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The interplay between individual and collective knowledge: technologies for organisational learning and knowledge building

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Abstract
This article presents a framework model that defines knowledge building as a co-evolution of cognitive and social systems. Our model brings together Nonaka's knowledge-creating theory and Luhmann's systems theory. It is demonstrated how collaborative knowledge building may occur – in an ideal situation – within an organisation, when people interact with each other using shared digital artefacts. For this purpose, three different technologies are introduced as examples: social-tagging systems, pattern-based task-management systems, and wikis. These examples have been chosen to demonstrate that knowledge building can occur with respect to both declarative and procedural knowledge. The differences and similarities between these technologies, as far as their potential for organisational knowledge building is concerned, are discussed in the light of the framework model.
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Introduction

New technologies and tools have emerged in recent years that are of great importance for knowledge management, organisational learning, and knowledge-building purposes. They provide communication facilities with new-style opportunities for organisational learning and collaborative knowledge building, because they facilitate and support a specific form of interplay between individual and social knowledge processes (cf. Kimmerle *et al.*, 2008). They originate from the development of so-called social-software systems and from innovative approaches to knowledge management (Wagner & Bolloju, 2005; Wagner, 2006). We are talking about software that is able to facilitate communication, collaboration, and interaction between people in large communities such as organisations (Kolbitsch & Maurer, 2006). This is achieved by supporting self-organising processes in these communities (Köhler & Fuchs-Kittowski, 2005; Wasko & Faraj, 2005). Although social software is primarily associated with communities based on the Internet, it is also relevant in the context of organisational learning and knowledge management (Fuchs-Kittowski & Köhler, 2005). We believe that such technologies do indeed have a great potential for organisational learning and collaborative knowledge building. We regard knowledge building as a socio-cultural process that takes place in a community and aims at creating entities which are relevant to

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that community, in order to enable its members to understand the environment that they are dealing with, such as theories, analyses, explanations, interpretations, and so on (Scardamalia & Bereiter, 1999; Bereiter, 2002). Knowledge building aims at producing new knowledge and includes innovation and a permanent advancement of ideas.

In our opinion, it would not make sense to consider individual learning and collaborative knowledge building as two entirely separate, distinct processes. The reason why we find the tools that we are talking about here so interesting is because they can facilitate a process in which individual and collective knowledge are merged and intertwined. In order to describe and explain this tight conjunction between individual learning and collective knowledge building adequately, we need a new theoretical framework model that will address this aspect. The model will need to identify how the knowledge of an organisation and of an individual may, so to speak, cross-fertilise each other, and how they can reciprocally support each other's development. This article attempts to develop such a theoretical model. We will proceed from two theoretical approaches.

The first one is the knowledge-creating theory by Nonaka & Takeuchi (1995). Its authors concentrate primarily on the aspect of building and transferring tacit knowledge. Even though this theory does not explicitly concern itself with computer-supported forms of knowledge transfer, we think that it is possible to apply key aspects from the model to a theory that deals in some depth with collaborative knowledge building on the basis of using software technologies for communication. Nonaka's central ideas on the transfer of tacit knowledge illustrate quite nicely how a technology-based knowledge building process may take place.

The second approach is systems theory in the sense of Luhmann (1995). This approach emphasises that people's cognitive (psychic) systems need to be distinguished from social systems. The theory also describes the different modes of operation of these two types of systems. These considerations are, in our opinion, a very good basis for describing the interaction between individual knowledge (cognitive system) and collective (e.g., organisational) knowledge (social system). Moreover, Luhmann's systems theory elaborates in detail on processes of self-organisation that are highly relevant to understanding knowledge building.

In the following section, we will introduce our co-evolution model of individual and collective knowledge. This model takes a closer look at cognitive processes of users and social knowledge processes (within a community), which are facilitated by digital artefacts that were products of collaboration. The model demonstrates how these cognitive and social processes influence each other mutually. It represents a theoretical framework which integrates many of the processes that are described by the theory of knowledge creation and the systems-theoretical approach. Another approach with a similar intention is a theory, developed by Spender (1996, 1998), which considers firms as dynamic systems. There are, however, some unique features that characterise our co-evolution model: it focuses on the interplay between individual cognitive systems and social systems, instead of merely analysing the organisation as a social system. Moreover, our model is particularly designed for taking technology-based knowledge building into consideration.

The general description of co-evolution of individual and collective knowledge will be followed by three concrete applications, in order to demonstrate how the use of such software can support collaborative knowledge building in organisations. For this purpose we will describe social-tagging systems, the deployment of pattern-based task-management systems, and the use of wikis. Each of these produces a specific type of digital artefact that supports knowledge building processes in a unique way.

The concluding section of this article will consider the differences and similarities between these technologies, as far as their potential for organisational knowledge building is concerned, and discuss the impact of our framework model in the light of the three examples.

Knowledge-creating theory

Nonaka's knowledge creation theory (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995; Nonaka & Toyama, 2003) assumes that in organisations only little knowledge is available in the form of explicit knowledge. Most of it exists in the form of experiences that people have made, or, in other words, as *tacit knowledge* (Polanyi, 1966). Tacit knowledge is characterised by the difficulty to express it in spoken or written form. Consequently, this kind of knowledge cannot be transferred to other people easily. A successful creation of knowledge will, however, require this type of transfer. To describe how a transfer of tacit knowledge can occur, Nonaka refers to four processes that build on each other dynamically. He calls these processes socialisation, externalisation, combination, and internalisation (for a critique of these processes cf. Gourlay, 2006).

In the course of *socialisation*, people share their experience, but in this process tacit knowledge can only be transferred from one individual to the other through immediate experience, through observation and imitation. The knowledge acquired by the observer as a result of this transfer is tacit knowledge as well. This is why a process of *externalisation* is necessary. This is the articulation of tacit knowledge and the translation of tacit knowledge into explicit knowledge. If knowledge has become explicit, it can be combined with other knowledge in order to develop new knowledge within the organisation. Hence, the process of *combination* refers to the re-arrangement (new structure, new links) of explicit knowledge. This is facilitated by interpersonal knowledge sharing. Finally, explicit knowledge will, once more, be converted into tacit knowledge through a process of *internalisation,* which is an individual process. Internalisation may occur as a result of 'learning by doing'.

Nonaka uses the metaphor of a 'knowledge spiral' in which the four processes succeed each other. In this sense, the knowledge spiral supports the inter-individual transfer of knowledge and at the same time the development of new knowledge within an organisation by combining externalised knowledge that had been tacit afore.

Systems theory

Luhmann (1995) has worked out a very differentiated systems theory that can only be outlined here briefly and as far as it concerns our framework model. Luhmann's theory is presented here with that degree of abstractness which is characteristic of that theory.

The basis of Luhmann's theory is the distinction between 'system' and 'environment' (Luhmann, 2006): whatever is not part of the system belongs to its environment. So a system is not defined by what it consists of, but by the boundary between itself and other systems, which form its environment. It is a system's mode of operation that constitutes what is part of the system and what, in contrast, is defined as external. Or in other words, what characterises systems is their activity and inherent dynamics: a system consists of operations which create the difference between the system and its environment. From this systems-theoretical point of view, it is necessary to distinguish between people's cognitive systems on the one hand and social systems on the other, because cognitive systems and social systems operate differently.

Communication is the mode of operation of a social system. Cognitive systems, however, operate via cognitive processes and processes of consciousness. The structure of a social system, such as an organisation, determines possible links and connections for communication. That means that the social system will establish how its communication takes place. Systems are autopoietic (Luhmann, 1986; cf. also Varela *et al.*, 1974): they are capable of self-production and self-reproduction, thus guaranteeing their own existence. Autopoiesis means self-reference, or, in other words, an operation which is capable of being followed by further operations (Luhmann, 1990). So systems (re-)produce themselves through their own operations, or, in other words, systems develop and sustain themselves.

The nature of a system is such that it is not in an immediate exchange with its respective environment, but 'operatively closed'. This operatively closed character of a system excludes communication between autopoietic systems, as these operate in different modes. But we can still observe that a system may be influenced by other systems and react to its environment. Luhmann (1995) has solved this problem by stating that a system is both open and closed, using the concept of structural coupling. In other words, a system is operatively closed, but still open for information from the environment: structural coupling is based on the structure of expectations that the system creates, which make it sensitive to irritations from other systems (the environment of that system). Irritations from the environment will be transferred into that mode of operation which is inherent in that system. With respect to cognitive and social systems (that are part of the environment of the respective other system) this means that cognitive and social systems can irritate each other. These systems will then respond to irritation by what their specific mode of operation provides for that purpose. By operating, they reduce irritation from their respective environment and in this way decrease the complexity of that environment. Along with that, systems can increase their own complexity (Luhmann, 1990). In other words, one system can influence the other in its progress by irritating it. For example, individuals (cognitive systems) may have an impact on the development of an organisation (social system), and processes in an organisation, in turn, can influence the thinking of individuals, for example, support individual learning processes. In this way, a system can supply its complexity to the development of the other.

From the point of view of the system, the environment will always be more complex and more chaotic than the system itself. The system will reduce this complexity by using a binary code that distinguishes what belongs to the system and what does not. The binary code is a safeguard to keep the system operatively closed. At the same time, reduction of complexity is a requirement of emergence (Kofman & Senge, 1993). Emergence refers to systems with hierarchical structure in which features may occur at the higher level of the system which cannot be explained by features of the lower level of the system. These features that exist at a higher level are created by reciprocal action (synergy) between elements at the lower level of the system. Only this holistic consideration makes it possible to explain phenomena of emergence, such as processes of knowledge emergence. This will not be achieved by a reduction into partial systems or subsystems.

Luhmann's theory is capable of describing computer-mediated construction and communication of knowledge. Shared digital artefacts and their respective communities may be understood, in Luhmann's terminology, as social systems that use written communication as their mode of operation. Communication is mediated, using an artefact, and the system is structurally coupled with the cognitive systems of the actors. This interplay of cognitive and social systems will be demonstrated in the remainder of this article in more concrete terms in order to describe how individual and collective knowledge influence each other mutually.

Co-evolution model of individual and collective knowledge

The authors of this article have recently introduced a theoretical framework that deals with the relationship between individual learning and collaborative knowledge building (Cress & Kimmerle, 2007, 2008; Moskaliuk *et al.*, 2008, 2009). In this model, learning and knowledge

building are regarded as an interplay between cognitive systems and a social system. If a knowledge community uses information and communication technologies for that purpose, collective knowledge not only appears as the fragile product of communication activities within a community, but also exists in the form of digital artefacts. Chat logfiles, wiki articles, weblog entries (or other communication that has been stored and saved) are examples of such artefacts.

Our model is based on the assumption that knowledge building can only be understood if the interplay between individuals and some collective (team, department, organisation) is taken into account.

The model is also based on the systemic perspective, as described above. In this context, learning processes and knowledge-building processes are interpreted as reactions of systems to irritations. Irritation is understood in the sense of Piaget's (1977) cognitive conflicts, assuming that the solution of cognitive conflicts contributes to the development of cognitive systems. It is a matter of a cognitive conflict when people's prior knowledge and the information available in their environment are to some extent incongruent. In order to solve cognitive conflicts, a process of equilibration is needed. Two types of equilibration processes should be distinguished from each other.

People may *assimilate* information, which means, just adding new information to their existing prior knowledge. Or they may *accommodate* their prior knowledge to new information (re-arrange, re-organise, re-define their existing knowledge). In both cases people will have to internalise information from their environment in some way. As a consequence, their cognitive systems become more complex. In other words, such a progress within a cognitive system (which corresponds to what is conventionally called individual learning) occurs through processes of assimilation or accommodation. Both processes are internalisations from the social system. Both assimilation and accommodation will take place as part of the development of a cognitive system. Our model assumes that processes that occur in a cognitive system through internalisation will also occur – analogously – in a social system through externalisation. By means of externalisation, a cognitive system can transfer an individual's knowledge to a shared digital artefact. People will not only internalise information from their environment into their cognitive systems, they also externalise their own knowledge (this externalisation from the individual's point of view represents – naturally – internalisation from the social system's perspective, but to simplify matters, our point of reference here is the cognitive systems of individuals). In other words, just as individuals can learn by internalising new information, social systems can also learn by incorporating information. People internalise information in their cognitive systems by either assimilating it or accommodating their prior knowledge. In an equivalent procedure, social systems can generate new collective knowledge by assimilation or accommodation. They can develop by simply adding new content (assimilation) or by altering their own structure (accommodation). Our assumption is that emergent effects will normally take place as a result of accommodation of shared artefacts. This external accommodation produces a higher complexity of the artefact. As a result, new equilibration processes in other people's cognitive systems are necessary. Therefore, individual knowledge supplies the content of an artefact, and the artefact, in turn, supplies the individuals with new information, releasing new cognitive conflicts, and so on.

The crucial aspect is that internalisation and externalisation processes – and, as a consequence, individual learning and collaborative knowledge building – will always depend on each other. Thus, learning and knowledge building should be considered as continuous exchange processes. This exchange between the social system and the individuals' cognitive systems is the basis for the development of new knowledge within organisations. Such a joint development of cognitive and social systems may be envisaged as a co-evolution.

At this point it is helpful to apply the four processes described by Nonaka to this co-evolution model of individual and collective knowledge. They will help to understand the exchange processes between cognitive and social systems as described by Luhmann. Externalisation here may be described in terms of what Nonaka calls *externalisation* and *combination*. Externalisation of one's own knowledge into a shared digital artefact has to take into account the following points:

- People somehow need to articulate their own knowledge, that is, they have to couch their cognitive concepts verbally or by describing procedures.
- This is only possible if they have transformed their own knowledge into a form in which others can understand it and follow their line of thought or carry out the same procedures.
- They have to take into account those pieces information that are already available in a digital artefact, in order to integrate their own thoughts or procedures adequately.
- People need to edit pre-existing information in order to establish a consistent presentation.

Internalisation combines the two processes which Nonaka labels *internalisation* and *socialisation*. When people incorporate information from a shared digital artefact into their own cognitive system, the following aspects are important:

- People search for data or information by browsing a shared digital artefact.
- In doing so, they gather and bring together relevant information.
- Then they have to transfer this relevant information into their own cognitive structures.
- Strictly speaking, the acquisition of new knowledge has only been complete when people succeed in retrieving and applying this knowledge in specific situations.

In the following section, we will illustrate these processes by describing three examples of shared digital artefacts. This is an idealised description of organisational learning and knowledge building, in order to make clear the basic assumptions of our model. We will explicate our ideas by using social tagging, pattern-based task management (PBTM), and wikis as examples. These technologies can facilitate knowledge processes in small groups (e.g., organisational teams), but also in extremely large groups (e.g., whole organisations, Internet communities). For each example, the processes of internalisation and externalisation will be considered in detail.

These examples have been chosen to demonstrate that knowledge building can occur with respect to both declarative and procedural knowledge. Both types of knowledge building are addressed by the use of these technologies.

Social tagging

Social tagging has become a standard element of many social-software tools (Marlow *et al.*, 2006; Nelson *et al.*, 2009). It may have great potential to play a major role in knowledge management and in scenarios of organisational learning.

The term 'tagging' in this context refers to the annotation of digital resources with keywords (Golder & Huberman, 2006). These resources are mainly objects in virtual environments like the Internet or organisational intranets: they may include photos, videos, websites, e-mails or any other piece of digital information. The keywords ('tags') can be selected by the users. So, tags represent the individual associations of a user with respect to the objects. Tagging is commonly used on platforms that offer the opportunity to share digital objects within a community. Labelling items with tags supports the search for and retrieval of information.

'Social tagging' refers to a social context in which all members of a community can benefit from tags. Most social-tagging systems allow users to tag all available resources individually and independently. Thus, all tags in a community that refer to a certain object can be aggregated, which results in a large set of metadata for that resource. The accumulated collection of tags represents the users' concepts and their categorisation of items. This compilation constructs a collectively created artefact of keywords that describe a specific resource. This artefact of metadata differs fundamentally from classifications that were created by single experts in top-down processes (a procedure that is still customary in many organisations). Quite in contrast, the social-tagging artefact is developed in a bottom-up process by numerous individuals within a community. Moreover, objects may be categorised in several dimensions, which may make it easier to retrieve them than in strict taxonomic hierarchies (Weinberger, 2007).

Another significant feature of social tagging is the indirect rating of resources by a community. The more individuals tag a resource, the more importance is attached to it by that community. Usually tags are visualised in so-called tag clouds that display the keywords in alphabetical order and these are weighted by the frequency of usage. Beyond their role of representing connected keywords, tags can also be applied as hyperlinks for exploring new resources that are related to a tag. In this way, browsing the hyperspace via tags offers new opportunities to discover new information.

The Internet or organisational intranets may have a great impact on learning. They provide heaps of information and offer great opportunities for the acquisition of knowledge. Users can browse information spaces with virtually no barriers and access information on almost any topic of interest. However, this is also a problem for knowledge building because of the overwhelming quantity of information that is available, and its inconsistent quality. Social-tagging systems can help to overcome these limitations: they provide tools for filtering and structuring information. Tags facilitate retrieval of relevant information and make this process more systematic.

Individual learning

As far as individual learning processes are concerned that are supported by social-tagging systems, we can distinguish between activities of externalisation and internalisation of knowledge. During externalisation users add tags to a specific resource and describe digital objects with their own keywords. For creating tags, users have to articulate their own cognitive concepts and translate them into keywords. The idea is that they help themselves, but also other users in the community to retrieve the stored information at a later date. Someone who adds tags externalises her/his own knowledge about a certain resource. Usually, this user will concentrate on critical concepts and connections of an item – for example, of a work report or website. Accordingly, this user may elaborate on the resource more comprehensively. This supplementary cognitive effort stimulates information processing in such a way that individual learning may occur (Budiu *et al.*, 2009).

In the internalisation process, a user will integrate novel information into the own cognitive system. In a social-tagging setting, people navigate through a website with the aim of exploring relevant resources. For this purpose they use tags as orientation and searching devices. The collectively created artefacts of metadata (the 'tag clouds') help them to browse the information space and to collect important information that is related to the tags. In doing so, users become aware of the keywords that were annotated by others. As a consequence, they learn how other users classified a resource. The artefact of tags may also show significant interconnections of concepts that may formerly have been unfamiliar to a user that comes across them. Thus, the information which is represented in the metadata of tags may lead to an incorporation of the community's concepts and to modification of the individual user's

cognitive structures. In an ideal case individual knowledge will grow and more things will be understood.

These processes of learning may also be described in terms of knowledge assimilation or accommodation. Assimilation in this context (merely adding new pieces of information to prior knowledge) takes place when people acquire additional facts about a certain resource without modifying the basic structure of the cognitive concepts. When people deal with new tags and related concepts that are in accordance with their prior knowledge, they may broaden their factual knowledge, but will not develop an entirely different concept on this subject matter.

Accommodation, however, occurs when prior knowledge is transformed because understanding a topic has reached a new quality. When other users have used very different keywords than that person would have done, it is evident that specific resources or tags are related to quite different concepts. Then, that user has the opportunity to learn that her/his associations on a specific subject matter were rather different, inaccurate, or even wrong, and will most likely modify her/his cognitive concepts accordingly.

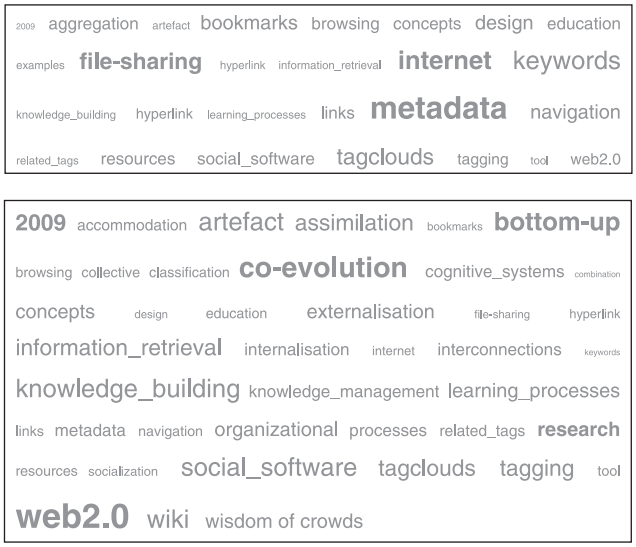

Figure 1 Two examples of tag clouds regarding a specific resource.

Organisational learning

An artefact of metadata develops in an incremental process of individual tagging. All individual tags of a community are combined into a digital artefact of keywords. This artefact is based on the tagging activities of many users. A single user, however, has only little impact on the whole product. Tags that have been used repeatedly are visually emphasised in a tag cloud; in this way, the community's concepts regarding a specific resource are accentuated. Figure 1 presents two examples of tag clouds.

In Figure 1 the lower tag cloud shows an artefact that is further developed than the upper one (more keywords and a different accentuation of tags). In the lower tag cloud, some new tags have been added (e.g., 'assimilation' or 'wiki'), other tags have gained more weight (e.g., 'social_software' or 'web2.0') or lost some of their significance (e.g., 'internet' or 'file-sharing'). The social-tagging artefact reflects a process of knowledge emergence, in that new tags appear (or existing tags become more prominent) and this implies a change of the conceptual information that a tag cloud contains.

The joint process of creating metadata provides the opportunity to incorporate 'the wisdom of crowds' (Surowiecki, 2004). It can incorporate the knowledge of all participating members of the organisation and contribute to progress of organisational knowledge. The collectively created artefact of tags (and, in this way, the social system itself) may benefit and 'learn' from the combined intelligence of all users.

A co-evolution of cognitive and social systems may occur when people use tags for navigating through the Internet or the local intranet of an organisation and discover relevant information. The cognitive processes of internalisation and the retrieval of new information may induce people to tag resources themselves. Consequently, the individuals' concepts are externalised and integrated into the artefact of metadata, which may lead to progress of the shared digital artefact. The organisation as whole can benefit from that. Each user in a social-tagging setting may provide and attain some knowledge, and a continuous advancement of knowledge occurs within the organisation.

In knowledge-management environments that provide social-tagging tools, people usually do not deal with pieces of abstract ivory-tower information, but will, of course, tag those resources that are relevant to them in some concrete context, or in other words: this tends to be information that addresses authentic real-life problems of the organisation. A community of involved members should regularly add new tags and resources to the artefact, and in this way develop new ideas, new connections, and new knowledge. In this process the artefact itself will not develop towards any defined target state, nor is it intended to become perfect or ideal at some point. What occurs is just a matter of constant improvement. The knowledge community as a whole should be responsible for the development and advancement of collective knowledge (cf. Brown & Duguid, 1991).

Pattern-based task management

PBTM is currently under discussion as a tool of organisational knowledge management and workflow management. PBTM systems are software technologies that may support co-evolution of individual and collective knowledge. The PBTM approach was initially presented by Riss *et al*. (2005) and elaborated upon by Riss *et al*. (2007) as an innovative type of workflow management. Workflow-management systems support members of an

organisation in carrying out routine tasks by providing workflows for various routines that occur frequently during their work.

So far, workflow patterns used to be designed in top-down processes, in which experts analysed tasks and tried to find the best ways to accomplish them. When members of an organisation have to carry out one of these tasks, they are supposed to apply the designed workflow, which leads them through all the required steps in a pre-defined order. Therefore, a typical top-down designed workflow-management system is rather inflexible, and all users have to conform to the system. Complex tasks, however, usually require flexibility so that people have some independence to bring in their own experience and to find their own way of accomplishing the task.

This is what makes PBTM interesting. It is a bottom-up task management approach. The users themselves create their workflows, that is, their own patterns for tasks which they have to accomplish repetitively. The patterns contain those activities that will lead to the required results. The task management system allows to contribute these artefacts to a shared repository, where they are available to all participants (for a discussion on lacking motivation to contribute information to a shared database, cf. Kimmerle *et al*., 2007; Kimmerle & Cress, 2009). So if someone has to carry out a certain task, they can search the shared repository for a suitable pattern. Users can modify patterns by adding, replacing, or deleting steps, and may then (re-)contribute them to the common repository. Here, the previous versions of the pattern are compared to the revision, considering all modifications. A current version is available that incorporates all earlier versions. For each step it is documented if this is a required or optional step, if alternative options exist, or if a particular step is unnecessary according to previous users of that pattern.

This course of action (creating, contributing, re-using, revising, re-contributing patterns) may optimise the patterns. The more frequently a pattern is used and revised, the better the result will be. So in the course of time, the system will shape patterns – high-quality patterns and useful steps will 'survive' and become more accentuated, while other patterns that are rarely used and steps that are dispensable become less prominent or disappear.

PBTM supports organisational learning in the field of *procedural knowledge*. This aspect of procedural knowledge has often been neglected because it is difficult to train and hard to transfer between people. Usually, procedural knowledge is tacit knowledge and people are hardly aware of it, but it is indispensable for problem solving and for applying conceptual knowledge in concrete situations. Patterns are tools that help to deal with this precious procedural knowledge (Alexander *et al*., 1977). When members of an organisation create patterns, they externalise their procedural knowledge, which is knowledge about how to plan things, how to accomplish projects, or how to get certain result. What patterns do is to capture people's practices, experiences, and procedures.

Individual learning

The bottom-up approach of PBTM is built on processes of externalisation. This leads to the documentation of practices and activities. People create patterns by trying to write down how they have accomplished certain tasks. The general aspects of the procedure form an initial pattern. Such patterns describe a generalised procedure that can be applied to diverse tasks. Whereas some patterns will fit several tasks, other – highly specialised – patterns need to be produced for highly specialised tasks. Therefore, the re-use of patterns will lead to a number of patterns with a different broadness of applicability.

Internalisation may occur when people have to accomplish new tasks and need to choose a pattern from the shared repository that was created by someone else. People may build on previous users' experiences when they use the pattern. In doing so, they may internalise different people's procedures and use them for their own tasks. Using a pattern may influence how people personally handle the task. So with this kind of internalisation, processes of assimilation as well as processes of accommodation may occur. People may adapt the pattern for their own task and for their own individual preferences in executing it (i.e., assimilation). Processes of accommodation will take place when use of a pattern guides people and shapes their activities. Hence, it is a matter of accommodation when patterns change the way how people execute a task.

Organisational learning

Processes of externalisation and internalisation enable collective processes of knowledge building as well – in this case, with regard to procedural knowledge. Users create patterns and contribute them to the shared repository. Other users can retrieve them, and the use of patterns may influence those individuals' manner of performing tasks. However, it is not only the individuals that might change their behaviour, the patterns are also revised and adapted. Patterns can improve over time; they are shaped and formed by experiences of their users. Figure 2 shows an example: here some user has identified a pattern (X′) that seems to be suitable for completing a certain task. This pattern includes four consecutive steps. Regarding the second step the user can choose between two alternative options. The frequency of the usage of these options by others is visualised by their brightness (the darker the more often an option was used). In the example the person uses this pattern with one of the alternative options and feeds this back to the shared repository. Then this information is processed and as a consequence the option that was used for step two becomes darker in X″, and the option that was not used becomes brighter.

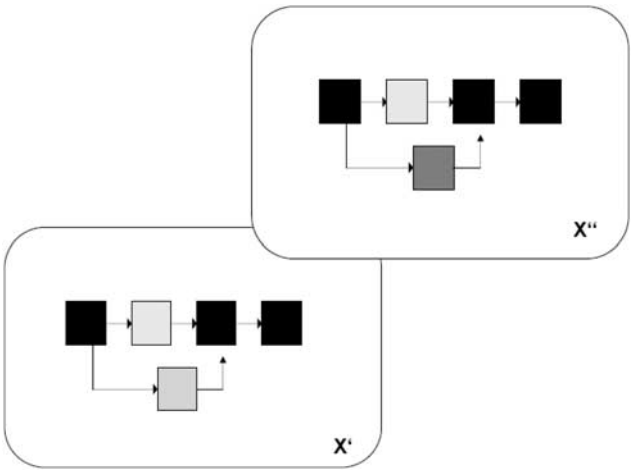

Figure 2 Example of a developing pattern.

A concrete example would be planning a trip to a conference. In the shared repository, a user may find a pattern called 'planning a conference trip'. This pattern includes four consecutive steps (e.g.: registration, manuscript submission, journey, and lodging). The user may use this as a starting point, but in a certain situation, it might be necessary to apply for a travel grant as well. Then, an extra step (say, 'applying for a travel grant') may have to be added. This would be a matter of external assimilation: the pattern in the repository will be expanded, but its structure as such will not be changed. What might also happen, however, is that a user will search the repository and find another pattern named 'applying for a research grant'. This is not exactly what the user needed here, but this pattern might still be helpful, and it might be modified for applying for a travel grant instead of a research grant. For this purpose, some different sub-steps would be needed. Subsequently, the user could merge both patterns 'planning a conference trip' and 'applying for a travel grant' in order to obtain a new, more complex pattern. This would be a matter of external accommodation, with two patterns that were combined in order to create a new one.

Through these collective processes, the social system can 'learn'. The software will find out which parts of a pattern were used more often than others, which are dispensable, and which are essential. Based on the history of patterns and on the log files, the system is able to support the emergence of collective knowledge. What takes place here is a co-evolution of the social system and the cognitive systems of those members of the organisation who are involved. The collectively developed patterns may shape the cognitive systems and practice of their users. However, it also works the other way round; the users' practices may also shape the patterns and improve them over time. This co-evolution may lead to a development and constant progress of knowledge. All members of the organisation are encouraged to participate in this advancement of knowledge. In a PBTM system everyone can bring in their own experiences and procedural techniques. In this way, all members of the organisation may have an impact on collective procedural knowledge. This diversity of experiences and ideas can support and facilitate the organisational knowledge-building process. Different individual practices can be combined into new procedural methods. PBTM might lead to a continuous improvement process of patterns.

This type of procedural knowledge building may support people in accomplishing their tasks and in handling difficulties that they come across in their day-to-day work. So people can deal here with issues and problems that are important and relevant to them. Moreover, PBTM gives members of the organisation an insight into other people's procedural methods. They have the opportunity to investigate how useful others people's procedures are, and to pick out those that are helpful for them. Accordingly, PBTM will not only support a simple exchange of information (cf. Cress *et al.*, 2006, 2009; Kimmerle & Cress, 2008), it can also support collaborative progress and improvement of procedural knowledge.

Wikis

Wikis are web pages that allow any user to modify their content online (Leuf & Cunningham, 2001). They can easily be implemented on the Internet or on a local intranet. Wikis can be applied in many contexts, including knowledge management in an organisation (Wagner & Bolloju, 2005; Wagner, 2006; Moskaliuk & Kimmerle, 2009) and educational settings (Wang & Turner, 2005; Chong & Yamamoto, 2006). With wikis people may revise a text with little effort; they are free to change, add, or even delete anything they want (Raitman *et al.*, 2005). With the help of wikis, users can initiate a community that works collaboratively on a certain topic and produces new content (Köhler & Fuchs-Kittowski, 2005). Most wikis have a revision-control feature that creates a new version with every revision of a wiki article. The prior version is then saved in a history file. Thus, each revision can be traced back without difficulty, and it is easy to restore an older version of the article.

Wikis can be established in schools or universities, in organisations, and in informal learning settings. They may be good tools to support individual and organisational learning. Wikis are convenient instruments for producing digital artefacts of collective knowledge. They might be particularly useful when people have controversial opinions on a topic. In a wiki, all users can express their own points of view on equal terms. People can articulate opposing opinions and integrate their views into a coherent text (Moskaliuk & Kimmerle, 2009).

Individual learning

Members of an organisation can acquire new relevant knowledge by internalising information from a wiki. They start by searching for information in a (more or less) target-oriented manner, browse the wiki and look for helpful information. When they have found relevant

Table 1 Example of a wiki article on the 'development of collective knowledge'

Development of collective knowledge	*Development of collective knowledge*
There is a theory of knowledge building. Knowledge building is considered as the collective development of public knowledge. Nonaka's knowledge creation theory considers distribution of knowledge as an important goal of organisations. Knowledge creation requires a transfer of knowledge among people.	In order to better understand the development of collective knowledge, diverse theoretical approaches need to be considered. For this purpose a theoretical framework is appropriate which integrates the concept of knowledge building with Nonaka's knowledge creation theory. The theory of knowledge building addresses how communities manage to develop knowledge collaboratively. Nonaka's knowledge creation theory also deals with the development of innovative knowledge. However, whereas the theory of knowledge building was developed in an educational context, Nonaka's theory emerged from research on knowledge management. A theoretical framework for the development of collective knowledge focuses on the major considerations of both approaches. In this framework collaborative knowledge building is considered to be an interplay between cognitive systems and a social system. …

Left-hand side: original structure of the article; right-hand side: accommodation of the article.

items, they will need to transfer these into their cognitive system, that is, they need to deal with the information somehow and include it in their existing knowledge. This internalisation process facilitates a growth of individual knowledge and the development of new insights. This individual learning may take place in the form of assimilation or accommodation – either by learning new facts without modifying existing cognitive concepts, or by incorporating new information in a manner that changes previous knowledge on the basis of new insights.

People who want to contribute something to a shared digital artefact need to externalise some parts of their own knowledge. When they introduce their knowledge into a wiki, they will have to make some effort to communicate to others what they know. So, they will need to transform their own thoughts into written language, preferably in a way that is easily comprehensible to others. Accordingly, people will have to consider the information that already exists in the artefact in order to integrate their own cognitive concepts adequately.

When members of the community make a contribution to a wiki, this may not only improve the wiki article, but also support learning processes of the contributors. People who externalise knowledge have to put some cognitive effort into this process. This cognitive elaboration, in turn, will help them to process their knowledge more intensively, and this will increase their understanding (cf. Craik & Lockhart, 1972). As a result, each externalisation process may initiate some modification of a person's individual knowledge, or in other words, externalisation may lead to individual learning.

Organisational learning

When members of the organisation introduce knowledge into the wiki, this information may, again, either be assimilated or accommodated. Assimilation in this case means attaching information to some pre-existing text, not connecting it to earlier information. In a well-organised wiki community, however, users should always attempt to interpolate new information consistently. Accommodation or re-arrangement in this case means the integration of new aspects into existing information, or an entire re-organisation of the wiki article.

An example of accommodation of a wiki article is shown in Table 1. On the left-hand side of Table 1 two approaches are mentioned independently from each other (the theory of knowledge building and Nonaka's knowledge creation theory), on the right-hand side, however, these approaches are explained in more detail, the theories are brought together, connected to each other, and put into context.

It is a case of accommodation when new aspects are integrated into existing information, when paragraphs are completely rewritten, or when a wiki article is totally reorganised.

Apart from their use for individual learning, wikis might be an attractive option for organisational knowledge-building purposes. The main aim of collaboration on a wiki is the progress of knowledge. Owing to a constant interplay between externalisation and internalisation processes, there might be a permanent development of individual and collective knowledge. The users' cognitive systems and the social system may continually being enhanced and advanced as a result of equilibration processes. All participating members of the organisation can exchange (provide and acquire) knowledge in this way. Anyone can bring in information and this information can be treated by every member of the community on an equal footing.

A wiki community can be installed when there is a need for finding solutions to problems collectively. Usually, the common denominator of a wiki community is an interest to develop and improve some ideas or knowledge items jointly. A thought that has been introduced into the artefact can stimulate and inspire other community members to develop and improve the idea. Accordingly, successful wikis rely very much on a diversity of different ideas. By a development of concepts and thoughts, the organisation may expand its knowledge. A successful wiki community will not only exchange pieces of information or facts, but – quite in contrast – it is a continuously broadening discourse that leads to an advancement of knowledge and a development of new ideas. It is essential for such discourse-oriented idea improvement that information provided by members is treated reasonably. Members of a wiki community, will, on the one hand, have to accept the opinions of other members. Simply discarding contributions of others will not really start a successful knowledge-building process. At the same time, successful knowledge building requires contributors who are critical of so-called authoritative information. Wiki communities in organisations need participants who are willing to challenge what others simply accept as facts, and develop the ideas of others.

Discussion

So far, this text has presented a framework model that considers knowledge building as a co-evolution of cognitive and social systems. The basic idea is that new knowledge develops in an organisation when 'knowledge workers' interact with each other using shared digital artefacts. These shared artefacts are the products in which collective knowledge becomes manifest. Various types of artefacts can be used for organisational knowledge building, and this process may refer to declarative as well as to procedural knowledge. Social-tagging systems and wikis deal mainly with declarative knowledge, but they address different types of declarative knowledge. Tagging systems are concerned with classifications and concepts, so they deal with a more abstract type of declarative knowledge that corresponds to the conceptual structure of the data. Wikis are quite the opposite in that they consist of more or less coherent texts and address declarative knowledge as such. PBTM, in turn, is about procedural knowledge.

Although all these technologies can be applied for organisational knowledge management, they vary in the extent to which they are appropriate tools for collaborative knowledge building. Two aspects should be emphasised here to characterise the knowledge-building potential of our three examples: the extent to which a digital artefact can be influenced and modified, and the ability of the respective technology to stimulate cognitive conflicts.

The three technologies differ in the extent to which their content can be manipulated. A social-tagging tool provides hardly any opportunity to manipulate the digital artefact as a whole. Users can only add some new tags or they may add a keyword that is already being used. In the case of a large tag cloud, however, this will not modify the artefact very much. In PBTM those people who are involved have a higher impact on the development of the artefact. They can contribute new patterns and revise existing patterns. These changes are analysed and patterns optimised over time. Thus, in PBTM all contributors' activities are recorded in the patterns. A wiki gives its users ample opportunities to manipulate its content – they can revise and modify any part of the wiki arbitrarily. The *status quo* of a wiki, as it appears on the screen, does not represent the sum total of all user activities (as with social tagging or PBTM), but only shows the result of the most recent activities. Thus, wiki users have the chance to influence the content of the wiki radically.

The extent to which a specific type of software is really useful for knowledge building will also depend on its capability to cause cognitive conflicts. As with the influence/manipulation aspect, the extent of potential cognitive conflict is progressively higher in the three examples. In social tagging, cognitive conflicts are mainly induced by discrepancies between someone's cognitive conceptual structure on the one hand and the conceptual structure presented by the digital artefact on the other. People can resolve this conflict mainly by changing their individual knowledge structure, that is, by internal assimilation and accommodation. In PBTM a cognitive conflict will be induced by the difference between someone's idea of how to complete a certain task and the procedure presented in a shared pattern. This might encourage them to re-think their own method and result in the development of a new procedure for performing the task. This new procedural method may then, in turn, be adopted by other members of the organisation. Wikis have the greatest potential to develop and solve cognitive conflicts. The content of a wiki can be absolutely different from a user's prior knowledge. Users who want to improve a wiki text have to connect new content to what already exists. For this purpose, they will have to re-organise and re-conceptualise content. This procedure may lead to improvement of the artefact and support knowledge building in an organisation.

It is the aim of our article to show the potential of specific technologies for knowledge management and organisational learning. They provide opportunities to combine processes of individual and collective learning. In our opinion, software tools might be particularly useful for knowledge-building purposes if they provide opportunities to manipulate and influence shared digital artefacts and if they have the capability to induce cognitive conflicts. Future developments of software and communication technologies for knowledge management and knowledge-building purposes may benefit from these considerations.

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