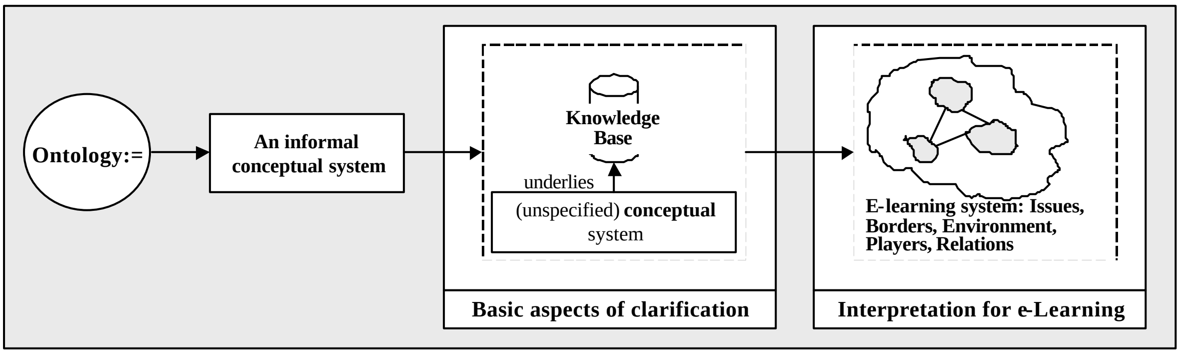

Figure 2. Ontology as an informal conceptual system

An ontology as an informal conceptual system (figure 2) in the context of e-learning means that we admit the presence of an (unspecified) conceptual system, which we may assume to underlie a particular knowledge base. This is the common hypothesis in e-learning implementations. Without systematic analysis of the relevant key issues we confront an e-learning system as a knowledge carrier that utilizes a hidden conceptual system which links and integrates several actors, variables and relationships.

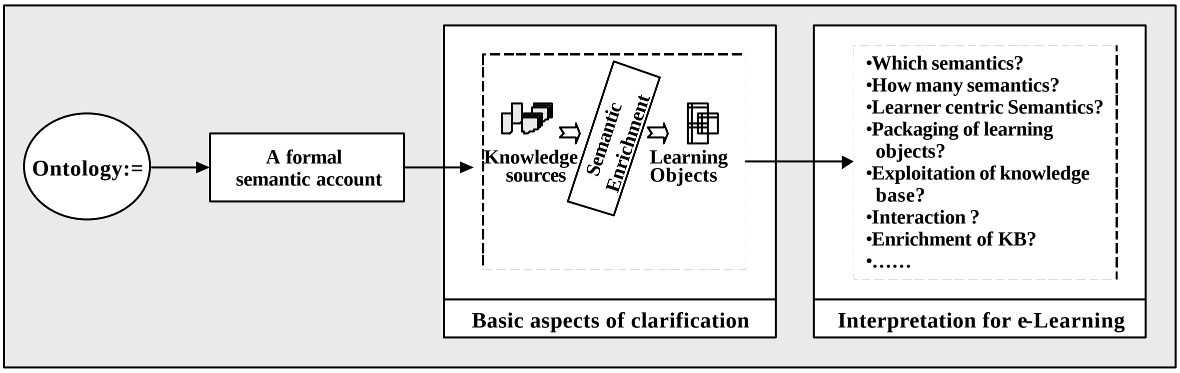

Figure 3. Ontology as a formal semantic account

An ontology as a formal semantic account (figure 3) means that we have analysed the phenomenon of e-learning and we have concluded several semantic elements that formulate a value layer capable of exploiting knowledge sources semantically. The major problem concerning this interpretation of ontology is the complexity of e-learning. The combination of learning and technology requires an extensive analysis of required technological components for the promotion of specific learning objectives.

The most common definition of ontology is the specification of conceptualization (figure 4). The precise meaning of such a definition depends on the understanding of the terms specification and conceptualization. Concerning e-learning, this specification implies a holistic approach to the several critical issues that affect performance. The conceptualization means that reality is reached through revealing causal relations. Entities are distinguished, relations are drawn and several axioms define logic.

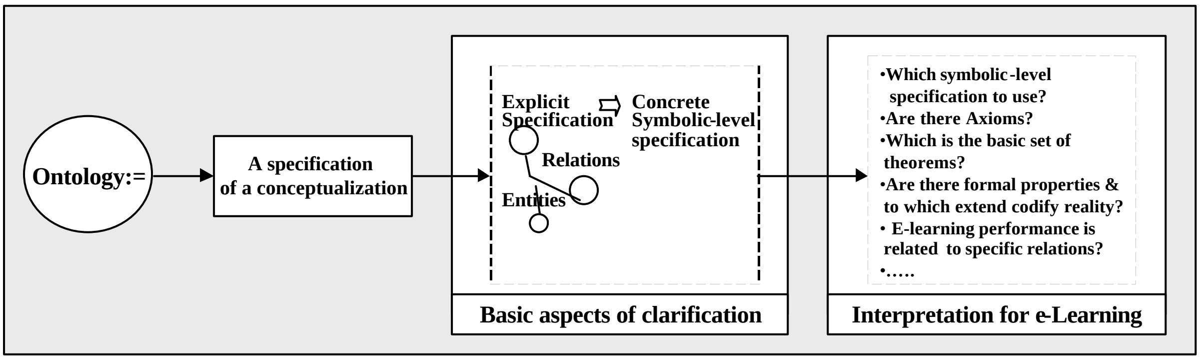

Figure 4. Ontology as a specification of a conceptualization

The next clarification, which considers ontology as the representation of a conceptual system via a logical theory (figure 5) is quite interesting for e-learning since a theory is a conceptualization of the reality that permits the development of socio-technical systems, according to the guidelines that are derived from the axioms and theorems of the logic. For example let us assume that the phenomenon of e-learning can be described via a logical theory. Then if we admit that a number of specific formal properties characterize learning resources then an enormous effort is required for their specification.

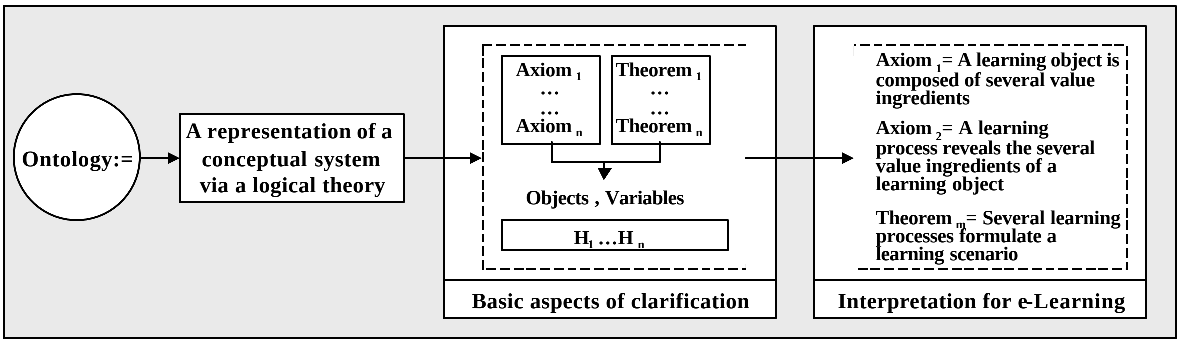

Figure 5. Ontology as a representation of a conceptual theory via a logical theory

The level of specification is directly related to the combination of theorems and axioms. So a critical question concerning the enrichment of this logical theory is how we prove the truth of a theorem or how we can expand the basic logical theory by justifying new logical propositions. Research methodologies in general can be followed in order to support research hypothesis, but as it stands for the real world basic axioms have to be taken for self-evident in order to start the building of a constructive learning theory.

A slightly different clarification considers ontology as the vocabulary used by a logical theory (figure 6). This differentiation focuses on logical definitions and clarifications of terms using an agreed syntax. Development of standards requires enormous effort on the specification of a vocabulary but undoubtedly vocabularies and logical theory are just the two sides of the same coin.

For example consider the case where the logical theory that supports our ontology for e-learning assumes axiomatic that a number of e-learning processes facilitate the value diffusion of learning objects. Then we have to use specific definitions for each process that is not only declarative, but also syntactic by using logical operands.

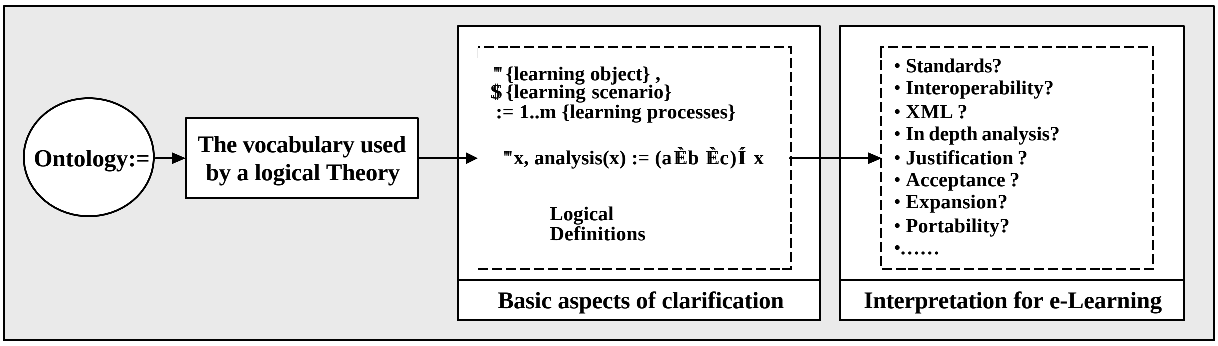

Figure 6. Ontology as the vocabulary used by a logical theory

Every time we need to analyse an aspect of reality, several levels of abstractions can be used. A common approach is to set an upper level or a meta-level (figure 7) where the emphasis of the analysis is on the specific object and the main logos.

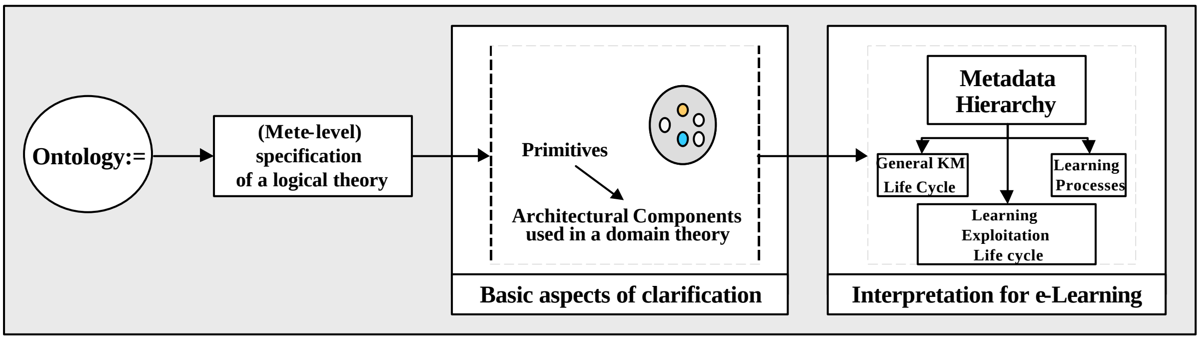

Figure 7. Ontology as a (meta-level) specification of a logical theory

To this end, we tried to set a context for ontological exploitation. In the next section we will ellaborate further the main explanations provided in the introduction. The overall objective is to concentrate on practical aspects on how to build an ontology according to the main facets of clarification that Guarino and Giareta contributed.

2. Towards the Development of an Ontology for E-learning

Several researchers have tried to justify a scientific way for developing ontologies. Perez and Benjamins (1999) propose design criteria and a set of principles that have been proved useful in the development of ontologies: Clarity and Objectivity, Completeness, maximum monotonic extensibility, Minimal ontological commitments, Ontological Distinction Principle, Diversification of hierarchies, modularity, minimization of the semantic distance and standardization of names.

These principles provide general guidelines for the development of an ontology, which consists of Concepts, Relations, functions/processes, axioms and instances. The ontology building process is a craft rather than engineering activity (Gruber 1995). In this next section we will present the craft approach for the development of ontology for e learning. The initial scepticism of the need to clarify an ontology for e-learning derives its origin to the numerous approaches for e-learning. The diversification of approaches and our involvement in several e-learning projects had convince us that in the e-learning puzzle there is a need to propose a holistic approach for integrating several conceptual and technological aspects.

The first phase in our approach deals with some primitive specifications. Our involvement in several e-learning projects formulated a deep belief that several principles are self-evident even though specific research approaches could support their justification. The three primitive specifications presented in figure 8, refer to learning objects, learning processes and learning scenarios. So a learning object is defined as a value integrator of the learners' needs, knowledge, motivation elements, problem solving capacity team synergy, packaging features and other learner-centric value ingredients.

Additionally for each learning object there are several learning processes, which can be applied, and reveal the embedded value ingredients of the learning object. Finally the primitive specifications recognize that a combination of several learning processes provide a learning scenario, a mode of interaction between learners and learning objects.

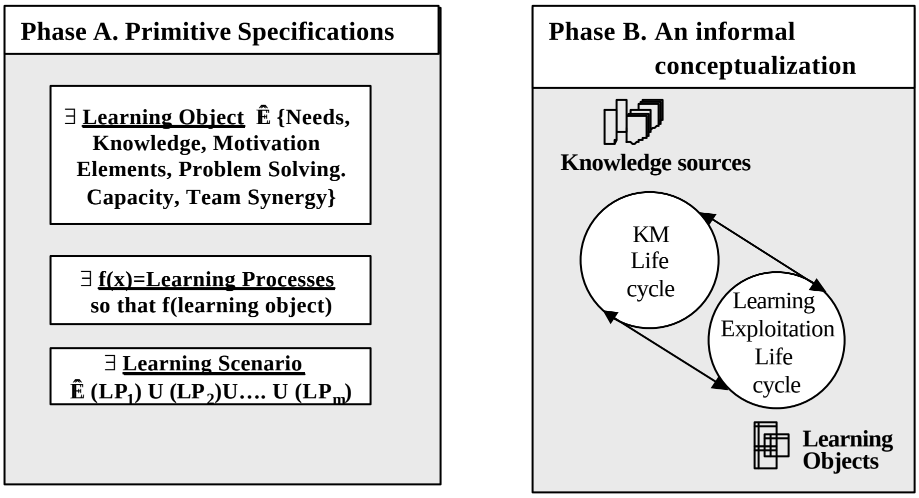

Figure 8. Phases A & B of the Development Process

The second phase of the ontology development refers to an informal conceptualization of the main issues that enlighten the phenomenon of e-learning. According to our conceptualization the e-learning phenomenon is mainly characterized from a content development process. Several knowledge resources are evaluated and through a constructive process and a hidden transformation mechanism are transformed to learning objects.

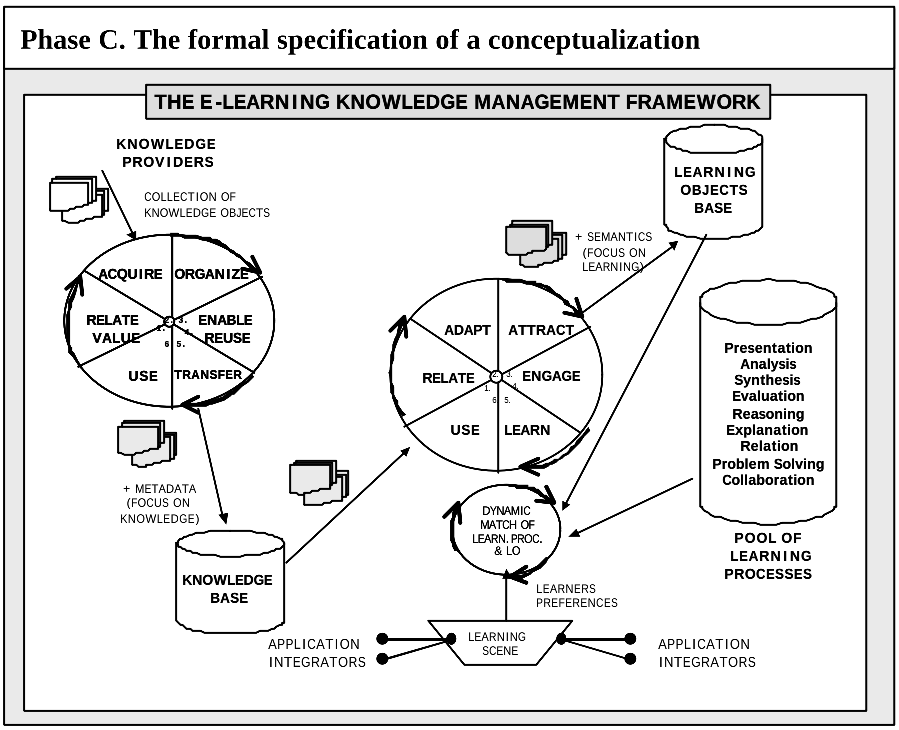

Figure 9. Phase C: The formal specification of a conceptualization

This process is realized in two stages. A general knowledge management life cycle where knowledge artifacts are selected and organized and a learning exploitation life cycle where specific knowledge artifacts are enriched in order to get exploitable learning value (Lytras, Pouloudi and Poulymenakou 2002a).

In Phase C, the specification of the conceptualization provides a richer picture. Through extensive research, both empirical and bibliographical, the two major transformations indicated in phase B, are specified in more detail. The knowledge management literature is supporting the first cycle while learning theories and analysis of three case studies provides the 6 stages of the second cycle. One more level of analysis is indicated. In an e-learning environment learning processes provide the interface and the value carrier for learners (Lytras, Pouloudi and Poulymenakou 2002b). The whole conceptualization underlies on an interactive learning scene, where a dynamic learning scenario is dynamically formulated integrating several learning process that correspond to specific learning objects which combine several knowledge artifacts and other value ingredients.

In phases A,B,C the focus of the development process of ontology is mainly on the clarification of conceptualizations without paying attention to technological issues. The specified logic is to this end descriptive implying several technological considerations that require formal descriptions (Lytras, Pouloudi and Poulymenakou 2002c).

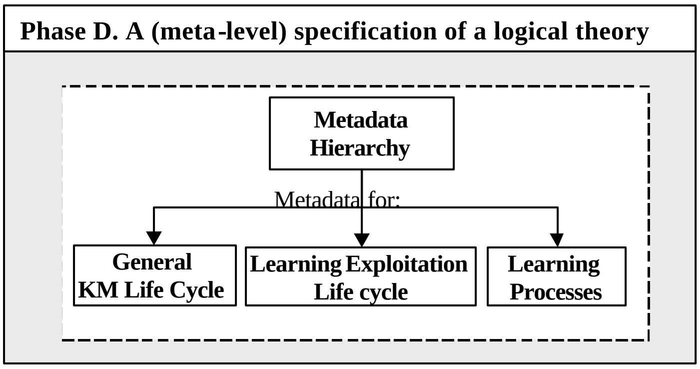

Figure 10. Phase D of the development process

Having identified that formalization has to concentrate on semantics that are applicable to a learning object, according to three value layers of enrichment, the next step in the development of the ontology for e-learning is to enlighten further the specification. The specification of the semantics for each exploitation layer provides a formal semantic account. The detailed definition of each semantic element provides the extended vocabulary. The level of formalization influences directly the capability of an ontology to be machine-readable. In the case of our approach this aspect of ontology is of critical importance. The development of dynamic e-learning systems capable to adapt on a learning value basis require technological specifications. Several XML-oriented languages have been developed and used for the presentation of ontologies. In our approach we selected RDF and currently we develop an extensive RDF vocabulary and a Java based platform for the realization of the ontology as an adaptive e-learning system.

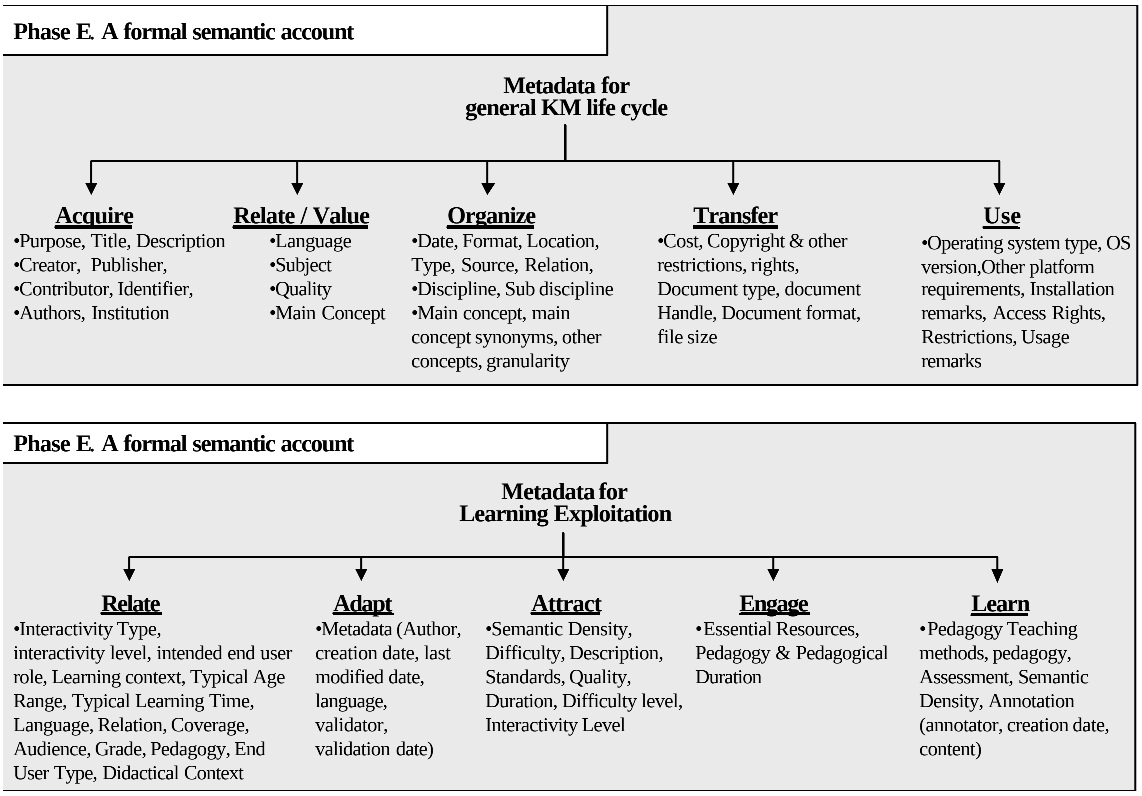

Figure 11. Phase E: Specification of the formal semantic account

3. Architectural Specifications

In the last years the field of learning technologies has entered into a phase of standardization. The appearance of XML, initially as another SGML transformation and after as a communication standard for heterogeneous environments, clarified a significant channel of data interchange among several learning platforms. Most of the work on this field (e.g. IMS, IEEE-LOM, and SCORM) has been compromised with the use of pure XML, in order to provide a learning ontology, to fulfil the requirements of learning standards.

In our architectural approach we use another model of computerized descriptions, called "Resource Description Framework" - RDF. RDF is a W3C standard and approaches semantically a metadata orientation of a computerized description, in current state a Learning Object. An adaptive e-learning system must satisfy two essential issues: (a) The platform independency and (b) the integration with external applications – platforms. The semantics of those specifications can be illustrated with technologies, which can assure that the above issues can be covered. Currently, a Java platform which follows an XML communication standard (SOAP, UDDI), through web services, in order to give an integration fulfilment between learners and learning repositories, is an ideal solution for designing a system which can be adopted easily. The architecture of this system must be able to provide:

- A single storage model for very different types of data and schemas in current state Learning Objects
- Reuse of the existing meta-data and learning objects without any extra effort.
- Modification of properties in Learning Objects

The above characteristics have a huge collection of Metadata and require a framework, which can provide a metadata level of transformation. Compared with pure XML, RDF –as a metadata modeling language- provides a more flexible framework because it can describe learning metadata easier than XML does. Following the above issues, an RDF syntax can be applied to MDL metadata (Lytras, Pouloudi and Poulymenakou 2004) as follows:

```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
<!—A generic rdf syntax for the semantic description of MDL Metadata for Learning
Prosesses -->
<rdf:Presentation about="http://location.of.leaning.resource/">
    <rdf:Description ID="presentation of MDL Metadata">
          <summary></summary>
            <purpose>Purpose of this Leaning Object</purpose>
              <Essential Resources>Resources</Essential Resources>
             <Annotation>Annotations<Annotation>
          <Topics>Several Topics</Topics>
   </rdf:Description>
  </rdf:Presentation>
.....
  <rdf:Analysis about="http://location.of.leaning.resource/">
      <summary>
          <rdf:Description ID="Analysis of MDL Metadata">
          ....
      </rdf:Analysis>
      .......
      <rdf:Problem Solving about="http://localtion.of.problem">
          <rdf:Description ID="Problem Solving">
               <summary></summary>
               <purpose></purpose>
               <relevant -knowledge-objects></relevant -knowledge-objects>
               <present -problem></present -problem>
               <sub -problem></sub -problem>
              .......
      </rdf:Problem Solving>
</rdf:RDF>
```

Figure 12: An RDF Syntax applied to MDL Metadata

The Semantic approach to learning metadata makes it possible to create a web-based eco-system for learning resources by freeing the material from being “trapped” in closed systems. One important example of this kind of technology is Edutella, an RDF-based peer-to-peer system under development, being designed to allow distributed access to learning resource meta-data expressed in many different schemas. A semantic approach to learning technology will help to:

- Implement more intelligent software agents in order to help the learner to find and use globally distributed learning resources
- Provide personal annotations of any leaning resources
- Give a collaborative and distributed environment for authoring and course construction
- Make reuse of learning material through RDF transformations in Learning Objects

By combining meta-data from many sources in a controlled but distributed way, cross-annotation and mutual reuse of material becomes a standard for a learning process through the Internet.

4. Conclusions and Future Research

The ultimate objective of our research is to justify e-learning as a field which requires a substantial modelling effort. Ontologies in this direction provide critical wisdom since they can be used as holistic tools for the representation of the knowledge in a specific domain. The innovation of our approach derives from our argument that e-learning has direct links to knowledge management and pedagogy. The common mistake to focus exclusively on the role of technology or pedagogy is the main reason for the failure of e-learning implementations. Balancing the effort among the several aspects of e-learning is the key answer to the increased demand of modern business organizations and universities for increased performance in (e)-learning investments.

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