The Knowledge Cube and Knowledge Conversions

Eckhard M. Ammann

***Abstract*— A new conception of knowledge and knowledge conversions is introduced. It is represented by a knowledge cube, a three-dimensional model of knowledge with types, kinds and qualities, and allows a description of general knowledge conversions between those. Through this conception we gain a sound basis for knowledge management. We can describe knowledge-intensive business processes in a company, be it human-driven, knowledge-driven or task-driven. Particularly, we substantially generalize the well-known knowledge development approach by Nonaka/Takeuchi as well as existing modeling approaches for knowledge-intensive business processes.**

The type dimension of knowledge extends the well-known tacit-explicit concept of knowledge and makes it clearer in addition. The kind and quality dimensions of knowledge reflect the the various kinds of knowledge (e.g. propositional versus procedural knowledge) and provide quality descriptions of knowledge, respectively.

Transitions between the various types, kinds and qualities of knowledge are described as general knowledge conversions, which are modeled as m-to-n transformations between knowledge and information assets. A set of basic knowledge conversions is given in a way, that more complex conversions may be easily gained by building on this set.

As indication for the applicability of this conception of knowledge and its conversions, a modeling approach for knowledge-intensive business processes with human interactions is described.

***Index Terms*— conception of knowledge, knowledge cube, knowledge conversions, knowledge-intensive business processes, human interactions,**

I. Introduction

Knowledge Management has come of age now. A number of approaches exist, including the classic asset-oriented approach, the process-oriented approach, the knowledge-intensive process-oriented approach, and finally the community-oriented approach, see [1], [5] and [8]. While the management aspect of knowledge management seems to be rather well understood and practised in many companies [8], there is no common concept and understanding of knowledge and of knowledge development as basis of it.

There exist several approaches, of course. The knowledge development model by Nonaka/Takeuchi [9] is built on the distinction between tacit and explicit knowledge and on four fundamental knowledge conversions between those knowledge types (SECI-model). However, discussions exist, whether to interpret the explicit knowledge part as still bound to the human being, or as already detached from him. Another important work is the introduction of the type/quality dimensions of knowledge in [4]. Finally, important distinctions of implicit knowledge are given in [7], which partly resemble the philosophy-based knowledge concept given in [12]. Common to all approaches is the overall understanding of knowledge as justified true belief, a definition to be traced back to the Greek philosophers.

In this paper, we introduce a new conception of knowledge, which combines and resembles parts of the existing approaches and extends them substantially. It is represented by a knowledge cube, a three-dimensional model of knowledge with types, kinds and qualities. The type dimension address the internal-external aspect of knowledge, seen from the perspective of the human being. Here explicit knowledge is a kind of interface between those two types, which drives human interaction and knowledge externalisation. The kind dimension distinguishes various knowledge kinds, namely propositional, procedural, strategic knowledge and familiarity. Finally, several quality measures of knowledge are given in the quality dimension.

Using this conception we introduce general knowledge conversions between the various knowledge variants. First a basic set of such conversions is defined, which extends the set of the four conversions of the well-known SECI-model [9]. Building on this set, general knowledge conversions can be defined, which reflect knowledge transfers and development more realistically and do not suffer from the restrictions of the SECI-model.

As an area of applicability of this new conception, a modeling approach for knowledge-intensive business processes in a company is introduced. Business process modeling and management is recognised as important part of organisational work and development [11]. Enterprise application integration and service-oriented architectures promise to support structured business processes in enterprises and help to assist and to implement them with orchestrated web services landscapes. The Business Process Modeling Notation (BPMN) [3] is the language of choice for this. However BPMN is lacking of knowledge-related constructs and is not considering the human role in business processes adaequately. A whole class of business processes and activities, especially the complex and creative ones, depend on knowledge utilisation and human-to-human interactions. One approach for those is given by Harrison-Broninski [6], but it is lacking the knowledge-related aspect.

The new modeling approach presented in this paper aims at knowledge-intensive business processes with possibly human interactions and provides an appropriate modeling

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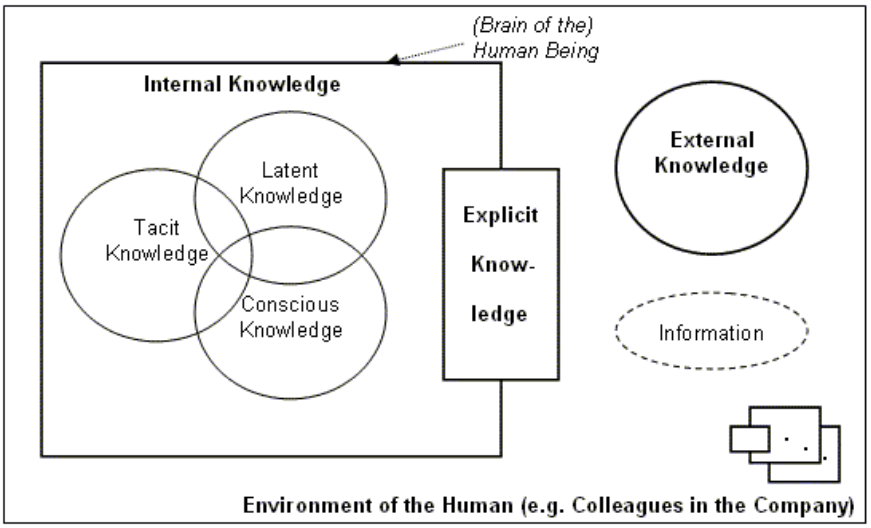

Fig. 1 Conception of knowledge types

notation. Using an extension of BPMN [3] it combines a well-known modeling notation for business processes with recognized existing models knowledge management. Most importantly, this new approach reflects the new conception of knowledge and knowledge conversions, by modeling the knowledge contributions to business processes, and the roles of humans and their mutual interactions, be it as single persons, teams, or communities of practice, in the activities of an organisation.

An example is given which proves the modeling power of this notation. A renewal planning process for a complex product is described, which requires substantial competences and knowledge for its design and implementation. This business process comprises activities of directly involved employees and of relevant knowledge communities in the company as well as various kinds of knowledge to be utilized.

The structure of the paper is as follows. After an introduction, the two sections II and III will introduce the new knowledge conception and the general knowledge conversions between knowledge and information assets. The fourth section describes an area of applicability of this conception, namely the modeling of knowledge-intensive business processes with human interactions. Finally, section V concludes the paper.

II. Conception of Knowledge

A. General Understanding of Knowledge

In this section we provide a conception of knowledge, and of knowledge types, kinds and qualities. As our base notion knowledge is understood as justified true belief, which is (normally) bound to the human being, with a dimension of purpose and intent, identifiying patterns in its validity scope, brought to bear in action and with a generative capability of new information, see [7], [8] and [12]. It is a perspective of "knowledge-in-use" [4] because of the importance for its utilisation in companies and for knowledge management. In contrast, information is understood as data in relation with a semantic dimension, but is lacking the pragmatic and pattern-oriented dimension, which characterises knowledge.

We distinguish three main dimensions of knowledge, namely types, kinds and qualities, and describe those in the following three sub-sections. The whole picture leads to the three-dimensional knowledge cube, which is introduced at the end of this section.

B. Type Dimension of Knowledge

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 for the owning human being, or can it be communicated, applied or transfered to the outside, or is it externally available in the company's organisational memory, detached from the individual human being? 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 of knowledge.

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 externalisation, the latter one ending up in external knowledge. Internal (or implicit) knowledge is bound to the human being. 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 organisational memory. Fig. 1 depicts the different knowledge types.

Internal knowledge can be further divided into tacit, latent and conscious knowledge, where those subtypes do partly overlap with each other, see [7]. Conscious knowledge is conscious and intentional, is cognitively available and may be made explicit easily. Latent knowledge has been typically learning as a by-product and is not available consciously. It may be made explicit, for example in situations, which are similar to the original learning situation, however. Tacit knowledge is built up through

Table 1 Type/kind-matrix of knowledge

Knowledge Type / Kind	internal			explicit	external
	tacit	latent	conscious		
propositional	X	X	X	X	X
procedural	X	X	X	(X) [1]	(X) [2]
strategic	X	X	X	(X) [3]	—
familiarity	(X) [4]	X	X	X	? [5]

Legend:
1 can be demonstrated, not to be articulated easily
2 partly through intelligent application systems
3 partly, can be demonstrated
4 if at all, unconscious acquaintance
5 if at all, possibly in future intelligent application systems

experiences and (cultural) socialisation situations, is specific in its context and based on intuition and perception. Statements like "I don't know, that I know it" and "I know more, than I am able to tell" (adapted from Polanyi [10]) characterise it.

C. Kind Dimension of Knowledge

In the second dimension of knowledge, four kinds of knowledge are distinguished: propositional, procedural and strategic knowledge, and familiarity. It resembles to a certain degree the type dimension as described in [4]. Propositional knowledge is knowledge about content, facts in a domain, semantic interrelationship and theories. Experience and practical knowledge and the knowledge on "how-to-do" constitutes procedural knowledge. Strategic knowledge is meta-congitive 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 [4].

Knowledge kinds go along with knowledge types in the sense, that they occur in most knowledge types. The type/kind-matrix given in Table 1 indicates, which pairs of characterstics normally appear.

D. Quality Dimension of Knowledge

The quality dimension introduces five characteristics of knowledge with an appropriate qualifying and is independent of the kind dimension, see [4].

The level characteristics aims at overview vs. deep knowledge, structure distinguishes isolated from structured knowledge. The automation characteristic of knowledge can be step-by-step-doing by a beginner in a domain of work or automated fast acting by an expert. All these qualities measure along an axis and can be subject to knowledge conversions, see section III. Modality as the fourth quality of knowledge asks for the representation of it, be it words versus pictures in situational knowledge kinds, or propositions versus pictures in procedural knowledge kinds. Finally, generality differentiates general versus domain-specific knowledge. Knowledge qualities apply to each knowledge asset.

E. The Knowledge Cube

Bringing all three dimension of knowledge together, we gain an overall picture of our knowledge conception. It can be represented by the knowledge cube, as is shown in Fig. 2.

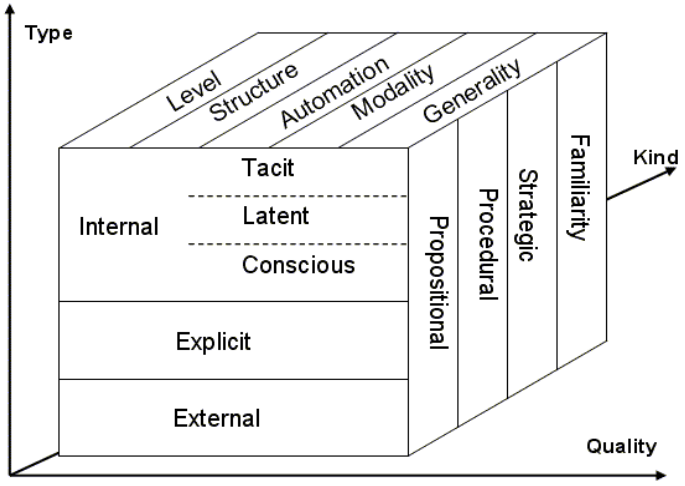

Fig. 2 The knowledge cube

Note, that the dimensions in the knowledge cube behave different. In the type and kind dimensions, the categories are mostly distinctive (with the mentioned exception in the sub-types), while in the quality dimension each of the given five characteristics are always present for each knowledge asset.

III. Knowledge Conversions

In this section we give a conception of knowledge conversions. The transitions between the different knowledge types, kind and qualities are responsible to a high degree for knowledge development in an organisation.

Most important for knowledge management purposes are conversions between the knowledge types and they will be the focus in the following. Among those, especially those conversions making individual and internal knowledge of employees usable for a company, are crucial for knowledge management. The explicitation and externalisation conversion described in this section achieve this. Implicitly socialisations between tacit knowledge of different people also may contribute to this goal.

Conversions in the kind dimension of knowledge are seldom, normally the kind dimension of knowledge remains unchanced in a knowledge conversion changing the type dimension. Those in the quality dimension are mostly knowledge developments aiming at quality improvement and will not change the type and kind dimensions of the involved knowledge assets.

Five basic knowledge conversions (in the type dimension) are distinguished here: Socialisation, explicitation, externalisation, internalisation and combination. Basic conversion means, that exactly one source knowledge asset is converted into exactly one destination knowledge asset. More complex conversions may be easily gained by building on this set as described later in this section. They will consist of m-to-n-conversions and include information assets in addition.

Socialisation converts tacit knowledge of a person into tacit knowledge of another person. For example, this succeeds by exchange of experience or in a learning-by-doing situation under supervision of an experienced person. 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 knowledge type case) or by using metaphors, analogies and models (in the latent type case). Externalisation is a conversion from explicit knowledge to external knowledge or information and leads to detached knowledge as seen from the perspective of the human being, which can be kept in organisational memory systems. Internalisation 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. These five basic knowledge conversions are shown in Fig. 3.

The Nonaka/Takeuchi-model [9] uses four basic knowledge conversions in the sense defined above and interact in a spiral of knowledge creation, which becomes larger in scale as it moves up the ontological dimension from the individual to groups and the whole organisation. This limiting linearity of its knowledge development spiral concept and the restriction to basic conversions have been the criticisms of their approach, besides the discussions on the meaning of explicit knowledge.

Our conception allows the generalisation of the basic five knowledge conversions described above. General knowledge conversions are modeled converting 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.

For example, in a learning-by-doing situation seen as a complex knowledge conversions, a new employee may extend his tacit and conscious knowledge by working on and extending an external knowledge asset in a general conversion, using and being assisted by the tacit and conscious knowledge of an experienced colleague. A piece of relevant information on the topic may also be available on the source side of the conversion. Here on the source side of the general conversion we have two tacit, two conscious and one external knowledge assets plus one information asset, while on the destination side one tacit, one explicit and one external knowledge asset (i.e. the resulted enriched external knowledge) arise.

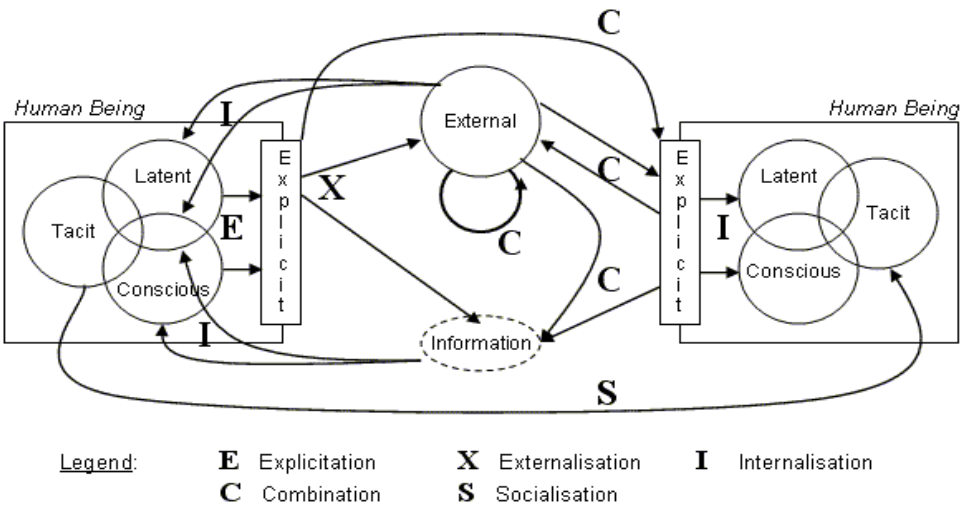

Fig. 3 Knowledge conversions in the type dimension

Completing this section, we shortly mention knowledge conversions in the quality dimension of knowledge. In three out of the five quality measures, basic conversions can be identified, which are working gradually. Those are, firstly, a deepening conversion, which converts overview knowledge into a deeper form of this knowledge. Secondly a structuring conversion performing improvement in the singular-versus-structure scale of the structural measure. Finally, conscious and step-by-step-applicable knowledge may convert into automated knowledge in a automation conversion, which describe a process from beginner to expert in a certain domain. The remaining two quality measures of knowledge, namely modality and generality, do not lend themselves to knowledge conversions. They just describe unchangeable knowledge qualities.

IV. Modeling Knowledge-Intensive Business Processes with Human Interactions

In order to indicate the usefulness of our knowledge conception and the general knowledge conversions, a modeling approach for knowledge-intensive business processes with human interactions is described, which using those conceptions.

We introduce an integrated model for knowledge management, which covers task-driven, knowledge-driven and human-driven processes in an organisation. It is based on seven very general entities (Process, People, Topic, Implicit, Explicit and External Knowledge, and Document) and the various interconnections between them. The model covers process-oriented approaches, reflects the human role in various forms (as individuals, groups, or knowledge communities plus the interaction between those) and the various types of knowledge with their mutual conversions. It is an extension of the model in [1] and reflects the new knowledge conception.

Our approach to human-to-human interactions in business activities is motivated by the observation, that there is no such interaction without transfer of knowledge and/or information. In other words, human interaction in fact goes on through the exchange of knowledge and information. This must not happen with spoken language only, but also via behaviour, gesture, or facial expression. Consequently, using our concept of general knowledge conversions as described in section III, a notion is at hand for modeling of human interactions. Note, that general knowledge conversions do not impose sequences of activities for their accomplishment.

As notation for our model we propose an expressional extension of the Business Process Modeling Notation BPMN [3], which we call BPMN-KEC2 (KEC stands for knowledge, employees, and communities, 2 indicates the second version). BPMN is widely used for business process modeling, there exists a whole body of tools to support the visual modeling procedure, to integrate it in service-oriented architectures and to map models to execution environments for appropriate IT-support.

For a detailled description of BPMN-KEC2 see [2]. The most important notational objects may be categorized as objects for knowledge and information, for knowledge conversions, for associations between knowledge and persons, and for persons. Knowledge objects are tagged with type/kind information according to the two knowledge dimensions as introduced in section III, see Fig. 4 for notational details. The quality dimension of knowledge is not reflected in this approach. Quality characteristics of knowledge assets may be implicitly denoted in the knowledge name if necessary. General knowledge conversions are denoted with an elliptical symbol.

As an example for the modeling power of the new model and the applicability of the corresponding notation, we model a business process for product renewal planning. The product is assumed to be knowledge-intensive and complex. The existing version of it should be possibly renewed by a new version. The overall process is modeled as sequence of four activities in BPMN notation: Propose product idea, define product characteristics, plan product development and finally decide on renewal. Here we will focus on the first one, which is really knowledge-intensive and requires human interactions. The expansion of this process using the BPMN-KEC2 notation is shown in Fig. 5. The main human actors are the product manager responsible for the product in the company, a knowledge community named *Expert Community*, and finally a product strategist.. The expanded sub-process relies on two knowledge conversions. *Generate Product Idea* is a general and complex knowledge conversion, *Formulate Product Idea* a basic externalisation conversion. The main origins for *Generate Product Idea* are on the one side explicit knowledge on new technologies (of the propositional knowledge kind), conscious knowledge on actual relevant research themes, both available in a knowledge community named *Expert Community*. On the other side, knowledge on market trends and the product position of the existing product in the

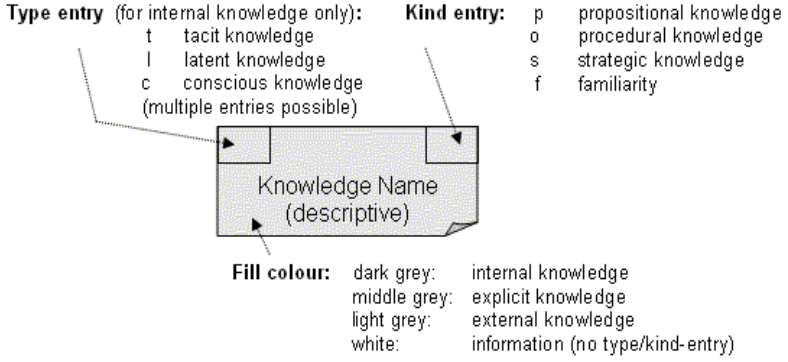

Fig. 4 Knowledge object notation

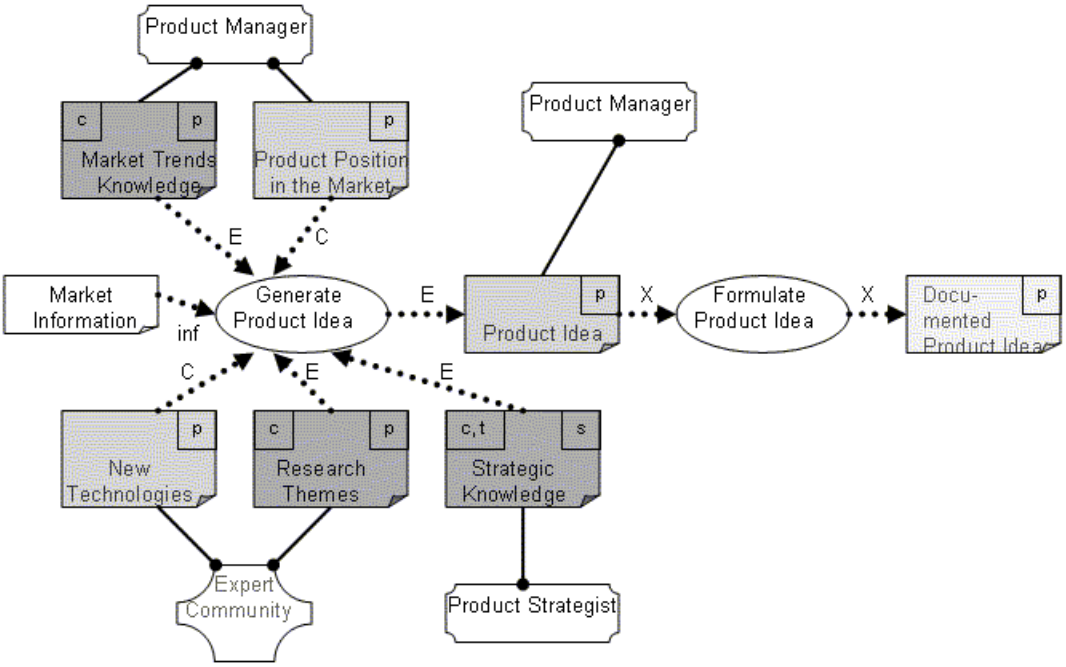

Fig. 5 Expanded process "Propose Product Idea"

market is available at the product manager as conscious and explicit knowledge, respectively. Thirdly, the product strategist applies his internal knowledge (of the types conscious and tacit and of the strategic kind). Relevant information (*Market Information*) is available. Bringing this together via the knowledge conversion *Generate Product Idea* will end in a general product idea, being explicit knowledge associated to the product manager. This explicit knowledge now will be externalised in the second conversion to end up in external knowledge, the documented product idea.

While there is some sequentiality in this process (a general knowledge conversion followed by an basic one) the first activity is clearly human-driven and knowledge-driven. Here several participants, the product manager, members of a community of practice and a product strategist interact by exchanging their ideas based on their internal and partly explicit knowledge. As described before, human interaction is modeled with the help of a knowledge conversion. Documental information (market information) supports the generation of a product idea. It is important to note, that those interactions do not follow a sequential schedule, as human interactions seldom do. The members of the community of practice interact informally to expand on ideas and proposals for new product version, independent of business schedules. The product strategist discusses ideas an opportunities with the product manager and the community. Those discussions may go on iteratively or in parallel efforts, just to name two alternatives.

V. Summary and Conclusion

A new conception of knowledge and its knowledge conversions has been introduced. With its three dimensions type, kind and quality, it can be represented by a knowledge cube. Mainly in the type dimension, general knowledge conversions as drivers for knowledge development has been defined. They substantially extend the well-known SECI-model by Nonaka/Takeuchi. This conception of knowledge and its conversions establishes a sound basis for knowledge management in a company. As an area of applicability, the modeling of knowledge-intensive business processes with human interactions has been described.

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