Towards a Human Resource Development Ontology for Combining Competence Management and Technology-Enhanced Workplace Learning

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Abstract. Competencies as abstractions of work-relevant human behaviour have emerged as a promising concept for making human skills, knowledge and abilities manageable and addressable. On the organizational level, competence management uses competencies for integrating the goal-oriented shaping of human assets into management practice. On the operational and technical level, technology-enhanced workplace learning uses competencies for fostering learning activities of individual employees. It should be obvious that these two perspectives belong together, but in practice, a common conceptualization of the domain is needed. In this paper, we want to present such a reference ontology that builds on existing approaches and experiences from two case studies.

1 Introduction

Competencies as abstractions of work-relevant human behaviour have emerged as a promising concept for making human skills, knowledge and abilities manageable and addressable. Although competencies are still an overly simplification of the "real" world, they are a more adequate approximation than the notion of "knowledge" in traditional knowledge management approaches as they can represent a *set* of skills, knowledge, and abilities that belongs together. Furthermore it seems to be common-sense that competencies of individuals have to be developed and that this development is a complex learning activity – in contrast to the language often used in knowledge-based approaches like "transferring knowledge" [1].

Current competency-driven approaches can be divided into two categories according to the perspective they take (organizational vs. individual):

– **Competence management** represents the organizational perspective and denotes a management approach providing processes and a methodological framework for developing the competencies of an organization by aligning human resource development activities (in a broad sense) with business goals. Proposed methods and activities have first focussed on identifying, securing and making use of competencies, but increasingly they are concerned with developing competencies by fostering learning processes of employees in manifold ways, e.g. by identifying potentials and by offering training activities [2].

– As a perspective focusing on the individual, **technology-enhanced workplace learning** has emerged as an approach bundling classical e-learning with knowledge management techniques for holistic workplace learning support covering both formal and informal learning. Its focus are learning activities integrated into work processes, merging e-learning, knowledge management, and performance support. Recent approaches like [3], [1] or [4] are all more or less competency-driven, i.e., they regard competencies as a major conceptualization for any technological enhancement in a business context.

It seems to be natural to combine the two perspectives. Technology-enhanced workplace learning needs the integration into the organizational environment, and current approaches show that there currently is a lack in the sustainability of this integration because usually changes are not adequately represented. On the other side, competence management in most cases still relies on a more traditional, formal way of human resource development and does not cover more intangible learning processes, e.g., result from informal teaching activities.

An important step towards this integration is a shared conceptualization of the two perspectives. In this paper we want to present a first step towards a reference ontology, which has been constructed based on ontologies and reference models developed in the project *Learning in Process* [1] on technology-enhanced learning and a competence management approach towards training needs planning in the healthcare domain [2], augmented by the consideration of existing ontology-based approaches. In section 2, we first want to summarize the requirements and purpose of such a reference ontology before briefly reviewing existing approaches in section 3. Section 4 and 5 will be devoted to describing and visualizing the key ideas of the reference ontology (the graphical notation is explained in fig. 5 in the appendix) before we will explain some implementation issues (section 6) and conclude the paper in section 7.

2 Requirements

Conceptualizations or models are always purpose-oriented. In first step, thus, it is important that we clearly state the purpose in the form of the requirements that this ontology should fulfill:

– *Alignment of human resource development with business processes and goals.* On a macro level, it is one of the benefits from competence management that it provides systematic alignment of development activities with business goals and processes. The conceptual model must provide the foundation for this alignment.
– *Automatability of learning micro management.* With the training and learning activities turning more and more individual and informal, the task of efficiently managing these activities becomes increasingly complex. Enhancements through technology in this context also mean that the micro management get automated as far as possible. The ontology needs to provide the basis for this.

– *Smooth transition to knowledge management activities.* Although competence management appears to be the successor of knowledge management, it should be acknowledged that we need to integrate the handling of explicit ”knowledge” in knowledge management systems. The ontology must make visible where the links to traditional ontology-based KM approaches are.
– *Holistic view on human resource development.* Human resource development must be understood in a broad sense, incorporating formal training, self-directed learning, informal and collaborative learning activities. The ontology should avoid an overly bias towards one of these forms, although it is clear that formal training is much better understood than informal and collaborative leanrning activities which is still subject of major research activities.

One important distinguishing aspect of ontologies (in a narrower sense, i.e., with a formal semantics) in contrast to other methods of conceptualization is that these models are machine-processable and can be directly used to make applications more aware of the domain semantics. So what kind of algorithms do we want to support? The following two cases have emerged:

– *Profile matching with similarity measures.* The most frequently analyzed case is the matching of a individual’s competency profile with a requirements profile, e.g. for applicant selection ([5], [6]) or for team staffing [6]. For this purpose, a framework for defining ontology-based similarity measures has already been developed by [7].
– *Finding learning opportunities with knowledge gap analysis and competency subsumption*. Whereas in the aforementioned case, the result is the degree how well a person fits to a requirement, another important use case is the identification of suitable learning opportunities that can even be proactively recommended. In order to realize this, a knowledge gap needs to be calculated by comparing the requirements profile with the current competency profile, yielding missing competencies [8]. One important aspects that needs to be taken into account here is the issue of competency subsumption, i.e., we cannot simply rely on direct comparison, but need to consider that a competency can be subsumed by another competency (e.g. higher competency level, generalization, composition).

3 Existing Approaches

So far, there has been no integrated approach that covers both the macro and the micro perspective as explained above. However, there is prior work we can build upon when creating a human resource development ontology. The most important for our goal are:

– In [9], an integrated approach to human resources management was developed that builds on ontology-based techniques. The developed ontology focuses on modeling of competency catalogs and job and employee profiles in order to apply similarity measures on profile matching.
– [10] developed a competency ontology framework, mainly for the use cases expert finder and team staffing. Its strength is the formal foundation.

- For describing learning objects and learning designs, several approaches exist, e.g. the ALOCoM ontology concentrates on describing learning content itself [11]; LOCO describes learning designs and proposes competency annotations [12]. The LIP ontology [1] was developed for competency-based context-aware recommendation of learning objects in work situations.
- A very limited step towards integrating competence management with learning paths is [13].

4 Defining and Assessing Competencies

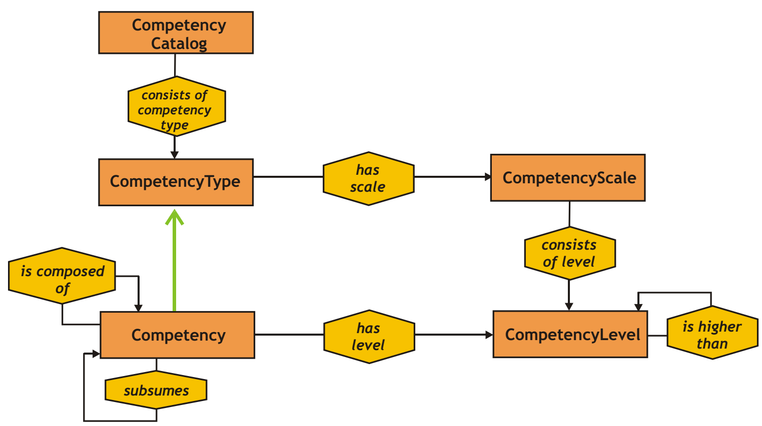

Fig. 1. Core part of the ontology: Modeling Competencies

For our reference ontology, competencies are defined as bundles of work-relevant skills, knowledge and abilities. Competencies are usually associated with competency levels to describe different degrees of an abstract competency type. Ordinal scales are typically used for that purpose like [14] or the reference levels for language proficiency [15]. In order to account for that, we introduce the distinction between competencies (having attached a competency level) and competency types (having attached a competency scale), where *Competency* is an instance of *CompetencyType*, introducing metamodeling (i.e., treating concepts as instances, see section 7 for how to represent this in OWL-DL). This makes sense because we can talk about competency concepts as such (e.g., English language proficiency), for you can define a scale to measure it, and individual competencies at a certain level (e.g., English C2 Mastery).

Useful competency models usually consist of hundreds of different competencies, which are hard to handle. In order keep them manageable, competencies can be organized hierarchically, where usually competencies can have more than a single parent competency (poly-hierarchy). This hierarchic structure is often semantically undefined so that real world catologs use nesting both for generalization and composition.

We propose to clearly differentiate between competency generalization (with an *is-a*-semantics) on the level of competency types (regardless of the competency level) and competency composition on the level of individual competencies (see 1, for a legend 5). One example for generalization could be a competency *Ontology Modeling* and a sub-competency *OWL Modeling*; generalization means that we can infer that an intermediate in *OWL Modeling* is also an intermediate in *Ontology Modeling*. Composition is more curriculum-like: the different levels of competencies are defined by enumerating the required elements, e.g. the competency OWL Modeling at intermediate requires that you have the competency of using a modeling tool at expert level and the competency of mastering a modeling methodology at beginner level.

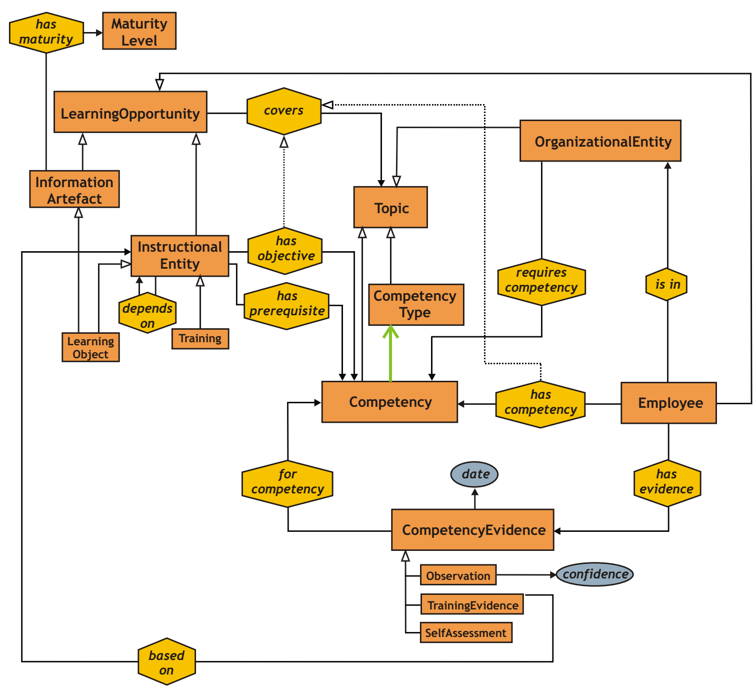

Fig. 2. High-level overview of the ontology

Competency-driven applications expect to have a clear statement that an employee has a competency, but one of the key problems of competency-oriented approaches is how to reliably diagnose competencies. Usually, one can only observe the performance of an employee and try to deduce from it the presence of a competence [16]. That means that the property *has-competency* is derived. This has also been reflected in the HR-XML standard on representing competencies by introducing *CompetencyEvidence* as a concept, which could represent observations, results from formal assessmenents (after training activities), or self-assessments (see overview in fig. 2).

5 Developing Competencies

The base concept for all development activities is the *LearningOpportunity*; it is an abstract representation of any form of (repeatable) activity that can contribute to competency development. In order to structure the ”learning opportunity landscape”, we classified them into maturing phases [17], ranging from emerging ideas via community formation and formalization to ad-hoc and formal training. Using this coarse model, we can identify the following subconcepts (from mature to immature):

- **InstructionalEntity.** An instructional entity is any entity that was designed for fostering individual learning processes. Subconcepts are, e.g., classical presence trainings, and learning objects or learning programs. For such entities, it can be assumed that they they have a well-defined learning objective. Although currently, this learning objective is rarely formalized, in our competency-based approach, we require that at least part of the learning object definition is the assignment of a target competency (see also [1]).

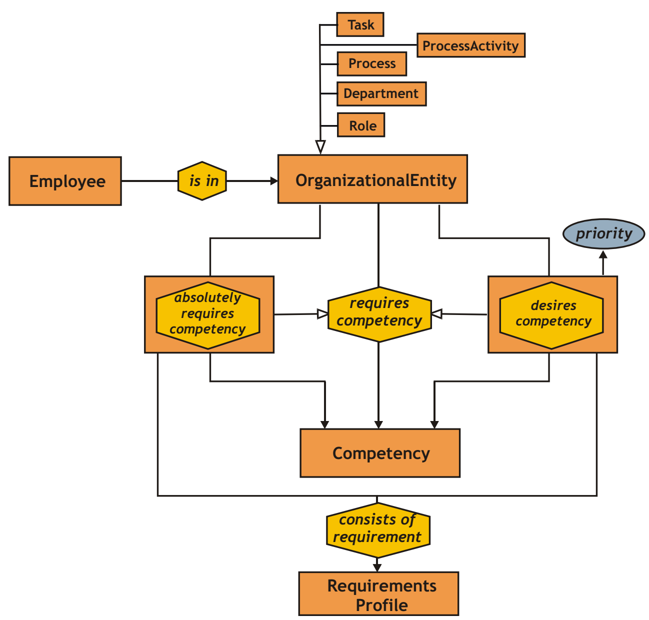

Fig. 3. The requirements part of the ontology

- **InformationArtefact.** In contrast to an InstructionalEntity, information artefacts were not didactically designed for learning activities. As a consequence, clear objectives cannot be formulated. Rather, these opportunities are about a subject or topic. To account for that, we introduce a semantically relaxed concept *Topic* and a relaxed property *covers*. By making *CompetencyTypes* a special kind of *Topic*, we

can smoothly integrate knowledge area (i.e., topic) taxonomies with competence catalogs. Information artifacts do not have to classified according to competencies, but we can still view CompetencyTypes as a special topic so that there is no need of two taxonomies.
- **Employee.** Informal learning activities via inter-human communication form a major part of workplace learning [18]. Thus it is important to represent the colleague as a learning opportunity. Here, the *has-competency* property can be viewed as a specialization of the *covers* property, referring to competencies.

But how do we know which *LearningOpportunity* is appropriate for a certain situation? As business process-oriented knowledge management [19] shows, the business context provides some clues on which aspects of a work situation require which competencies. In competence management, requirement profiles are used that are typically attached to roles, or organizational units. In our ontology, we introduce the concept of an OrganizationalEntity that is connected to a Competency via a *requires-competency* property (see fig. 3). As our experience in [2] shows, we need to distinguish between hard requirements (competencies that are absolutely needed) and soft requirements (competencies that are a desired goal for short- to mid-term future). These properties can be reified to group such requirements into *RequirementProfiles*.

6 Implementation

This ontology has been iteratively refined based on implementation experiences within the project *Learning in Process* and subsequent research activities. Starting with RDF(S), the formalism of choice has now become OWL-DL.[3]

6.1 Implementing in OWL-DL: The Issue of Metamodelling

Our modeling approach explicitly allowed for metamodeling (i.e. considering concepts as both instance and concept) in order to represent the domain in a natural way. OWL-DL (as the edition of OWL for which practical reasoners exist) on the other side does not allow for metamodeling.[4] If we have a closer look at our model, we discover that we have only used metamodeling for differentiating between Competency and CompetencyType. This can be mapped to OWL-DL without loosing too much domain semantics by:

- The concept *CompetencyType* is completely eliminated from the OWL ontology.
- It is assumed that competencies are modeled in a concept hierarchy (under *Competency*) representing generalization on competency types.
- *CompetencyScales* are assigned to the relevant subconcepts of *Competency* via annotation properties.

[3] The OWL-DL ontology is released under a CreativeCommons license under `http://www.professional-learning.eu/competence_ontology.html`

[4] A more natural implementation would be possible in the KAON RDFS extension with the concept of spanning instances [20]

– For classifying information artefacts, we use instance of a competency concept that do not have any competency level associated with it.

This mapping inevitably looses some domain semantics, but for algorithms operating on this ontology, this has not turned out to be problematic.

6.2 Implementing Derived Properties

More severe is a problem that we have not considered yet. Many of the properties in the ontology are time-dependent and uncertain (which applies especially for the derived property *has-competency*).

For representing time-dependence, we could reify properties into concepts, of course, and add a validity period to them, but this would clutter the resulting ontology and thus reduce the usability drastically. We see the solution in having a database with the complete history below and feed the instance-level of the ontology with a snapshot view for a specific instant in time. The uncertainty resulting from deriving heuristically from other facts is addressed likewise by having a user context management layer (for technical details see [21]) below that stores all facts and aggregates them into *has-competency* statements. In order to account for the fact that competencies can be lost if they are not actively used, this user context management service provides configurable aging mechanisms for collected and inferred data.

Although originally foreseen, it has turned out that SWRL rules are not suitable for computing derived properties (apart from syntactical shortcuts). For the *has-competency* property, this has mainly to do with the uncertainty and temporal aspects. For the *subsumes* property, the complexity of the algorithm cannot be represented in SWRL rules in a reasonable way.

7 Conclusions and Outlook

We have presented the basic concepts of our reference ontology for human resource development in a technology-enhanced setting. This ontology brings together the different disciplines concerned with learning in organizations, see fig. 4):

– **Competence Management.** It incorporates as its core the competency catalog for describing and organizing competencies and provides concepts to align competencies with business entities by specifying requirements profiles. These requirement profiles can carry both short-term goals and mid-term development routes.
– **Knowledge Management.** Knowledge taxonomies can be integrated with competency modeling so that easily less mature information artefacts (sometimes called knowledge assets) can co-exist with more mature training material.
– **Business Process Management.** The ontology also provides the link to business processes, which are represented as a special *OrganizationalEntity* in the model.
– **Technology-enhanced workplace learning.** In addition to requirements, organizational entities can also be annotated with additional domain knowledge for adapting learning support based on the organizational context, e.g., for specific business processes it can be specified whether learning embedded in this process is possible at all or not (as for process activities with direct customer contact).

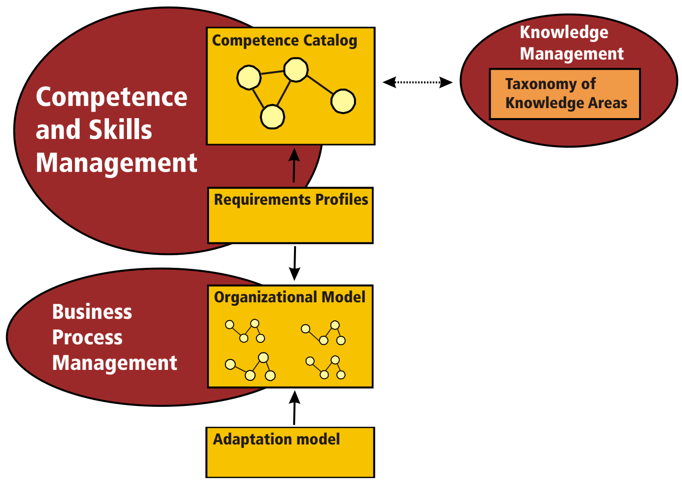

Fig. 4. The ontology and its relationship to different areas

The next step on our agenda is the definition of reference processes that consider the dynamics of such a human resource development ecosystem. This includes processes for maintaining and developing competency catalogs and requirement profiles, processes for developing more mature training content.

Appendix: Notation

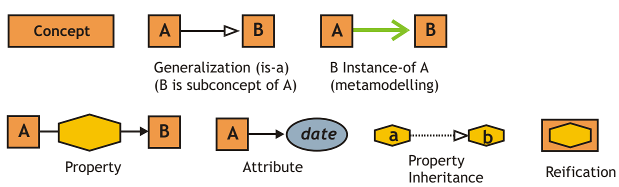

Fig. 5. Graphical notation for representing the ontology

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