An Ontological Representation of Learning Objects and Learning Designs as Codified Knowledge

Salvador Sánchez-Alonso
Computer Science Department,
University of Alcalá, Madrid, Spain

Dirk Frosch-Wilke
Faculty of Business Management,
University of Applied Sciences, Kiel, Germany

The authors

Salvador Sánchez-Alonso
Dirk Frosch-Wilke

Keywords

E-Learning, Learning Objects, Ontologies, Knowledge Management

Abstract

In current organizations, the models of knowledge creation enunciate concrete processes and elements that drive the production of knowledge aimed at satisfying organizational objectives. The Knowledge Life Cycle (KLC) model of the KMCI provides a comprehensive framework for situating learning-oriented artefacts as part of the organizational context. Recent work on the design and creation of learning resources can be compared to this model of knowledge production, as well as the so-called integration processes may be considered to subsume programmed organizational learning activities. In this paper, we discuss about the similarities between the life cycle of KM and the processes in which learning objects are created, evaluated and used. The learning object concept will then be connected to existing KLC models in order to provide a more comprehensive framework for reuse-oriented e-learning and KM. This paper also depicts the framework's integration into the KLC of the KMCI in the form of ontological definitions.

Introduction

Models of knowledge creation inside organizations are considered as dynamic processes of development that evolve over time (Cavaleri and Reed, 2000). Such models provide a breakdown of the creation process in terms of concrete processes and elements that drive the overall production of knowledge as targeted to satisfy organizational expectations. For example, the *Knowledge Life Cycle* (KLC) model of the KMCI[1] distinguishes the *Knowledge Processing Environment* (KPE) from the *Business Processing Environment* (BPE), describing the latter as the context of actual usage and field assessment of the claims produced and evaluated in the former. This emphasizes the fact that knowledge codified in artefacts as part of *Knowledge Production* (KP) processes and disseminated as part of *Knowledge Integration* (KI) processes will be subject to further validation in actual business experience. KLC models provide a comprehensive framework for situating learning-oriented artefacts as part of the organizational context. Concretely, the design and creation of learning resources (Downes, 2004) is not different at its essence from knowledge production, and integration processes may be considered to subsume programmed organizational learning activities. Furthermore, meta-claims about the knowledge produced – in the case of learning oriented artefacts – may be interpreted as the recording of usage conditions, hypotheses and assumptions on the learning resources being created. In consequence, the relationships between Knowledge Management (KM) and the design of reusable learning resources can be approached from two perspectives. On one hand, there is some similarity between the life cycles of KM and the processes in which learning objects (Polsani, 2003) are created, evaluated and used in organizational contexts. On the other hand, the application of the learning object concept can be put in connection with existing KLC models, in an attempt to provide a comprehensive framework for reuse-oriented e-learning and KM. This latter view is the one addressed in this paper, following the rationale that e-learning can be considered an important component of the KM function, as described by Wild, Griggs, and Downing (2002).

The described relationships provide a direct mapping both for the codification of ontological commitments about learning theories (Sicilia and Lytras, 2005), and also for metadata approaches that follow a contractual paradigm (Sicilia and Sánchez-Alonso, 2003). In this paper, we approach the integration of concepts related to learning resources into the framework of the KLC. This would clarify the relationships between Knowledge Management and e-learning paradigms that have been yet addressed elsewhere in its main directions (Sicilia and García, 2005). The method to develop the conceptual integration is that of engineering an initial ontological description for the main concepts,

[1] http://www.kmci.org

connecting them to existing ontological databases. This continues existing work described by Sicilia, Lytras, Rodríguez and García (2005) regarding the ontological description of learning activities as an extension of the ontology of KM described recently by Holsapple and Joshi (2004).

Formal ontologies (Baader et al., 2003) are a vehicle for the representation of shared conceptualizations that is useful for technology-intensive organizations. Ontologies based on description logics (Gruber, 1995) or related formalisms provide the added benefit of enabling certain kinds of reasoning over the terms, relations and axioms that describe the domain. A pragmatic benefit of the use of formal ontologies is that it is accompanied by a growing body of Semantic Web (Berners-Lee, Lassila and Hendler, 2001) tools, techniques and knowledge. Previous work considered here as a point of departure (Sicilia, García, Sánchez-Alonso and Rodríguez, 2004) has described the integration e-learning technology concepts with the *OpenCyc* knowledge base, the open source version of the *Cyc* system (Lenat, 1995). Additionally, the provision of knowledge representations integrating KM and e-learning standards has been pointed out as an important research direction (Sicilia and García, 2005).

The rest of this paper is structured as follows. The second section describes learning objects and learning designs and depicts their integration into the KLC of the KMCI. Then, the third section provides the main ontological definitions required to represent the proposed integration, putting them into relation with previous research in the topic. Finally, conclusions are provided in the fourth section.

Integrating learning objects and learning designs in a KLC ontology

In this section, the related concepts of learning object and learning design are described as the two main elements to be integrated as resources in the KLC. Then, their integration inside the KLC model of the KMCI is described.

Learning objects and learning designs

The increasing interest in Web-based education has resulted in a number of standardization efforts aimed at fostering the portability and shared usage semantics of learning contents and learner information across vendors, platforms and systems. As a matter of fact, it is possible today to package a Web-oriented course according to standard formats - e.g. according to SCORM[2] packaging models – and then importing and using that same content inside any Learning Management System (LMS) that is compliant with the given standard packaging rules. In addition, the scope of such standards and specifications is continuously expanding and covering new areas; for example, the SCORM "sequencing and navigation" specification addresses the standardization of complex navigation and sequencing strategies. Another interesting example is that of IMS "Learning Design"[3], which is targeted to modelling rich learning activities and their pedagogical considerations. The concept of *Learning Object (LO)* is at the centre of the new paradigm for instructional design of Web-based learning that emphasizes reuse as a quality characteristic of learning contents and activities. For example, Polsani (2003) includes reuse in his definition of learning object as "an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts", and Wiley (2001) also mentions the term in his learning object definition "any digital resource that can be reused to support learning". The basic metadata elements associated to learning objects have been described in the IEEE LOM standard (IEEE, 2002). Learning objects are considered as reusable elements that can be used as part of *Learning Designs (LD)*. The IMS LD provides a powerful language for the expression of learning designs targeted at the realization of activities. An activity is considered as a piece of interaction among a number of specified roles played by persons that produce a tangible outcome by using a concrete environment made up of learning objects and services (facilities available at runtime). Activities can be further decomposed in sub-activities, and they are aggregated into methods, that specify the conditions for application of the learning design, along with the planned objectives that will eventually match the outcomes of the activities. Methods can be structured around concurrent plays and these in turn can be structured in sequential acts, the latter allowing the specification of execution conditions. This schematic description of LD gives an idea of the flexibility the specification provides in describing activity-based learning programs. The practical use of LD-based tools would then allow for the definition of the activities resulting from a process of instructional design that takes as point of departure a concrete perspective about learning that drives the crafting of the activities.

A conceptual framework for integration

The main elements of the integration are depicted in Figure 1, which has been elaborated from the original KLC of the KMCI by including mappings to concrete LO and LD usage points.

As depicted in Figure 1, both LOs and LDs are part of organizational knowledge, and concretely, they can be classified as Codified Knowledge Claims (CKC) in a general sense. Nonetheless, the nature of such claims is of a diverse nature:

- Some of them may be considered as "elementary" in the sense that they will not usually be subject to a formal cycle of evaluation in the Business Processing Environment. The reasons for this are that some external codified knowledge as courses on basic computer skills are not actually related to

[2] http://www.adlnet.org

[3] http://www.imsproject.org

"business processing outcomes", so that they are not subject to direct revision processes by business experience, even though they may be subject to revision as part of other revision processes in which they are required as prerequisites. This is why, they "survive" while they are useful for operational reasons. Another example is that of LOs that are used to communicate internal information like the distribution of the office building or the way to find somebody in the company. These will be "falsified", i.e. changed as part of the normal functioning of administrative processing, not necessarily related to business functions. These less controversial elements can be considered as simple "information" and not "knowledge" that have survived an evaluation process.

- The knowledge provided by LDs as opposed to the learning objects it uses, is of a pedagogical or methodological nature, i.e. their contents are related to how produce learning in purposefully arranged learning activities. In consequence, they will be subject to evaluation in processes of *Knowledge Integration* (teaching, sharing or similar ones), rather than in the *Business Processing Environment*. In context of KM such evaluations must be often different from evaluations of "traditional" course design, because production of knowledge (and the LOs that spin out of that) is mostly a collective activity (Allee, 2000). In consequence, this might imply that social constructs (e.g. Communities of Practice, Virtual Teams) of corporations have to be integrated in activity-based learning programs. The effectiveness of this integration as well as the relevance of communities in Knowledge Integration processes have to be evaluated here.

The *Knowledge Production* part of the model must be extended to cope with a specific form of *Problem Claim Formulation* that we have called "LO/LD contract/goal". The idea of this extension is that the knowledge gap may in some cases be stated in terms of learning goals. *Contract-based* techniques (Sicilia and Sánchez-Alonso, 2003) can be interpreted as claim-producing procedures for educational goals, specially targeted to LO and LD selection and/or composition. *Individual and group learning* activities may produce knowledge from LOs and the activities that surround them, and *Information Acquisition* can in some cases take the form of processes of search and composition of learning objects or activities. This is a form of *reuse* in the process of production that is complementary to the reuse taking place routinely in the business processing environment. Finally, the critical process of *Knowledge Claim Evaluation* will in some cases entail the evaluation of learning objects via existing validated instruments (Vargo et al., 2003) or quality criteria.

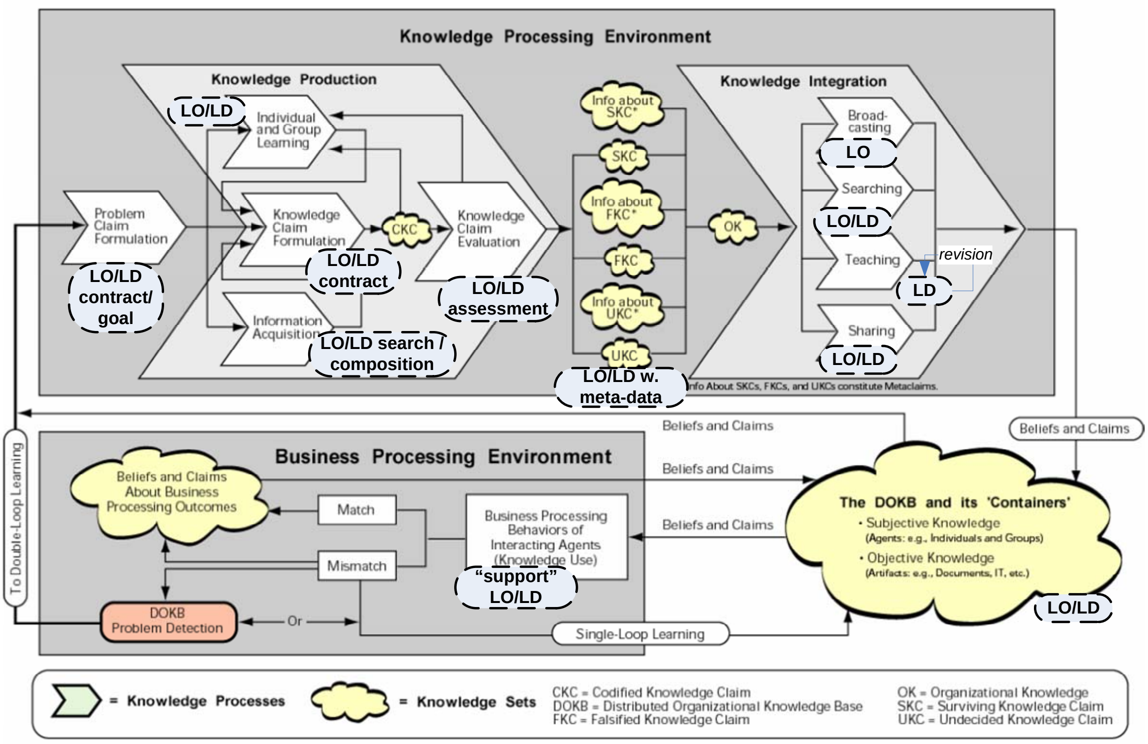

Figure 1. Mapping of the main elements of learning objects and learning designs to the KLC model

The positive outcomes of evaluation are considered as (surviving) knowledge that becomes part of the DOKB. In the particular case of producing LOs/LDs, these become available for use inside the organization. Here it is important to note that meta-claims for learning objects are commonly considered as *intrinsic* to them, i.e. the metadata is considered as part of the learning object or design.

An additional detail in the model is that some LOs and LDs are suited to supporting business processing. Even though not all of them may come from a knowledge validation process, this should be taken into account at least for the purpose of tracking and measuring their usefulness for actual operations. In this context LOs/LDs are used like every other knowledge objects of the DOKB. Vice versa knowledge objects in the DOKB can be downsized to LOs resulting in relevant and up to date learning content.

Main elements of a KLC-based ontology of learning objects and learning designs

This section sketches the main integration points of the KLC with learning objects and learning designs in the framework of existing work in formally conceptualizing KM. In addition, it describes the main structural elements of LOs and LDs regarding the concept of CKC in the KLC model.

Main connecting elements

The ontology of Holsapple and Joshi (2004) describes fundamental KM concepts and axioms. The definition of KM in H&J ontology "An entity's systematic and deliberate efforts to expand, cultivate, and apply available knowledge in ways that add value to the entity [..]" [DKMC1]. This requires the early definition of "entities'" capable of engaging in KM, which are considered to include at least individuals, organizations, collaborating organizations and nations, as stated in [DKMC2-5]. The term `Organization` in *OpenCyc* covers all such entities. The concept of knowledge processor [DKMC10] as a member of an entity can be modelled by the concept of `IntelligentAgent`, which are by definition "capable of knowing and acting, and of employing their knowledge in their actions". Humans are by logical definition intelligent agents and certain software pieces may also be, since they are not restricted to not being able to know [AKMC10]. The subtype `MultiIndividualAgent` fits the definition of collective agents [AKMC11]. According to Cavalieri and Reed (2000), knowledge creation is "the result of efforts by agents, acting either as individuals, or collaboratively, as an element of a system, to make sense of their environment". This definition focuses on the *identity* of the organization as a key driver of its learning behaviour, and is complemented by a concrete view on creation as a process in which agents apply rules to perceived sets of circumstances to attain desired outcomes.

The definition of *Knowledge* as "that which is conveyed by usable representations" [DKMC6] can be integrated in *OpenCyc* by considering usable representations [AKMC2] as information bearing things, i.e. "Each instance of `InformationBearingThing` (or "IBT'") is an item that contains information (for an agent who knows how to interpret it)". This is appropriate at least for CKC that are tangible outcomes of the production process. Nonetheless, the KLC emphasizes the evaluation of information as tentative *Knowledge Claims*, so that terms subsumed by IBT are required to adequately fit in the KLC, including the following:

- `EvaluatedKnowledgeClaim` representing the "surviving" claims, which are required to have been `subjectTo` at least one `KnowledgeClaimEvaluation` process with a positive outcome.
- `FalsifiedKnowledgeClaims`, with the opposite definition.
- The rest of the `KnowledgeClaim` instances are subsumed by `UndecidedKnowledgeClaim`, representing different states before or after claim evaluation.

`KnowledgeClaimEvaluation` instances are a concrete kind of knowledge manipulation. The recognizable kinds of knowledge manipulation are referred to as *Knowledge Manipulation Activity* (KMA) [DKMC12]. Activities in *OpenCyc* are represented as `Action`s, which are a collection of Events carried out (`doneBy`) a "doer'". This generic concept of action can be specialized to represent KMA executions by restricting them to be carried out by intelligent agents. The predicate `ibtUsed` (subsuming the above mentioned `subjectTo`) can be used to represent the knowledge representations manipulated by KMAs. In addition, since KM activities are deliberate, it is better to use the subclass `PurposefulAction.` Each of the processes in Figure 1 can be considered as KMAs.

Learning in the H&J ontology is defined as "a process whereby KRs are modified; an outcome of a KME involving change in the state of an entity's knowledge" [DKMC17]. This entails that learning is considered as a (positive) change in one or several IBTs, or in some specific cases, in the knowledge attributed to one or several agents inside the organization. Discrete learning events can be characterized as the difference in the extent of the `knows` predicate of an agent after the execution of a concrete KMA. This can be expressed by referring to each know-related item through a `learntIn` predicate (a specialized inverse of `eventOutcomes`). However, it should be noted that learning may take place in the context of knowledge production, knowledge integration and even in business processing. The main difference is that conventional "programmed" learning activities are more often carried out at integration time.

A framework to describe objects and designs for learning

Learning objects in the context described are considered as codifications of information, some of them bearing information regarding one or several `EvaluatedKnowledgeClaim`s. Nonetheless, there is still a need to clarify what are the nature and structure of that particular class of `IBT`s. Regarding their nature, they can be of any granularity or purpose, including business strategies, organizational models, product strategies, but also finer-grained elements like the particular knowledge on the characteristics of a product component. Regarding their structure, anything covered by existing learning standards like SCORM could in principle represent complex document or hypermedia structures. Nonetheless, as stressed by Frosch-Wilke (2004), the relationships between them should be made clear and precise. Since we are interested in learning objects encoding claims that suffer evaluation procedures, other claims that are premises for inference of each given one must be explicitly recorded. This would enable the "transitive" evaluation or falsification of claims. In other words, when evaluating a given codified claim, the claims that depend on them are tacitly put under evaluation, and the eventual rejection of the claim will result the dependant ones to become at least "undecided". Moreover, every learning object referring to a recently falsified claim should be marked as outdated or obsolete to prevent misuse of information.

Learning designs are of a different nature in that they are prescribed courses of action in which concrete `Agent` roles are required to engage in `Actions` with well-specified objectives. Here the consideration of evaluation differs in that the criteria become that of the estimated or demonstrated usefulness of the concrete arrangement of activities, resources and roles to achieve certain learning or knowledge-producing goals. In addition, learning designs in the context of Knowledge Production should be oriented to creating *Communities of Inquiry*, which differ from *Communities of Practice* in that the criteria for the claims considered best is not consensus or democratic opinion, but formal evaluation procedures in which evidence and justifications are subject to rigorous evaluation. This is not required in Knowledge Integration or business processing contexts, in which the main outcome is learning or support for business functions.

Conclusions

Learning objects and learning designs can be integrated in the broader framework of a Knowledge Management Lifecycle, providing guidance for Information System development and insights into notions of organizational value of learning resources, which remain largely unexplored. Concretely, a feasible integration of such concepts into the KMCI KLC model has been described. Learning objects and learning designs are considered as codified knowledge claims, some of them being used and reused in actual business processing. In addition, they are the product of some knowledge production processes and become a vehicle for dissemination in Knowledge Integration activities. Their evaluation can take place as part of knowledge production, business processing or even in the context of knowledge integration, in which activity programs should become evaluated as artefacts for dissemination in themselves.

The resulting ontological schemes are intended as a foundation for further research and standardization activities.

References

Allee, V. (2000) E-Learning is Not Knowledge Management, LiNE Zine, Fall 2000, http://linezine.com/2.1/features/vaenkm.htm.

Baader, F., Calvanese, D., McGuinness, D., Nardi, D. and Patel-Schneider, P. (eds.). (2003). *The Description Logic Handbook. Theory, Implementation and Applications*, Cambridge.

Berners-Lee, T., Hendler, J. and Lassila, O. (2001). The Semantic Web. *Scientific American*, 284(5), 34-43.

Cavaleri, S. and Reed, F. (2000). Designing Knowledge Creating Processes. *Knowledge and Innovation*, 1(1).

Downes, S. (2004). Resource Profiles. *Journal of Interactive Media in Education*, 2004 (5).

Frosch-Wilke, D. (2004). An Extended and Adaptable Information Model for Learning Objects. In *Proceedings of the ICALT 2004*, pp.166-170.

Gruber T. (1995). Towards principles for the design of ontologies used for knowledge sharing. *International Journal of Human-Computer studies*, 43 (5/6), 907 - 928.

Holsapple, C.W. and Joshi, K.D. (2004). A formal knowledge management ontology: Conduct, activities, resources, and influences. *Journal of the American Society for Information Science and Technology*, 55(7), pp. 593-612.

IEEE Computer Society. (2002, September 6) *IEEE Standard for Learning Object Metadata*, http://standards.ieee.org/, IEEE Std P1484.12.1TM-2002.

Lenat, D.B. (1995). Cyc: A Large-Scale Investment in Knowledge Infrastructure. *Communications of the ACM* 38(11): 33-38.

Polsani, P.R. (2003). Use and Abuse of Reusable Learning Objects. *Journal of Digital information*, 3(4).

Sicilia, M.A. and García, E. (2005). On the Convergence of Formal Ontologies and Standardized e-Learning. *Journal of Distance Education Technologies*, 3(2).

Sicilia, M.A., García, E., Sánchez-Alonso, S. and Rodríguez, E. (2004). Describing learning object types in ontological structures: towards specialized pedagogical selection. In *Proceedings of ED-MEDIA 2004 - World conference on educational multimedia, hypermedia and telecommunications*.

Sicilia, M.A. and Lytras, M. (2005). On the representation of change according to different ontologies of learning. *International Journal of Learning and Change*, 1(1) (to appear)

Sicilia, M.A., Lytras, M., Rodríguez, E. and García, E. (2005). Integrating Descriptions of Knowledge Management Learning Activities into Large Ontological Structures: A Case Study. *Data and Knowledge Engineering* (to appear).

Sicilia, M.A. and Sánchez-Alonso, S. 2003. On the concept of learning object "Design by Contract". *WSEAS Transactions on Systems* 2(3) pp. 612-617.

Vargo, J., Nesbit, J., Belfer, K. and Archambault, A. (2003). Learning object evaluation: Computer mediated collaboration and inter-rater reliability. *International Journal of Computers and Applications* 25(3).

Wild, R.H., Griggs, K.A. and Downing, T. (2002). A framework for e-learning as a tool for knowledge management. *Industrial Management & Data Systems* 102/7, 371-380.

Wiley, D. A. (2001). *The Instructional Use of Learning Objects*. Association for Educational Communications and Technology, Bloomington.