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Modeling of Knowledge-Intensive Business Processes

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***Abstract*—**Knowledge development in companies relies on knowledge-intensive business processes, which are characterized by a high complexity in their execution, weak structuring, communication-oriented tasks and high decision autonomy, and often the need for creativity and innovation. A foundation of knowledge development is provided, which is based on a new conception of knowledge and knowledge dynamics. This conception consists of a three-dimensional model of knowledge with types, kinds and qualities. Built on this knowledge conception, knowledge dynamics is modeled with the help of general knowledge conversions between knowledge assets. Here knowledge dynamics is understood to cover all of acquisition, conversion, transfer, development and usage of knowledge. Through this conception we gain a sound basis for knowledge management and development in an enterprise. Especially the type dimension of knowledge, which categorizes it according to its internality and externality with respect to the human being, is crucial for enterprise knowledge management and development, because knowledge should be made available by converting it to more external types.

Built on this conception, a modeling approach for knowledge-intensive business processes is introduced, be it human-driven, knowledge-driven or task-driven processes. As an example for this approach, a model of the creative activity for the renewal planning of a product is given.

***Keywords*—**Conception of knowledge, knowledge dynamics, modeling notation, knowledge-intensive business processes.

I. Introduction

A number of knowledge management approaches exist, including the classic asset-oriented, the process-oriented approach, the knowledge-intensive process-oriented and the community-oriented approach, see [1], [6] and [9]. While the management aspect of knowledge management seems to be understood to some extent, 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 and Takeuchi ([10]) is built on the distinction between tacit and explicit knowledge and on four fundamental knowledge conversions between those knowledge types (SECI-model). However, many discussions exist, whether to interpret the explicit knowledge part as still bound to the human being, or as already detached from him.

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Another important work is the introduction of the type/quality dimensions of knowledge in [5]. Finally, important distinctions of implicit knowledge are given in [8].

In this paper, we introduce a new conception of knowledge, which combines and resembles parts of 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 addresses 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 and strategic knowledge, and familiarity. Finally, in the quality dimension, several quality measures of knowledge are given.

Using this conception we introduce general knowledge conversions between the various knowledge (and information) assets. First a basic set of such conversions is defined, which extends the set of the four conversions of the SECI-model. 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. These general knowledge conversions are the building blocks to model knowledge development, i.e. all of acquisition, conversion, transfer, development and usage of knowledge, in an enterprise.

Built on this conception of knowledge and knowledge dynamics, a modeling approach for knowledge-intensive business processes in companies is introduced. These processes are characterized by a high complexity in their execution, weak structuring, communication-oriented tasks and high decision autonomy, and often the need for creativity and innovation. They may be human-driven, i.e. requiring human-to-human interaction, or knowledge-driven or task-driven.

The well-known Business Process Modeling Notation (BPMN, see [4]) is the language of choice for business process modeling. However BPMN is lacking of knowledge-related constructs and is not considering the human role in business processes adequately. 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 ([7]), but it is lacking the knowledge-related aspect. Our modeling approach presented in this paper aims mainly at knowledge-intensive business processes with possibly human interactions and provides an appropriate modeling notation. Its modelling notation is an extension of BPMN and reflects the new

conception of knowledge and of knowledge conversions. As a modeling example a renewal planning process for a complex product is described, which requires substantial competences and knowledge for its design and implementation.

II. Concept 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 (at least 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 [8] and [9]. It is a perspective of "knowledge-in-use" (De Jong/Fergusson-Hessler [5]) 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 transferred 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.

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 a 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 [8]. Conscious knowledge is conscious and intentional, is cognitively available and may be made explicit easily. Latent knowledge has been typically learned 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 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 [11]) characterise it.

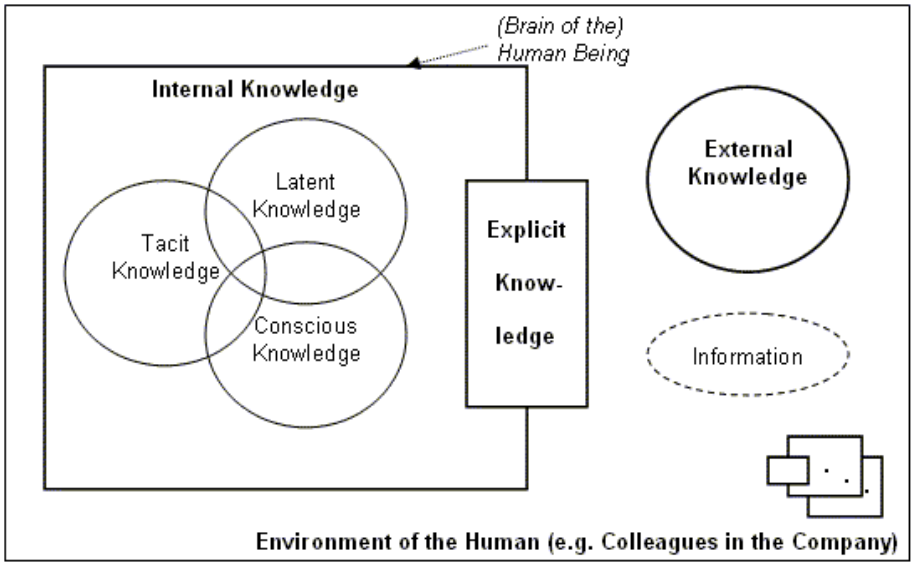

Fig. 1 Conception of knowledge types

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 [5]. 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" 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.

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 [5]. 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 3. 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 a knowledge cube, as shown in Fig. 2.

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).

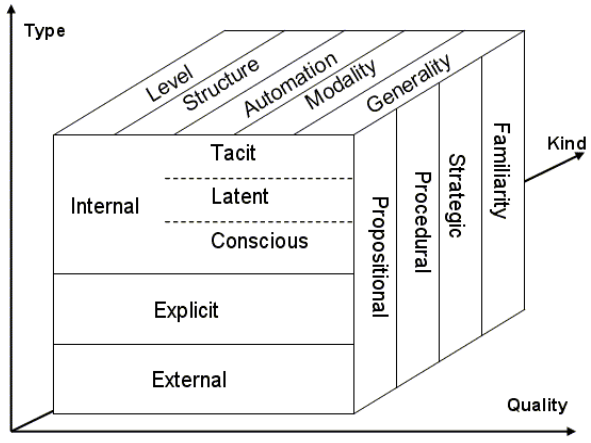

Fig. 2 The knowledge cube

However, in the quality dimension each of the given five characteristics are always present for each knowledge asset.

III. Knowledge Dynamics

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. These general knowledge conversions are the building blocks to model knowledge dynamics, i.e. all of acquisition, conversion, transfer, development and usage of knowledge, in an enterprise.

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 unchanged 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. 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 ([10]) uses four basic knowledge conversions in the sense defined above and interact

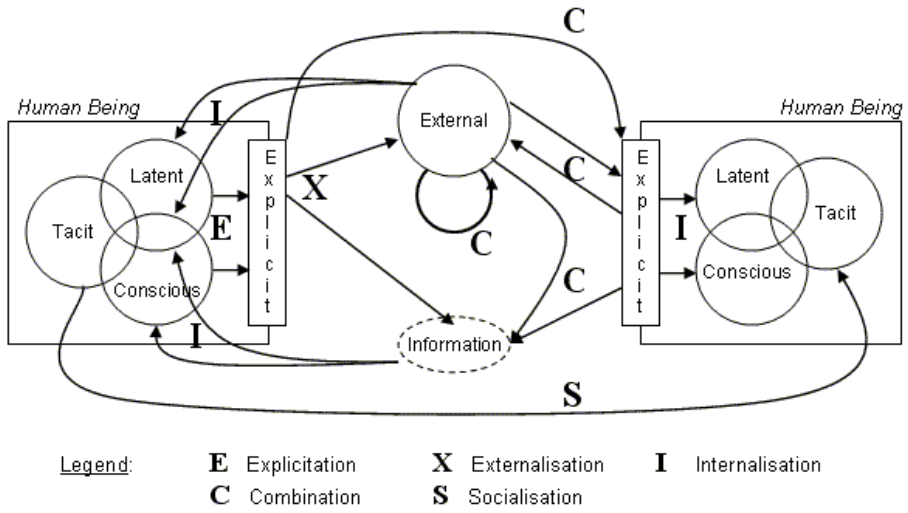

Fig. 3 Knowledge conversions in the type dimension

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 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. Fig. 4 shows this scenario.

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, there is 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 an automation conversion, which describes 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.

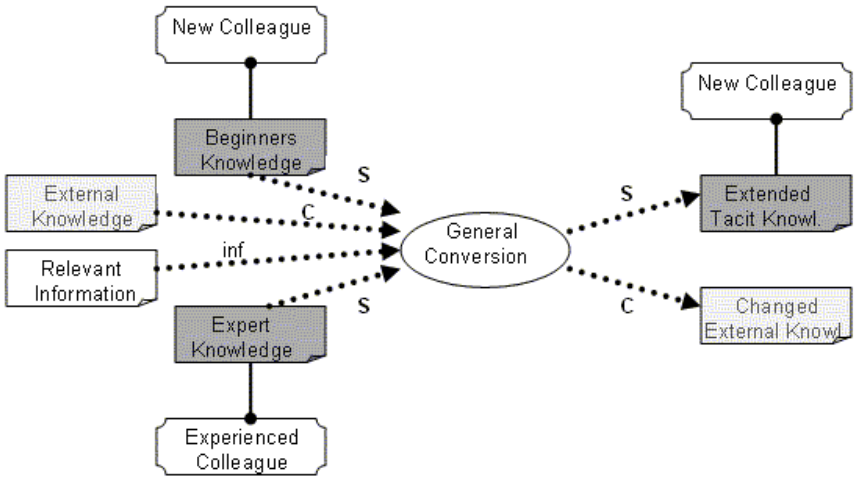

Fig. 4 Supervised learning-by-doing

IV. An Area of Applicability

Two main categories of application scenarios for knowledge development in an enterprise can be identified: constructive and analytic scenarios. Analytic scenarios try to resolve situations, where one or several gaps in the knowledge development representation of the scenario are present. For example, the knowledge requirements for a project are known as well as the learning options in the company. From that, one would try to identify minimal knowledge requirements for a new employee, who should work in the project and should be able to fulfil the requirements at least after some learning efforts. See [3] for this scenario category and a supporting solution, which is based on a knowledge ontology, which implements our knowledge development conception, and on the application of reasoning and rule processing.

In this paper, we focus on the constructive scenario category. Here knowledge development chains are built. As an example, which indicates the applicability of our knowledge development conception, we describe a modeling approach for knowledge-intensive business processes with human interactions.

This modelling approach 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 derived from a meta-model for knowledge management and extends the model in [1].

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 3, 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 we propose an expressional extension of BPMN ([4]), which we call BPMN-KEC2 (KEC 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 IT-support.

For a detailed 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 marked with type/kind information according to the two knowledge dimensions as introduced in section III, see Fig. 5 for the notational details. General knowledge conversions are denoted with an elliptical symbol.

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.

As an example we model a business process for product renewal planning with this notation. 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 high-level activities in BPMN notation, which each are expandable: Propose product idea, define product characteristics, plan product development and finally decide on renewal as shown in Fig. 6. 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. 7.

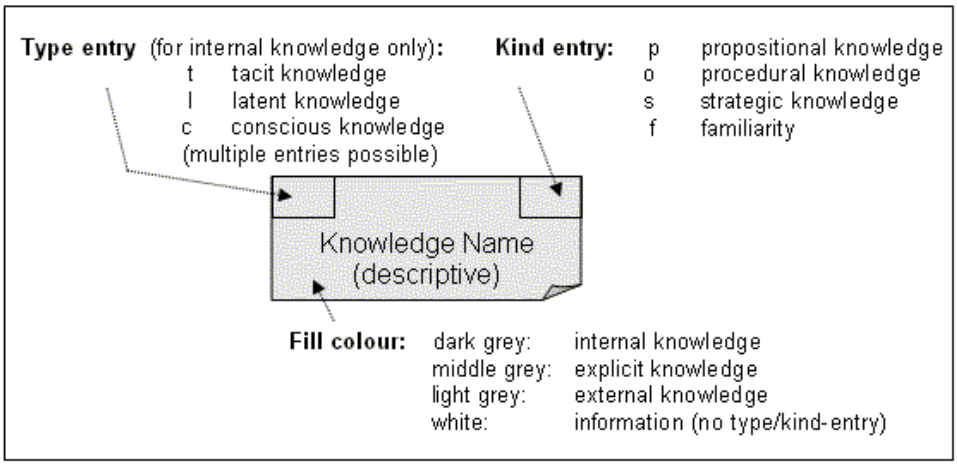

Fig. 5 Notation of knowledge and information objects

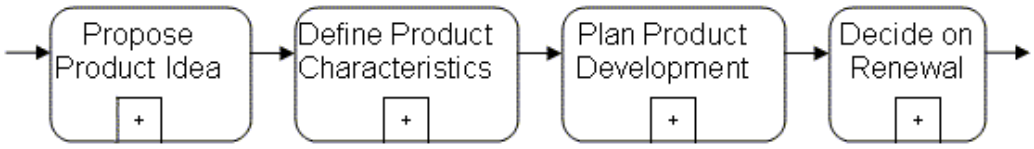

Fig. 6 Process "Product Renewal Planning" in BPMN notation

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 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 first activity in this example is human-driven and knowledge-driven. The participants interact by exchanging their ideas based on their internal and partly explicit knowledge. Information supports the generation of a product idea. 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 and opportunities with the product manager and the community. Those discussions may go on iteratively or in parallel efforts, just to name two alternatives.

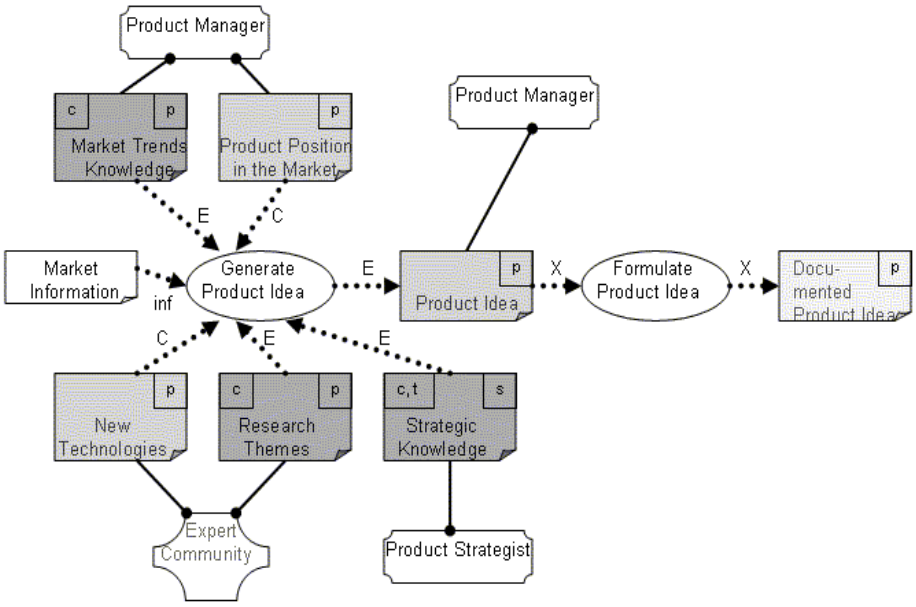

Fig. 7 Expanded process activity "Propose Product Idea"

V. Summary and Conclusion

A conception of knowledge and its knowledge conversions has been introduced, based on a knowledge concept with three dimensions and very general knowledge conversions. Mainly in the type dimension, general knowledge conversions have been identified as drivers for knowledge dynamics in a company. This conception of knowledge and its conversions establishes a sound basis for knowledge development. As an area of applicability of our conception a modeling approach for knowledge-intensive business processes with human interactions has been described. This notation expands the well-known BPMN notation by notational concepts of knowledge and knowledge conversions. As an example of a model of a knowledge-intensive business process in this notation, a product renewal planning process has been modeled.

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