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TOWARDS THE SEMANTIC E-LEARNING: AN ONTOLOGICAL ORIENTED DISCUSSION OF THE NEW RESEARCH AGENDA IN E-LEARNING

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Abstract

In the last decade the evolution of education-related technologies forced an extraordinary interest to new methods of delivering learning content to learners. Several times the role of technology was overestimated, causing a myopic consideration of the critical issues in e-learning. This paper provides an initial discussion of the new research agenda within the field of e-learning. Several aspects are investigated with main emphasis given to ontologies in the context of e-learning. 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 literature review of semantic web and its implications is provided, while a clarification of term ontology is investigated and the main issues are used for the description of the developmental process of the e-learning ontology entitled MDL. The final conclusion balances conceptualizations and technological formulations by drilling down abstract concept to data declarations and thus machine-readable semantics.

Keywords: Ontologies, semantic Web, P2P knowledge networking, adaptive e-learning systems

Introduction

In recent years the focus of research on e learning is concentrated on issues that treat e-learning as a value carrier or a critical asset that can be managed effectively. By emphasizing the fact that e-learning development costs are too high, solutions that secure re-usability and revision of courses are justified through extensive conceptualizations. The analytical process of bringing forward the main underlying issues that affect learning performance and knowledge exploitation within a given e-learning context is of critical importance for the employment of technology. A number of novel approaches have emerged providing new insights in the general epistemology of e-learning: Semantics, Ontologies, P2P knowledge networking, Metadata and Repositories. In this context the semantic web initiative and international established bodies analyze in depth the importance of new technologies like XML and RDF for the realization of adaptive e-learning systems. In Table 1, we provide an interesting collection of significant research concerning the new landscape of e-learning research agenda. In our approach we consider all the depicted issues as complementary facets of the same vision. Especially in e-learning the objective of implementation is directly related to learning performance, which requires a multidimensional analysis of several variables. Ontologies, semantic web, metadata, p2p technology are realizing the parameterization of e-learning systems. The more flexible the learning settings are, the more active the participation of learners is. In the next paragraphs we discuss in more detail the main findings from the literature review in order to provide in a following section a holistic approach.

Table 1. A Literature Review Concerning the New Research Agenda Within the E-Learning Field

Issue	References	Main contribution
Semantics for e-learning & metadata	(Naeve, Nilsson and Palmér 2001)	Learning framework / model based on layers
	(Stojanovic, Staab and Studer. 2001)	Representation layers of meaning Three dimensional semantically structure space
	(Nilsson 2002)	Discussion of metadata misconceptions Key characteristics of semantic enabled architectures for metadata support
	(Allert, Dhraief, Kunze, Nejdl and Richter 2002) (Dhraief, Nejdl, Wolf and Wolpers 2001)	Embodiment of different instructional principles and theories for Open Learning Repository Analysis of scenario-based evaluation
	(Allert, Dhraief and Nejdl 2002)	Critique of Metadata category Role in the LOM standard
	(Lytras, Pouloudi and Poulymenakou 2002c)	A knowledge management oriented metadata schema enabling semantics for learning exploitation
Ontologies & E-learning	(Perez and Benjamins 1999)	Ontologies and Problem solving methods as complementary entities that can be used to configure systems from existing, reusable components
	(Maedche and Zacharias 2002), (Maedche and Staab 2001)	Clustering of metadata generated by ontologies Measures of similarity
	(Stephan Baumann 2002)	Application of ontologies, simple heuristics and document similarity measures for a dynamic e-learning system
	(Zhang, Kim and Ramesh 2001)	An ontology supporting the development of Multiagent systems.
	(Papatheodorou 2002)	Ontologies as a mean for the development of taxonomies of learning resources Clustering techniques
	(Supnithi, Inaba, Ikeda, Toyoda and Mizoguchi 1999)	Ontologies support for Learning Goals Support. Opportunistic Group formation and relation to Collaborative Learning
Adaptive e-learning systems & Peer-to-Peer Knowledge Networking for E-learning	(Aldridge 2002)	Analysis of the use of software agent technology within the field of e-learning
	(M. E. S. Mendes, Martinez and Sacks 2002)	Description of fuzzy clustering algorithm and Topic Maps to discover and represent knowledge respectively
	(Manouselis and Sampson 2002)	Matching of learners needs and knowledge routes according to cognitive styles and multi-criteria techniques.
	(Brantner 2001)	Elaborates on components of an educational market-place model (including LR, Agents, Rights and Delivery systems)
	(Krishna Kant, Ravi Iyer and Tewari 2001)	Integration of P2P modes and E-learning
	(Golle, Leyton-Brown and Mironov 2001)	Investigation of incentives for sharing in P2P networks directly related to motivation
	(GartnerGroup 2001)	P2P modes and possible applications

Semantics for E-Learning and Metadata

The annotation of learning content is not a novel approach. Nowadays new techniques have expanded enormously the capabilities for content indexing not only according to a librarian consideration but mainly according to meaningful considerations for the quality of content and its potential learning capacity. Enrichment of learning objects is based on several aspects: Technical, Pedagogical, Relationship, Relevancy, Quality, Time and Duration and several others. The critical question is: Why annotate the content or the learning resources? The common answer is for reusability, but this word is confusing.enough. Reuse means use

again but from a learning perspective this can be explained in several qualitative levels. (Stojanovic et al. 2001) summarized the layers of representational structures that are needed in order to "express the meaning", the ultimate objective of semantic web. Layers that represent the structure, the meaning, the formal agreement about meaning of data and intelligent reasoning with meaningful data are of critical importance and provide the building blocks (see figure 1). They conclude that the merits of the semantic web can be summarized in a three-dimensional semantically structured space that permits the description of the semantics (domain dependent ontology), the definition of the learning context and the formation in learning courses of the learning material.
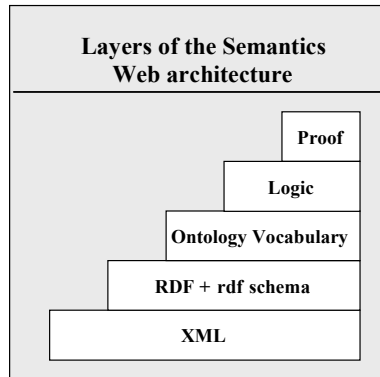
**Layers of the Semantics
Web architecture**

Proof

Logic

Ontology Vocabulary

RDF + rdf schema

XML

Figure 1. Layers of the Semantic Web Architecture (Source: Berners-Lee)

The annotation of a learning object is directly related to value parameters. It is obvious that the several metadata categories do not support the same value perception for learners. For example the filename of a learning object does not diffuse the same value as the quality of content tag. From a logical perspective each learning object could be represented as a vector. By defining specific value dimensions, we could map each learning object on a multidimensional space according to value metrics. In Figure 2 such an abstraction is provided. A three dimensional space is defined according to three general categories of value enrichment (Knowledge Intensity, Learning Capacity & Learning Processes). An e-learning system is not a black box. Its viability depends on its capacity to provide continuously updated content. A major obstacle in static e-learning implementations is the absence of a mechanism of integration that would be responsible for the embodiment of experiences obtained from past users of learning resources. Unfortunately the interaction of learners and learning content is not used for the enrichment of the knowledge base of an e-learning system.

Semantics as value vectors

High

1.

Z-value dimension
(e.g. Learning Processes)

High

Y-Value dimension
(E.g. Knowledge Intensity)

Low

Low

High

X-value dimension
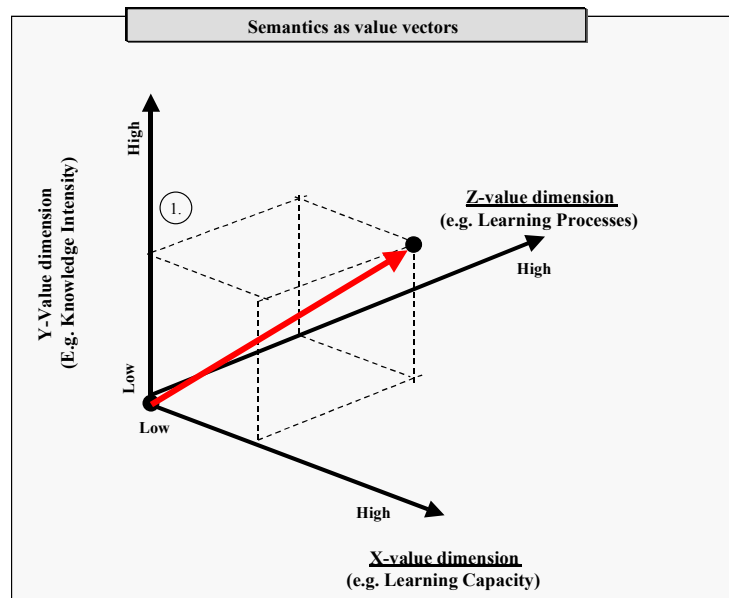**(e.g. Learning Capacity)**

Figure 2. Semantics as Value Vectors

(Naeve et al. 2001) according to the layered approach of many technological platforms emphasize on the importance to establish a learning framework or model where value layers constitute the basic ingredients. In the same article they discuss in detail the issue of interoperability between Learning Management Systems and conclude that five layers bat least could support the demand for adaptive e-learning systems: Physical and Transport layer, Exchange layer, Semantic layer, service layer and application layer. The practical implications of their approach can support areas such as content management, knowledge navigation and experience-oriented environments. (Nilsson 2002) emphasizes several misconceptions concerning metadata considerations that slow down the adoption of Semantic Web Technology. More specifically the main features of these misconceptions include: metadata is objective data about data, metadata for a resource is produced only once, metadata must have logically defined semantics, metadata can be described by metadata documents, metadata is the digital version of library indexing systems, metadata is machine readable data about data. According to their findings and discussions they claim that any semantic consideration of metadata has to be based on an architecture that is subjective and non-authoritarian, evolving and supporting a dynamic meta-data eco-system, extensible allowing introduction of new vocabulary with new semantics, distributed supporting descriptions by anyone, flexible supporting unforeseen uses of resources and conceptual supporting the evolution of human knowledge.

Adaptive E-Learning Systems and P2P Knowledge Networking

The concept of adoption is a quite interesting within the Information Systems literature. Flexible and dynamic capabilities of customization, personalization and diffusion require a multidisciplinary approach. Most e-learning systems are evaluated as monolithic. The technology of agents is setting new challenges for e-learning (Aldridge 2002). Several classifications of software agents can be found on literature but mainly four types depicted on figure 3 , can be justified. The current debate on e-learning is concentrated on smart techniques that will match specific learner characteristics and annotations of learning content in order to provide dynamic diffusion modes for learning content. In this context collaboration and learning are mixed so that a specific knowledge networking approach to provide the routes for the exploitation of stored learning materials. In case of dynamic adaptive systems, a more challenging idea is pursued.: the dynamic formation of distinct learning elements to meaningful learning situations. In the current consideration of semantics web the main emphasis is concentrated on a single-object interoperability without considering the challenging issue of providing a higher level of integration where interoperability will provide not only a transmission mechanism but also and a backbone for services of added value. Consider the case of a peer-to-peer network where a semantic layer provides an application, where several learning objects are matched in a case study builder for scenario planning learning.
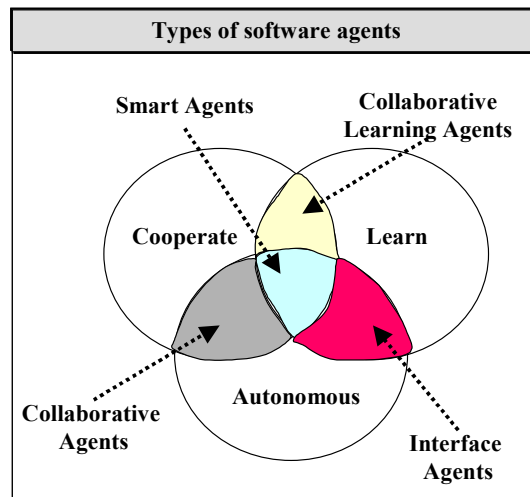
Figure 3. Types of Software Agents

(M. E. S. Mendes et al. 2002) discuss the importance of dynamic knowledge discovery and representation. Undoubtedly a key issue for e-learning success is not the fascinating technology that realizes the learning content packaging but the capacity of the infrastructure to support effective learning. In their approach two interesting techniques are evaluated: Fuzzy clustering and Topic Maps. The concept of clustering has recently been in the agenda of e-learning research community. Clustering algorithms aim to group data elements according to some similarity measure so that related elements are attributed to the same cluster. In this

statement we base a critical research question: Is it possible in an e-learning system to attach in every learning object a metric of value according to pedagogical criteria?

Ontologies

Ontologies semantically are composed by two words: "On" + "Logos" (in Greek), which means talking about the meaning of the object. By this definition, it is implied that any scientific research effort is ontology by definition. Several researchers provide clarifications of the term according to several aspect of the axiomatic Greek definition. Mizoguchi (1995) summarized the merits in an 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 realizes the backbone of the knowledge within a knowledge-based system. Finally he 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 on modelling. According to Van Belle research on ontologies, ontology engineering focuses on upper-level i.e. the equivalent of the meta-level in modelling. (Staab and Maedche 2000) , (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 N. 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 4 .
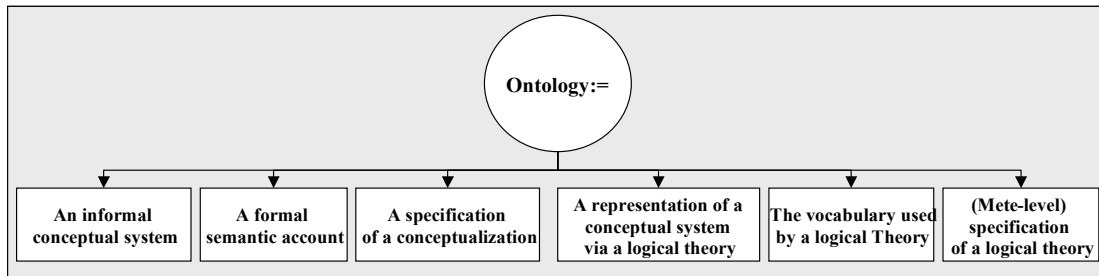

Figure 4. A Basic Clarification of Ontology

The above clarification sets a context for discussion of ontologies in the context of e-learning. In case of developing ontology for e-learning we can gain significant wisdom if we try to understand the deeper meaning of its definition.

An **ontology as an informal conceptual system** (Figure 5) 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. 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.
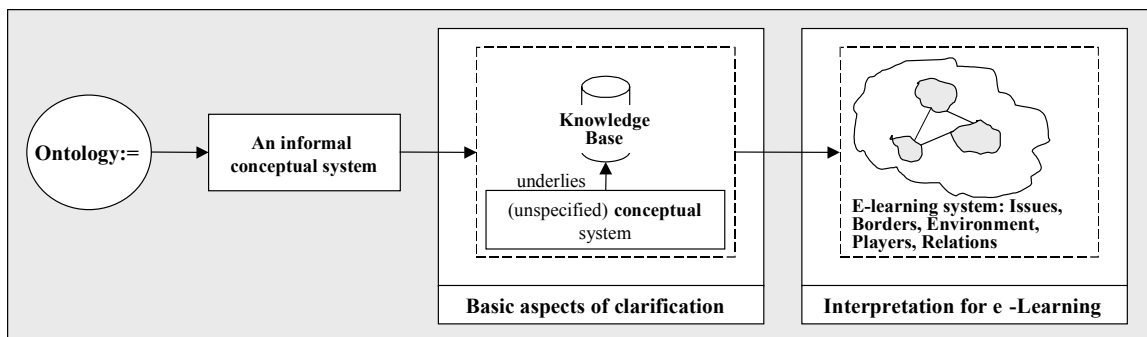

Figure 5. Ontology as an Informal Conceptual System

An ontology as a **formal semantic account** (Figure 6) means that we have analyzed 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.
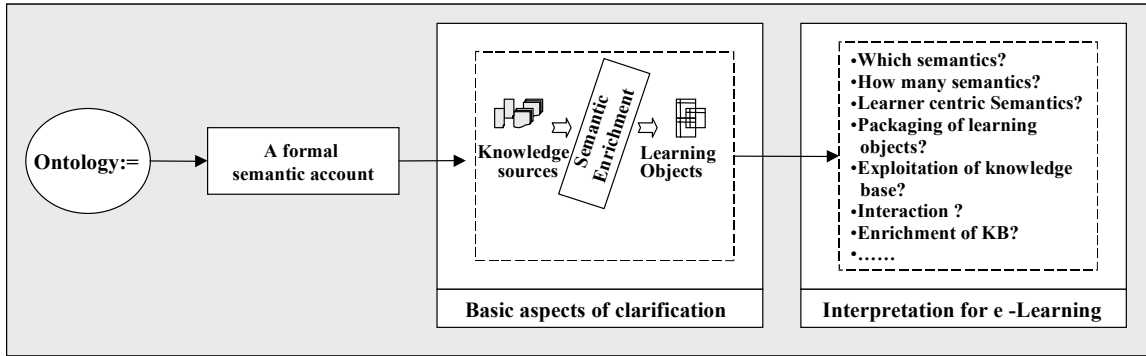

Figure 6. Ontology as a Formal Semantic Account

he most common definition of ontology is the **specification of conceptualization** (Figure 7). The precise meaning of such 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 the revelation of causal relations. Entities are distinguished, relations are drawn and several axioms define logic. In e-learning the conceptualization in implementation several times is not analyzed deeply. The employment of an e-learning system is based upon preconceptions of learners' cognitive levels and predefined abstractions of how people learn through technology.
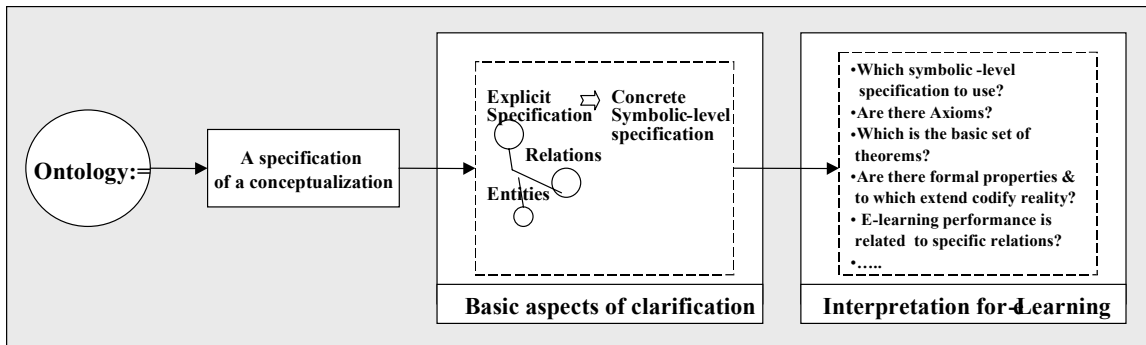

Figure 7. Ontology as a Specification of a Conceptualization

The next clarification, which considers ontology as the **representation of a conceptual system via a logical theory** (Figure 8) is quite interesting on e-learning context 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 admit 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 it is required an enormous effort for their specification.

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 do we prove the truth of a theorem or how can we 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 stand for the real world basic axioms have to be taken for self-evident in order to start the building of a constructive learning theory.
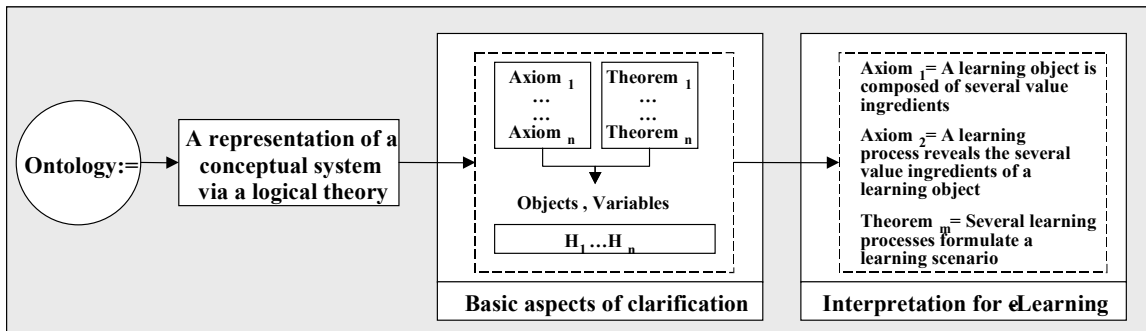

Figure 8. Ontology as a Representation of a Conceptual Theory via a Logical Theory

A slightly different clarification considers ontology as the **vocabulary used by a logical theory**. This differentiation focuses on logical definitions and clarifications of terms using an agreed syntax. Development of standards requires an enormous effort on the specification of a vocabulary but undoubtedly vocabularies and logical theory are just the two sides of the same coin. Another important aspect of this ontological perspective is the requirement to set extensible vocabularies avoiding extensive revisions of the whole set. For example consider the case where the logical theory that support 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 not only declarative, but also syntactic by using logical operands.
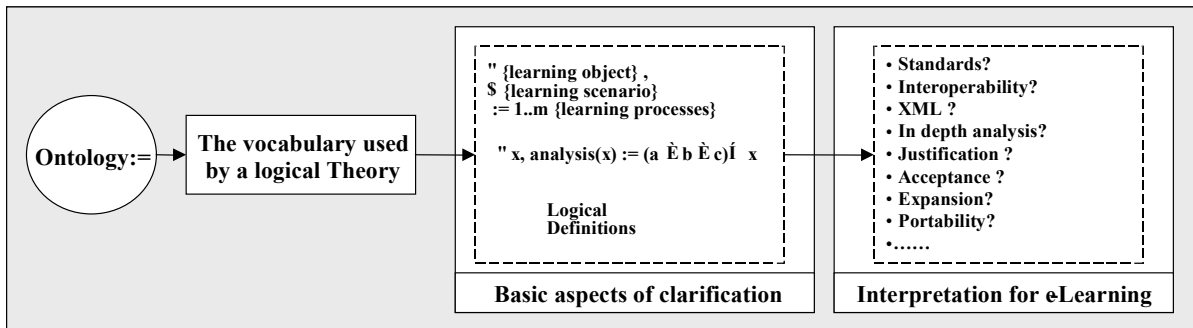

Figure 9. Ontology as the Vocabulary Used by a Logical Theory

Every time it is needed to analyze an aspect of reality then several levels of abstractions can be used. A common approach is to set an upper level or a meta-level where the emphasis of the analysis is on the specific object and the main logos.   To this end, we tried to set a context for ontological exploitation. In the next section we will elaborate further the main explanations provided in the Introduction. The overall objective is to concentrate on the practical aspects on how to build an ontology according to the main facets of clarification that Guarino and Giareta contributed.

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 according to (Perez and Benjamins 1999) 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. Our scope is not to illustrate exhaustive the several aspects of this process but to set a context for further exploitation. The conceptual

and the technological character of ontology are balanced and a combination of conceptualizations, formalizations and technological specifications in XML are provided. 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 convinced us that in the e-learning puzzle there is a need to propose a holistic approach for integrating several conceptual and technological aspects.
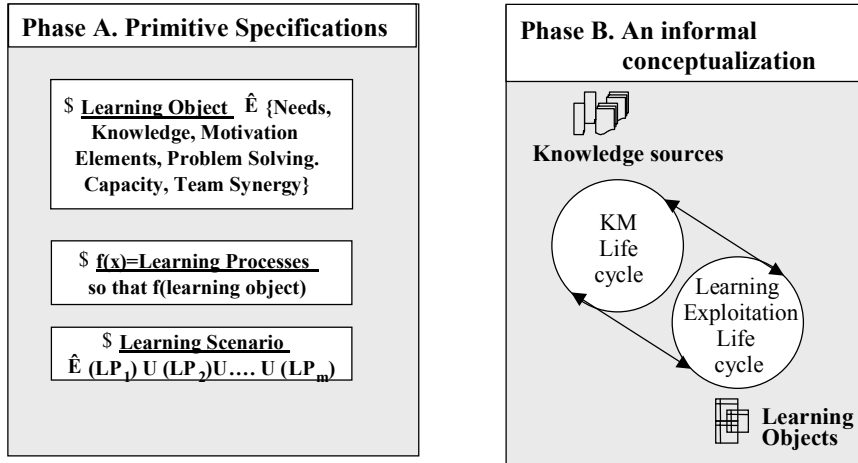

Figure 10. Phases A & B of the Development Process

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 10, refer to learning objects, learning processes and learning scenarios. So a learning object is defined as a value integrator of 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.
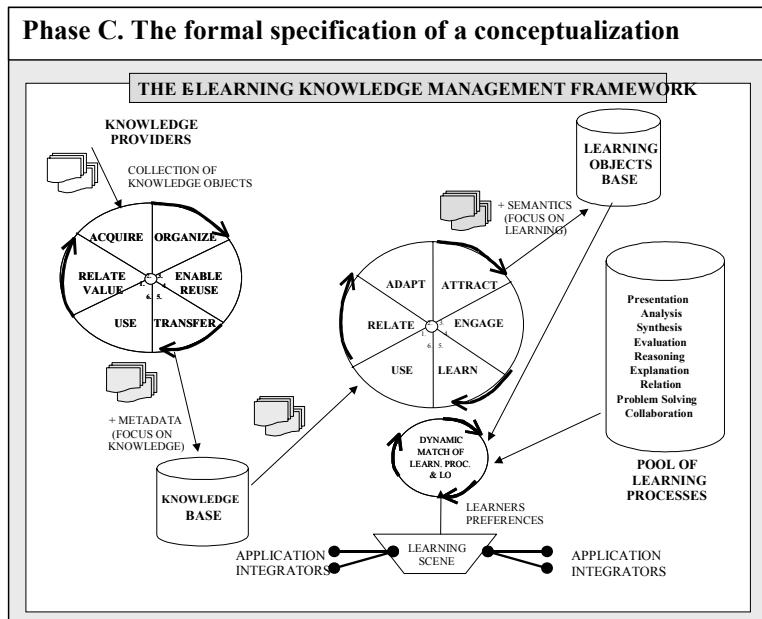

Figure 11. Phase C: The Formal Specification of a Conceptualization

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. 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 artefacts 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 et al. 2002c). By identifying that formalization has to be concentrated 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. From this perspective 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.
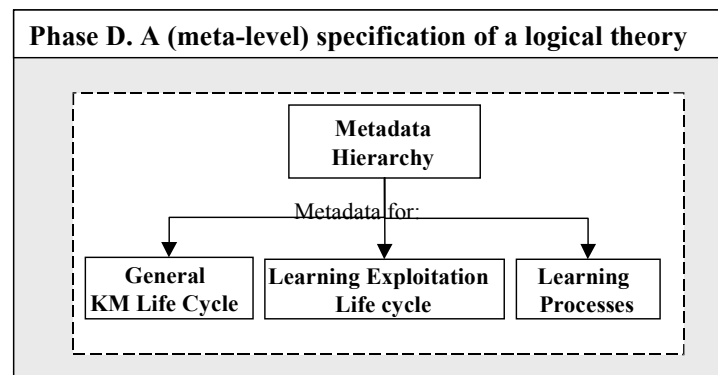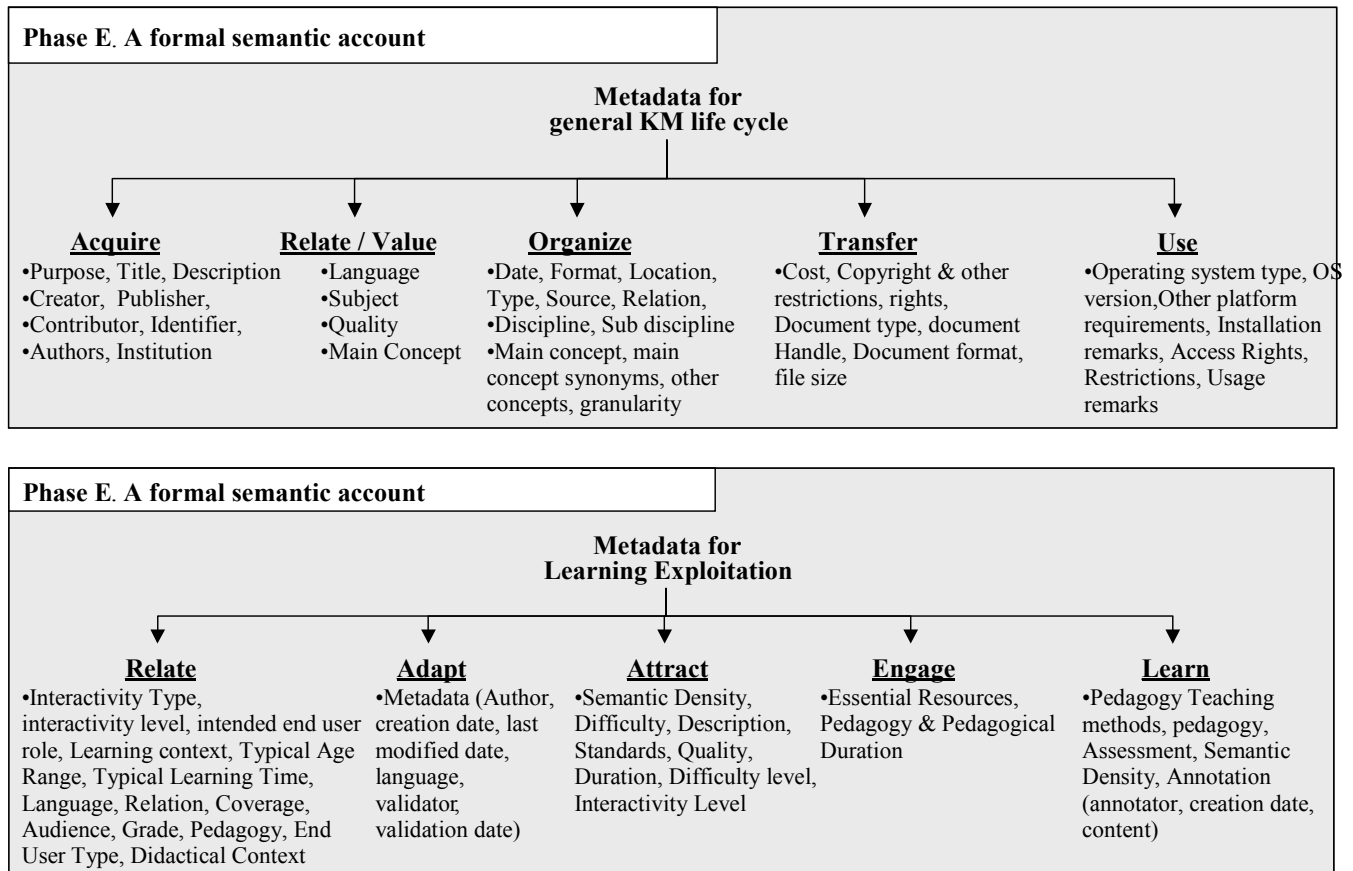

Figure 12. Phase D of the Development Process

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.

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 later 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 fulfill 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 of Learning Objects.

Phase E. A formal semantic account

**Metadata for
general KM life cycle**

Acquire	**Relate / Value**	**Organize**	**Transfer**	**Use**
•Purpose, Title, Description	•Language	•Date, Format, Location,	•Cost, Copyright & other	•Operating system type, OS
•Creator, Publisher,	•Subject	Type, Source, Relation,	restrictions, rights,	version,Other platform
•Contributor, Identifier,	•Quality	•Discipline, Sub discipline	Document type, document	requirements, Installation
•Authors, Institution	•Main Concept	•Main concept, main	Handle, Document format,	remarks, Access Rights,
		concept synonyms, other	file size	Restrictions, Usage
		concepts, granularity		remarks

Phase E. A formal semantic account

**Metadata for
Learning Exploitation**

Relate	**Adapt**	**Attract**	**Engage**	**Learn**
•Interactivity Type,	•Metadata (Author,	•Semantic Density,	•Essential Resources,	•Pedagogy Teaching
interactivity level, intended end user	creation date, last	Difficulty, Description,	Pedagogy & Pedagogical	methods, pedagogy,
role, Learning context, Typical Age	modified date,	Standards, Quality,	Duration	Assessment, Semantic
Range, Typical Learning Time,	language,	Duration, Difficulty level,		Density, Annotation
Language, Relation, Coverage,	validator,	Interactivity Level		(annotator, creation date,
Audience, Grade, Pedagogy, End	validation date)			content)
User Type, Didactical Context				

Figure 13. Phase E: Specification of the Formal Semantic Account

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. In current state 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. It is not immediately obvious that 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 modelling language- provides a more flexible framework because it can describe learning metadata more easily than XML does. Following the above issues, an RDF syntax can be applied to MDL metadata (Lytras et al. 2002a; Lytras, Pouloudi and Poulymenakou 2002d) as follows:

Table 2. RDF Syntax Applied to MDL Metadata

```
<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>
```

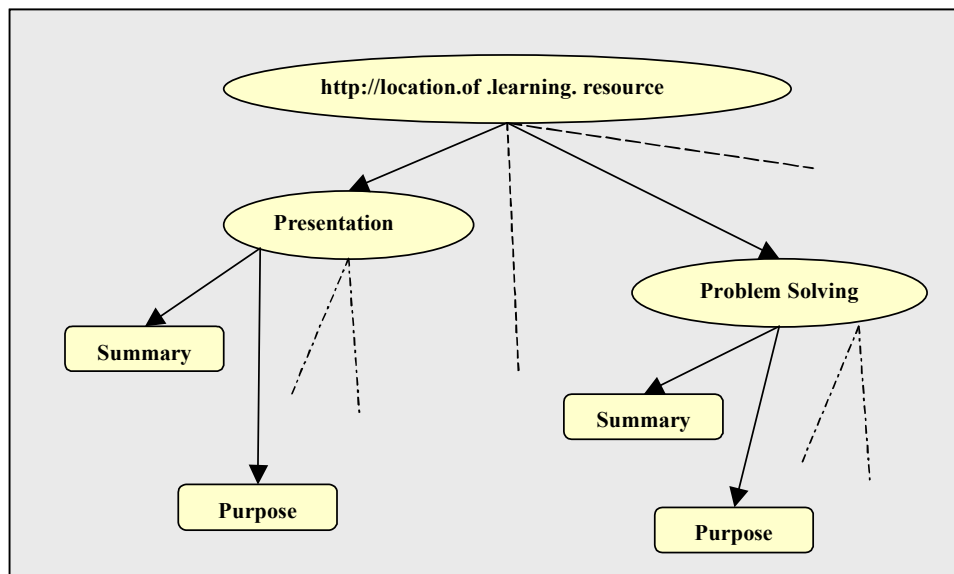Semantically the previous RDF notation can be visualized as follows :

Figure 14. A Visualized RDF Model for 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.

Conclusion and Future Research

The ultimate objective of our research is to justify e-learning as a field which requires enormous modeling 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 is building on our perceptions of reality that e-learning has direct linkages to knowledge management and pedagogy. The common mistake to overestimate the role of technology or pedagogy exclusively is the main reason for the failure of e-learning implementations. Balancing the effort between 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. In parallel with the ontological approach to e-learning we have done an extensive research on knowledge management and e-learning convergence (Lytras et al. 2002a; Lytras et al. 2002d) which guide us for the development of an e-learning platform entitled Semantics for E-learning.

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