Organizational memory supporting the continue transformation of engineering curricula

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Abstract. We consider seven knowledge components that constitute the pillars for building a document-based organizational memory for engineering curriculum design: epistemology, pedagogy, Philosophy, universal knowledge, internal academic knowledge, external academic knowledge and extra-academic knowledge. We present domain ontology for guiding access to, and management and retrieval of knowledge and information stored in annotated documents. The curriculum oriented organizational memory supports the construction, evaluation and continuous evolution of engineering curricula. The integration of knowledge and information for continuous curricular transformation is illustrated with a case study of an informatics curriculum.

Keywords. Knowledge management, organizational memory, ontology, curricula

1 Introduction

In early knowledge Systems, knowledge was extracted from experts of domain. Knowledge was represented as a set of heuristic rules for problem solution. The difficulty to construct heuristics based on the imprecise language of experts, without a methodological guide and a constrained space, delimited by the existence of heuristics, to solve problems, stimulated the use of models for knowledge acquisition and management. The approaches centred on the models construction dealt with different types of knowledge and differentiate knowledge explaining the system behaviour from knowledge related to implementation. Moreover, knowledge extracted form experts does not distinguish clearly Domain knowledge from Reasoning knowledge. Although this aspect has captured the interest of approaches oriented to models construction, the characterization of reasoning knowledge is not yet easy, as it remains constrained to reasoning about

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identified domain objects. We propose to extend the reasoning to consider created domain objects, additional semantic features, created agents from specific and global context, existent and created contextual objects and abstract interventions of existent and created agents. In this way, our work uses a meta-model of knowledge, in [4] in order to clarify the knowledge categories on the outside of domain knowledge. The concept Utilisation Context of a system, for example, is only a part of the Context and exceeds the scope of traditional reasoning models. In effect, Utilisation Context includes the existent and created agents, means and methods, as well as physical and abstract interventions of these agents, involving domain existent objects and created objects.

Knowledge meta-model presents two general categories: Domain Knowledge and Context Knowledge. Domain knowledge is currently represented as ontologies. In the last years a lot of ontologies have been proposed in different domains. For instance, enterprise ontologies are found in [10] and in TOVE project described in [8]. The work referred in [7] presents an ontology of organizational processes. An ontology of information systems is included in [11]. In European project INTEROP (www.interop-noe.org) ontology is a central concept in order to assure the interoperability of enterprise and software system. The same importance is recognized to the concept ontology in e-learning domain. Examples for ontologies in this domain are presented, among others, in [1, 2, 3, 5, 6].

We introduce the *Curricula Knowledge Ontology*, which is headed by concepts obtained from the two knowledge general categories of knowledge meta-model. The *Utilisation Context*, for exploiting curricula models, supports the definition of remainder concepts of the ontology.

Based on *Curricula Knowledge Ontology*, an Organizational Memory for curricula management is proposed. A study case centred on the construction, storage, retrieval, trace and transformation of a systems engineering curriculum, illustrates the application of the Organizational Memory.

After the Introduction, this paper is organized as follows. The selection of Knowledge and Information Areas corresponds to Section2. Ontology and Organizational Memory Structure is explained in Section 3. A study case in Systems engineering domain is presented in Section 4. Section 5 deals with the results and future works. Bibliography is the object of last Section.

2 Delimitation of knowledge and Information

Curriculum is, in general sense, a set of knowledge areas arranged, in space and time, for teaching and learning. Thus, curriculum relates knowledge, methods, resources, strategies, managerial concepts to facilitate teaching and learning. In this reference frame, it is necessary to delimit the scope in order to construct a curriculum model for engineering programs.

At first, knowledge general areas are conceptualized using the knowledge meta-model proposed in [4]. This knowledge meta-model contains two capital knowledge categories: *Domain Knowledge* and *Context Knowledge*. For sake of space, knowledge meta-model is not depicted.

The natural domain for curricula development encloses the part of the universal knowledge necessary to satisfy social needs belonging to the field of engineering. This fraction of knowledge feeds the curriculum model with knowledge arising from these two contexts. The two next paragraphs verify which categories of knowledge Meta-model provide the knowledge for engineering curriculum models.

Domain Knowledge includes knowledge centred on: existent and created domain objects, considering object's features and their relationships, object semantic concepts and Agent Interventions, which involve physical and intellectual treatments of objects. Agent intervention expresses actions and interactions of agents. It uses known and created relationships among objects. Thus, *Domain Knowledge* contains the knowledge associated to the domain objects, which represent the part of the universal knowledge necessary to satisfy social needs, belonging to the field of engineering.

Context Knowledge is focused on: existent and created agents, means and methods, contextual objects, semantic concepts and Agent Interventions involving existent and created context objects. Agents Interventions may be physical or intellectual. We consider three context types: Social, Organizational and Systemic. Context Knowledge is divided into *Global Context Knowledge* and S*pecific Context Knowledge*. Existent and Created agents, means and methods, their semantic characteristic and their relationships constitute the *Specific Context Knowledge*, while contextual objects, their semantic characteristics, their relationships and agent interventions involving the contextual object compound the G*lobal Context Knowledge*. Agent interventions, involving means, methods and domain objects determine the *Utilisation Context*, which defines the interactions of agents of the *Specific Context Knowledge* involving the part of the universal knowledge necessary to satisfy social needs, belonging to the field of engineering. This part of universal knowledge belongs to *Domain knowledge* and is found in particular knowledge areas constituting the support of engineering curricula models.

The problem at this point consists of determining knowledge general categories of engineering curricula models, leading to the construction of these models. Because of this, we construct the Utilisation Context of engineering's curricula, Figure 1, aiming to define knowledge general categories considering typical interactions of agents. From a pattern of typical interactions of commercial agents, presented in [9], we keep only two interactions: "Request and delivery of service and objects of information and knowledge" and "Request and delivery of information and knowledge: scientific, technological, technique, social, marketing, organizational, commercial, economic, legal and personal".

The agents related by the engineering curricula are introduced in the *Utilisation Context*, in Figure 1. By imagining the above proposed typical agent interaction, using the envisioned engineering curricula models as a means, the following general categories of knowledge are identified: epistemology, pedagogy, philosophy, universal knowledge, internal academic knowledge, external academic knowledge and extra-academic knowledge.

From these general categories of knowledge, the particular categories of knowledge are defined in next Section

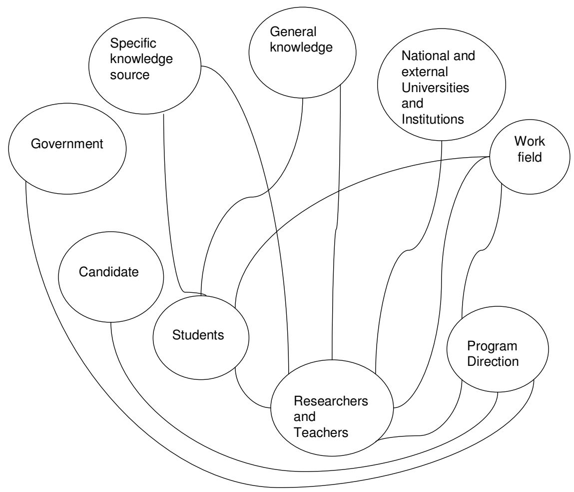

Figure 1. Curricula Utilisation Context

3 Ontology and Organizational Memory Structure

The elements and relationships presented in the Ontology of Curricular knowledge Categories constitute the resources to construct the curricula models. Moreover, the ontology contains the essential categories to organize and trace the knowledge related to the construction, application, evaluation and transformation of curricular models. This knowledge may be managed in an Organizational Memory structured according to concepts of the ontology.

3.1 Ontology of Curricular Knowledge Categories

Domain Knowledge and Context Knowledge specialize the top concept of the curricular knowledge ontology. The knowledge general categories of engineering curricula models, defined in the previous Section, constitute the second level of ontology depicted in Figure 2. Other ontology levels consider the particular categories of knowledge, which are essential meta-concepts to construct curricula models. Meta-concepts of the Ontology of Curricular knowledge Categories lead to define the concepts for constructing the engineering curricula models. For instance, the meta-concept Universal Knowledge leads to define the concepts Mathematic, Physic, Chemistry, Biology, Economy, Management, etc.

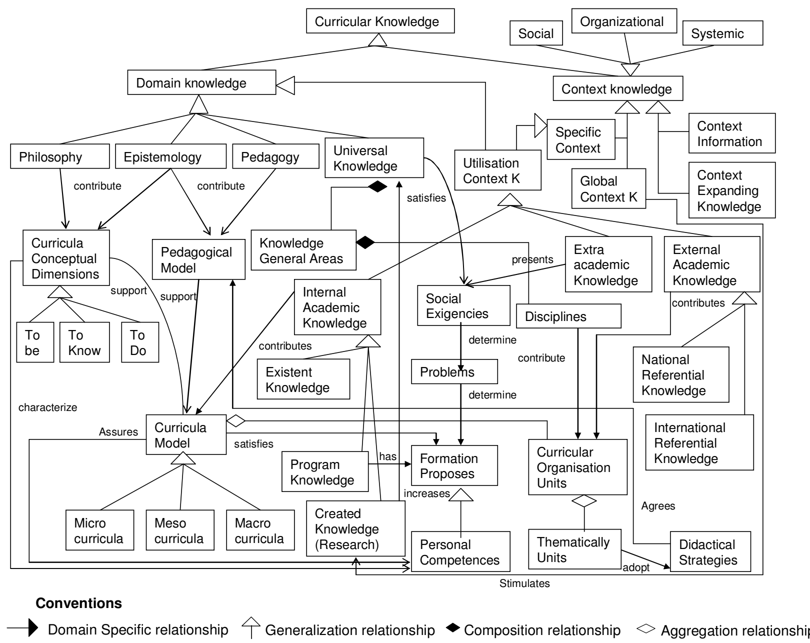

Figure 1. Ontology of Curricular Knowledge Categories

The ontology drive to define *what* Curricula models may do, *how* they do it, *why* they do it, *for what* they do it, as well as to construct pertinent and effective curricula. For assuring that curricula answer the mentioned questions, we propose a set of criteria that the curricula models of engineering have to incorporate:

a) Be focused on an undergraduate engineering curriculum adopting specific formation proposes.
b) Be based on solution of problems related to social needs.
c) Pertinence and effectiveness in the problems solutions
d) Be supported on pedagogical models centred on research. The students are directly related to knowledge.
e) Adaptability facing the social, economic, scientific, technological and technical changes
f) Be fed by scientific and technological developments
g) Be oriented to create open mind, autonomous and creative engineers
h) Integral formation of persons, considering three human dimensions.: to be, to know and to do.
i) Flexibility aiming to offer alternative formations and to develop vocational options for the students
j) Pertinence in contents according to specific areas of knowledge of other national and international institutions and to new knowledge trends.
k) Continuous revision and improvement of curriculum

Relating these criteria to the concepts of the second ontology's level, the remainder concepts of the ontology, in Figure 2, are defined.

Criterion a) drives to discover the concepts *curriculum model* and *formation purposes*. *Social Needs* and *Problems* arise from criterion b). From criterion c) arises the concept *extra academic knowledge*. Criteria c), d) and i) induce the concepts *knowledge general areas*, *curricular organization units*, *thematic units*, *didactical strategies*. *Personal competences* are a concept suggested by criterion g). Criterion h) provides the concept *Curriculum conceptual dimensions*. The analysis of criterion j) produces the concept *external academic knowledge*.

The predominant relationships among ontology concepts are: "is- a", "composition", "aggregation" and "specific of domain" relationships. These relationships leave from domain knowledge, in particular from the concepts expressing semantic characteristics of the domain objects.

3.2 Organizational Memory Structure

Considering that the ontology represents the essential concepts to construct curricula models, these concepts are pertinent to structure an Organizational Memory aiming to stores, retrieval, trace and transformation of curricula models. Ontology concepts constitute the tags to annotate their associated documents arranging an XML document. Thus, the Organizational Memory Structure is an instanceable hierarchy of tags containing the annotated documents related to ontology concepts. These concepts are complemented in the Organizational Memory, with characteristics such as class, type, subtype and attributes, in order to make possible the storage of nested instances of different document types. The new elements are created objects, important for referencing and representing structured documents. Created objects do not constitute, in principle, essential domain objects.

This characterization of created objects validates our classification of *Information* and *Information systems*, introduced in [4]. In this report, three categories of *Information* and *Information Systems* are considered. That is, the *Traditional Information Systems* involve Consolidated Information (Domain Predefined knowledge), while the *Evolving Information Systems* manage Transitional Information (Domain Referenced Knowledge). The third category corresponds to *Prospecting Information Systems*, which deal with Emerging Information (Domain Discovered Knowledge).

Here, we verify the transition from *Traditional Information Systems* to *Evolving Information Systems* (e.g. XML based systems, Web systems), by introduction of domain created objects and knowledge engineering techniques. In effect, the transition is marked by the introduction of new domain objects, created objects, in order to represent and manage the information by means of nested information structures. There, the information is not yet managed in predefined well established processes, but organized to be systematically dealt with knowledge engineering techniques.

Next Section illustrates the use of the Organizational Memory for managing knowledge that guides the construction, trace, evaluation and transformation of an engineering curriculum model.

4 A study case in Systems engineering domain

The ontology of curricular knowledge categories constitutes a meta-model of engineering curricula. Specific curricula of different fields of engineering are instances of ontology. The meta-concepts of the ontology are judged pertinent and sufficient for constructing, storing, retrieving, tracing and transforming of engineering curricula models. In effect, these meta-concepts allow us to identify and manage an extended gamma of knowledge of different nature.

The results of the study of curriculum model for the program of systems engineering at the University of Antioquia is a worthwhile model for testing the goodness of the Organizational Memory.

The Memory covering all the concepts of the ontology assures the quality of the knowledge required to make the engineering curricula evolve. For the sake of simplicity, we do not include the whole XML-model based Organizational Memory for a systems engineering curriculum. Next paragraph depicts some tags corresponding to problems arising from social context characterized as extra academic knowledge.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSPY v5 rel. 2 U (http://www.xmlspy.com)-->
<CURRICULA_KNOWLEDGE xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="C:\Documents and Settings\German Urrego\Mes documents\CE2007\ONTOLOGIA\CURRICULUM ONTOLOGIA_version_EJEMPLO.xsd">
    <CONTEXT_KNOWLEDGE>
        <UTILISATION_CONTEXT_KNOWLEDGE>
            <EXTRA_ACADEMIC_KNOWLEDGE>
                <SOCIAL_EXIGENCIES>
                    <PROBLEMS>El desarrollo de soluciones informáticas para la transacción (transmisión, consulta, almacenamiento y procesamiento) de información a través de amplias redes de computadores</PROBLEMS>
                    <PROBLEMS>El desarrollo de sistemas informáticos que apoyen la gestión organizacional moderna</PROBLEMS>
                    <PROBLEMS>El desarrollo de herramientas informáticas didácticas, que apoyen el proceso docente-educativo</PROBLEMS>
                    <PROBLEMS>Automatización y control de procesos</PROBLEMS>
                </SOCIAL_EXIGENCIES>
            </EXTRA_ACADEMIC_KNOWLEDGE>
        </UTILISATION_CONTEXT_KNOWLEDGE>
    </CONTEXT_KNOWLEDGE>
</CURRICULA_KNOWLEDGE>
```


5 Conclusions and Future Works

The delimitation of total Universal Knowledge for defining the domain of curricula models uses the knowledge meta-model, introduced in [4], where *domain* and *context knowledge* are considered. The characterization of *domain* and *context* concepts, introduced in [9] contributes to relate information engineering and knowledge engineering. The Knowledge General Categories for the domain ontology are extracted from the total universal knowledge, using the *Context Utilisation Model*. This model represents interventions of agents of the *Specific Context* involving *Domain objects*.

Knowledge General Categories constitute the second level of the ontology, which are subordinated to one of the first level concepts: *Domain Knowledge* and *Context Knowledge*. The remainder of ontology is fed with Knowledge Particular Categories arising from proposed criteria to define curricula models.

The elements of the Ontology of Curricular Knowledge Categories are meta-concepts. These elements cover the instances of curricular models in all fields of knowledge. In this work we are centred on engineering curricula models

The transition from the ontology to the Curricular Organizational Memory involved new domain objects, created objects, in order to represent and manage the information by means of nested information structures, e.g. XML models. That signifies the transition from Traditional Information Systems, centred on predefined information, to Evolving Information Systems, in which information is not yet managed in predefined well established processes, but organized to be systematically dealt with knowledge engineering techniques (e.g. XML based systems, Web systems).

The XML-based Curricular Organization Memory is illustrated in this work by a systems engineering curriculum. Only a small part of the instantiated Organizational Memory of Engineering Curricula is presented in this work.

Ongoing work searches to construct Curricula Organizational Memories for different engineering programmes and for other academic aspects. At the same time, we propose to apply Curricula Organizational Memories in e-learning fields using the web infrastructure..

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