Towards an Ontology for Enterprise Knowledge Management

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***Abstract*—Enterprise knowledge management is about approaches, methods, and techniques, which will support the management of the resource "knowledge" in an enterprise for the purpose of support and advancement of businesses. An important part of it is knowledge development of individual and organizational knowledge. This paper provides an overall conception of enterprise knowledge management in the form of a layered set of ontologies, which are enriched by appropriate rule systems. This set consists of general (i.e. enterprise-independent) and of enterprise-specific ontologies. General ontologies in this set include ontologies for knowledge and knowledge development and for human interaction. Enterprise-specific ontologies formalize specific domains in the enterprise as well as managerial principles and finally a whole enterprise.**

Keywords*—*Knowledge management ontology, knowledge development, organizational learning, human interaction, managerial and enterprise ontology.

I. INTRODUCTION

Enterprise knowledge management is about approaches, methods, and techniques, which will support the management of the resource knowledge in an enterprise for the purpose of support and advancement of businesses. An important part of it is knowledge development of individual, group, and organizational knowledge. Several approaches for knowledge management exist, one of them is the process-oriented approach see [1], [12], and [14]. One specific approach for enterprise knowledge development is EKD (Enterprise Knowledge Development), which aims at articulating, modeling and reasoning about knowledge, which supports the process of analyzing, planning, designing, and changing your business; see [7] and [9] for a description of EKD. EKD does not provide a conceptual description of knowledge and knowledge development, however. An approach for knowledge access and development in firms is given by Boisot [6]. Here, development scenarios of knowledge in the Information Space are provided. For the conception part of knowledge development, there exists the well-known approach by Nonaka/Takeuchi [14], which is built on the distinction between tacit and explicit knowledge and on four knowledge conversions between the knowledge types (SECI-model). Approaches for knowledge transfer are surveyed in [13]. Concepts for organizational learning, which is closely related to knowledge management, are given by Argyris and Schön [4, 5] and by Senge [17]. The latter refers to system thinking as very important fifth discipline of organizational learning. In [3] a new conception of organizational learning based on knowledge dynamics is presented.

For intellectual capital, which is a more strategic view on knowledge in a company, see [19] for an approach towards an ontology for this domain.

In this paper, we propose a conception towards an ontology for enterprise knowledge management. To this end, we first summon up the tasks of knowledge management in an enterprise from a process-oriented point of view. Important items are knowledge processes, knowledge management processes, knowledge flows, and organizational learning. Second, we explain a conception of knowledge itself and of knowledge dynamics.

Based on this, we present a new conception for a formalized model for enterprise knowledge management. It consists of a layered set of ontologies. This set includes ontologies for knowledge and knowledge dynamics, for human interaction, for management, and for the whole enterprise. They together will support the mentioned processes related to knowledge management.

One of the basic constituents of this model is presented in detail as a semantic implementation of the conception of knowledge and knowledge dynamics, namely a corresponding ontology and rule system. Other constituents of the model have yet to be developed.

The structure of the paper is as follows. After an introduction, section II provides an outline of knowledge management and its tasks from a process-oriented point of view. This reflects knowledge processes, knowledge management processes, knowledge flows and organizational learning. Section III shortly presents the conception of knowledge and of knowledge dynamics. Then, section IV introduces the overall semantic-based concept as a layered set of ontologies with special recognition of the processes and tasks identified in section II. Section V describes the developed ontology for knowledge and knowledge development with the corresponding rule system. A summary and outlook section will conclude the paper.

 ISBN: 978-1-61208-175-5

II. OVERVIEW ON TASKS AND PROCESSES OF KNOWLEDGE MANAGEMENT

In this section, an overall view on the tasks and processes of knowledge management is given from a process-oriented point of view. We describe knowledge processes, knowledge management processes and knowledge flows as essentials parts of knowledge management. In addition organizational learning is shortly explained, which is closely related to knowledge management.

The extended knowledge cycle was originally introduced by Probst [16] as far as the outside cycle is concerned. Lehner [12] in addition introduced the correspondence to knowledge-intensive business processes and the knowledge flows. This again has been rearranged and changed by the author to the version as given in Figure 1.

As basic notion we have knowledge processes (depicted as yellow activities in Figure 1), which compose a whole knowledge cycle from identification, acquisition, structuring (constructing, combining, representing), storage, distribution (communication), usage until keeping and preservation. They may be grouped into four areas: preservation of new and existing knowledge, generation of new knowledge, making available knowledge, and using knowledge. These groups are indicated by the dotted rectangles in Figure 1. Two additional special knowledge processes (the blue arrows in Figure 1) are meta-level processes and close the overall cycle by goal-setting, knowledge evaluation and the feedback.

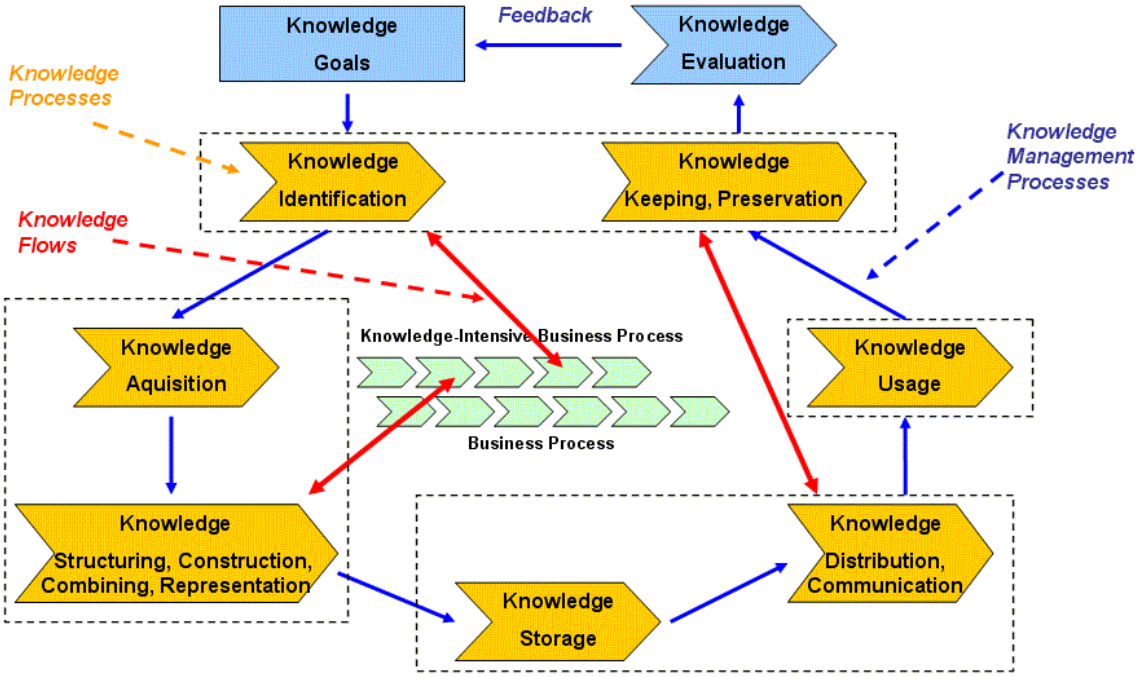

Figure 1. Tasks and Processes of Knowledge Management (Sources: Ammann, reworked from Probst [16] and Lehner [12])

Knowledge Management Processes keep the knowledge cycle going. Knowledge goals are set and drive the knowledge cycle until an evaluation. In general the blue arrows in Figure 1 represent knowledge management processes. For example, a knowledge management process takes care inside the above-mentioned knowledge process group “making knowledge available”, that employees are encouraged to communicate knowledge. The final feedback in the cycle is an important knowledge management process. Here gained knowledge is compared against the original goal and possibly a new cycle with a new or changed goal is initiated.

In our process-oriented view, business processes of the company, especially the knowledge-intensive ones, relate to knowledge processes. For example, in an earlier activity of the business process the need for new or re-combined knowledge is becoming clear, while in a later phase this knowledge is communicated to certain employees. This relation is provided by knowledge flows. In addition, knowledge flows can also interrelate different knowledge processes, as shown in Figure 1 between the knowledge distribution and knowledge preservation processes.

Organizational Learning is closely related to knowledge management. This resembles the classic triad composed of knowledge, learning, and storage. The latter one can be provided by the organizational memory. Organizational learning has been described with the help of single-loop, double-loop, and deutero learning, see [4, 5]. A novel

 ISBN: 978-1-61208-175-5

approach to build those organizational learning cycles on top of knowledge dynamics is given in [3]. See the following section for details on this knowledge and knowledge dynamics conception.

III. A CONCEPTION OF KNOWLEDGE AND KNOWLEDGE DYNAMICS

In this section, a conception of knowledge and knowledge dynamics in a company is shortly described. More details of this conception are given in [2].

A. Knowledge Conception

We provide a conception of knowledge with types, kinds and qualities as three dimensions. As our base notion, knowledge is understood as justified true belief (in the propositional kind), which is (normally) bound to the human being, with a dimension of purpose and intent, identifying patterns in its validity scope, brought to bear in action and with a generative capability of new information, see [1, 10, and 12]. It is a perspective of "knowledge-in-use" [8] because of the importance for its utilization in companies and for knowledge management.

The type dimension is the most important for knowledge management in a company. It categorizes knowledge according to its presence and availability. Is it only available to the owning human being, or can it be communicated, applied or transferred to the outside, or is it externally available in the company's organizational memory? It is crucial for the purposes of the company, and hence a main goal of knowledge management activities, to make as much as possible knowledge available, i.e. let it be converted from internal to more external types.

Our conception for the type dimension of knowledge follows a distinction between the internal and external knowledge types, seen from the perspective of the human being. As third and intermediary type, explicit knowledge is seen as an interface for human interaction and for the purpose of knowledge externalization, the latter one ending up in external knowledge. Internal (or implicit) knowledge is bound to the human being. It can be further divided into conscious, latent and tacit knowledge, where those subtypes do partly overlap with each other; see [10]. It is all that, what a person has "in its brain" due to experience, history, activities and learning. Explicit knowledge is "made explicit" to the outside world, e.g., through spoken language, but is still bound to the human being. External knowledge finally is detached from the human being and may be kept in appropriate storage media as part of the organizational memory.

In the second dimension of knowledge, four kinds of knowledge are distinguished: propositional, procedural and strategic knowledge, and familiarity, resembling to a certain degree the type dimension in [8]. Propositional knowledge is knowledge about content, facts in a domain, semantic interrelationship and theories. Experience, practical knowledge and the knowledge on "how-to-do" constitute procedural knowledge. Strategic knowledge is meta-cognitive knowledge on optimal strategies for structuring a problem-solving approach. Finally, familiarity is acquaintance with certain situations and environments; it also resembles aspects of situational knowledge, i.e. knowledge about situations, which typically appear in particular domains.

The quality dimension introduces five characteristics of knowledge with an appropriate qualifying and is independent of the kind dimension: level, structure, automation, and generality. See [2, 8] for more details.

This knowledge conception can be visually represented by a knowledge cube as shown in Figure 2.

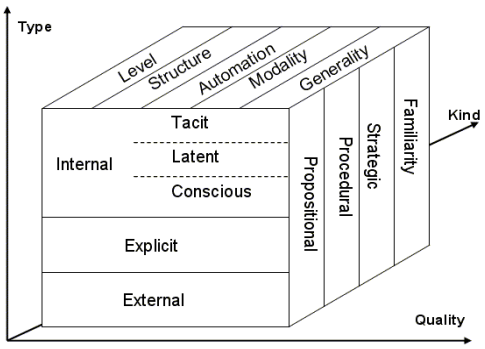

Figure 2. The knowledge cube

B. Knowledge Dynamics

Knowledge conversions, i.e. the transitions between the different knowledge types, kind and qualities between or within humans are responsible to a high degree for knowledge development in an organization. These conversions are the building blocks to model knowledge dynamics, i.e., all of acquisition, conversion, transfer, development and usage of knowledge, in an enterprise.

Five basic knowledge conversions in the type dimension are distinguished here: socialization, explicitation, externalization, internalization and combination. Basic conversion means, that exactly one source knowledge asset is converted into exactly one destination knowledge asset and exactly one knowledge dimension (i.e. the type dimension in this case) is changed.

Socialization converts tacit knowledge of a person into tacit knowledge of another person. This may succeed by exchange of experience or in a learning-by-doing situation. Explicitation is the internal process of a person, to make internal knowledge of the latent or conscious type explicit, e.g. by articulation and formulation (in the conscious case) or by using metaphors, analogies and models (in the latent case). Externalization converts from explicit knowledge to external knowledge or information and leads to detached

 ISBN: 978-1-61208-175-5

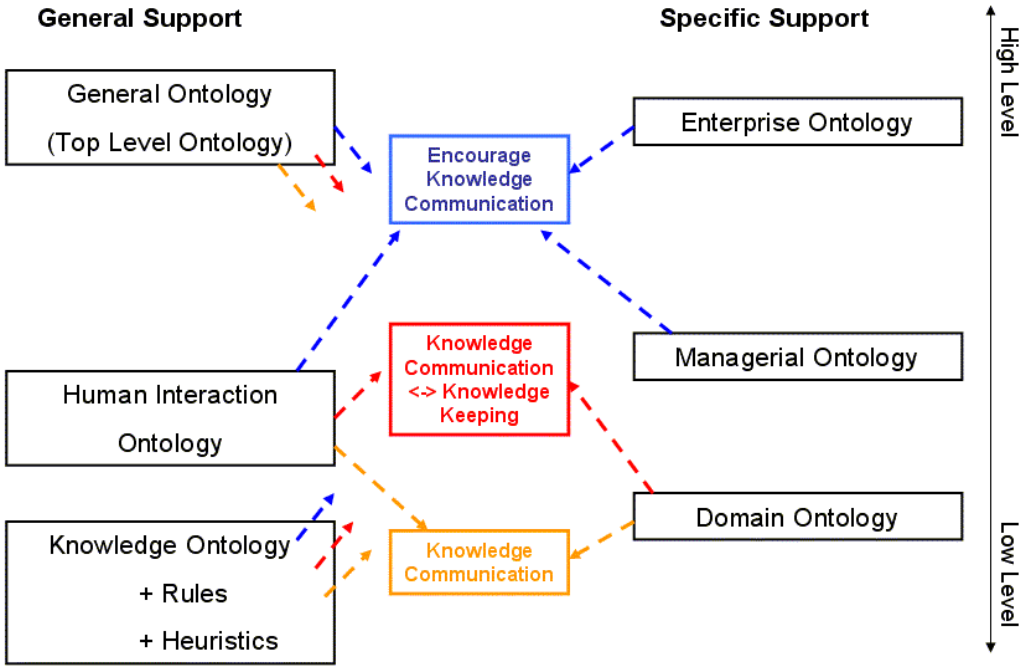

Figure 3. Layered set of ontologies with rule systems

knowledge as seen from the perspective of the human being, which can be kept in organizational memory systems. Internalization converts either external or explicit knowledge into internal knowledge of the conscious or latent types. It leads to an integration of experiences and competences in your own mental model. Finally, combination combines existing explicit or external knowledge in new forms.

Basic knowledge conversions in the kind dimension of knowledge do not occur. Those in the quality dimension are mostly knowledge developments aiming at quality improvement. Examples include basic conversions changing the overview, structure and automation quality, respectively.

More complex conversions can be easily gained by building on this set. They consist of n-to-m-conversions and include information assets in addition. General knowledge conversions convert several source assets (possibly of different types, kinds and quality) to several destination assets (also possibly different in their knowledge dimensions). In addition, information assets are considered as possible contributing or generated parts of general knowledge conversions.

IV. OVERALL SEMANTIC CONCEPT OF KNOWLEDGE MANAGEMENT

Having provided the tasks and processes of knowledge management in section II and a conception of knowledge and knowledge dynamics in section III, we now proceed with the introduction of an overall concept for semantic support of knowledge management. This can be viewed as a step towards an ontology (or a set of ontologies) for knowledge management.

Figure 3 depicts this conception of a layered set of ontologies and gives a example, how knowledge processes, knowledge management processes, and the knowledge flows are supported by the various ontologies in this conception. We propose a hierarchical structure, which is also divided in a general and a specific part. At the general support side, we start with an ontology of knowledge and knowledge dynamics at the bottom layer. The Knowledge Ontology as described in the following section V implements the corresponding conception as introduced in section III. It is complemented by a set of rules and (in the future) of heuristics, which enhance the support for reasoning in incomplete knowledge application scenarios. An incomplete scenario consists of one or more general knowledge conversions, where one or more places (source or destination knowledge objects or conversions themselves) are not known. They may be implied by an application of an appropriate rule or a heuristics. While rules support the proper handling of knowledge conversions and transfers, heuristics will be needed for those cases of knowledge dynamics, where no unique resolution of source and destination knowledge assets in complex knowledge conversions is possible with rules. The following section V will describe the Knowledge Ontology and the corresponding rule system.

Built on top of the Knowledge Ontology a Human Interaction Ontology conceptualizes human-to-human interactions. The knowledge and knowledge dynamics

 ISBN: 978-1-61208-175-5

support is utilized here, based on the observation that human-to-human interaction always comes along with knowledge transfers (conversions). To state is differently, human-to-human interaction can be modeled by appropriate general knowledge conversions between people. As top layer on the general side, a top level ontology will provide general concepts like time, locations, and so on.

On the specific support side, one or more Domain Ontologies reflect the domains of interest in the enterprise. On top of it, a Managerial Ontology provides management conceptions related to knowledge management. This again is utilized on the next layer by an Enterprise Ontology, which conceptualizes the whole (specific) enterprise.

Figure 3 gives an example how the knowledge processes, knowledge management processes, and the knowledge flows are supported by the various ontologies in this conception. The same color code is used in Figure 3 as in Figure 1. Each type of processes is supported by the Knowledge Ontology and the General Ontology on the general side. A knowledge process like "knowledge communication" utilizes the Human Interaction Ontology and the appropriate specific Domain Ontology in addition. The same kind of support can be observed for knowledge flows, as can be seen for the flow from "knowledge communication" to "knowledge keeping" in Figure 3. Finally knowledge management processes like "Encourage Knowledge Communication" will take hold of the Human Interaction Ontology from the general side and the Managerial and Enterprise Ontologies from the specific side.

V. THE KNOWLEDGE ONTOLOGY

In this section we present the Knowledge Ontology, which implements the conception of knowledge and knowledge dynamics as described in Section III. It is one of the building blocks in the set of ontologies as described in section IV. Here we describe the ontology, restrictions and reasoning, and rules. For more details, see [2].

The ontology (as visually shown in Figure 4) is divided in four core concepts: *Knowledge*, *Information*, *Knowledge_Conversion* and *Knowledge_Dimension*. The three different knowledge dimensions are represented as: *Type_Dimension*, *Kind_Dimension* and *Quality-Dimension*. *Knowledge* is defined according to these dimensions. Properties are used to model the relationships between *Knowledge* and *Dimensions*: *hasType*, *hasKind* and *hasQuality*. For example, *Explicit_Knowledge* is defined as every piece of knowledge, which is related to the instance *Explicit_Type* via the *hasType* property. In the same way, *Knowledge* in general must be related to every quality sub-dimension through the *hasQuality* property.

Two properties have been defined to model the knowledge conversions: *hasSource* and *hasDestination*, with knowledge conversions as ranges, and pieces of knowledge and information as domains.

A General Conversion is modeled through the *Knowledge Conversion* concept, and its only restriction is the fact that it must have at least one source asset and one destination asset. *Basic Conversions* are more specific, in the sense that

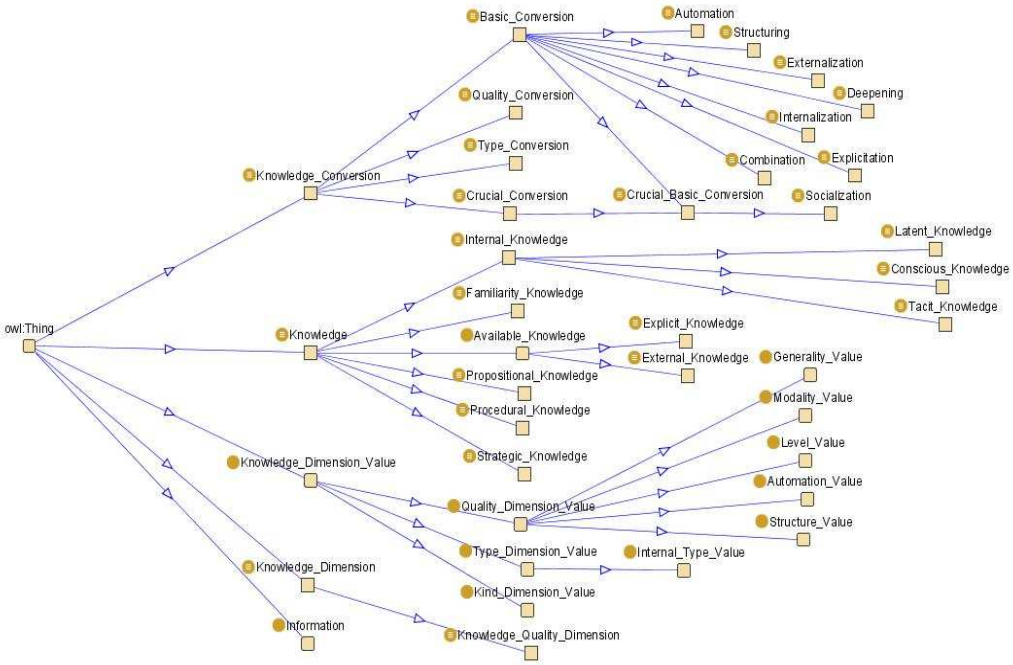

Figure 4. Knowledge ontology hierarchy

they have only one source and only one destination. The concept *Crucial_Conversion* gathers those conversions that contribute to the goal of making the knowledge available for the company.

Basic reasoning is based on subsumption mechanisms that deal with the ontology hierarchy. However, ontologies can contain more complex elements to enable advanced reasoning. In this way, the Knowledge Ontology has been extended with OWL restrictions to enable new ways of generating interesting new knowledge.

Ontology restrictions allow us to infer new characteristics of a given concept or instance. However, in some cases we could require to generate new instances in the ontology depending on certain situations. In these cases rules have been used, so the Knowledge Ontology will be able to infer all the possible conversions given some pieces of knowledge. SWRL [18] rules have been defined and the Jess rule engine [11] has been used. One rule will create basic conversions with all the possible source-destination pairs, and then, the same engine will characterize these conversions, inferring the changing dimension for each case. Six further rules have been established to infer the changing dimensions of each of the new discovered conversions: one for the type dimension and five for the quality ones. For example, the rule for the type dimension is as follows:

```
Knowledge(?k1) ^ Knowledge(?k2) ^
hasTypeValue(?k1, ?v1)  ^ hasTypeValue(?k2, ?v2) ^
differentFrom(?v1, ?v2) ^ Knowledge_Conversion(?c1) ^
hasSource(?c, ?k1) ^ hasDestination(?c, ?k2)
 →
hasChangingDimension(?c,
                Knowledge_Type_Dimension)
```

This development has already opened the path, to solve open questions in application scenarios for knowledge development. With the help of representations, these scenarios can be mapped to general knowledge conversions, which are subject to rule processing in relation to the Knowledge Ontology. A final interpretation step leads back to the solved scenario. See [2] for examples of some application scenarios solved with this method.

VI. SUMMARY AND OUTLOOK

An overall semantic conception for enterprise knowledge management has been given in this paper. It consists of a layered set of ontologies of the important and relevant sub-domain of this domain. This conception was motivated by the observation of tasks of processes of knowledge management, i.e. knowledge processes, knowledge management processes, and knowledge flows.

One of the basic constituents of this conception, namely the knowledge ontology together with reasoning support and a rule system already exists and has been described in this paper.

Future work includes the development of the other ontologies in our layered set of ontologies on the one side and an implementation of knowledge processes, knowledge management processes, knowledge flows and organizational learning cycles based on the set of ontologies on the other side.

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 ISBN: 978-1-61208-175-5