Social Software and Knowledge Building: Supporting Co-Evolution of Individual and Collective Knowledge

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Abstract: This paper presents a framework model that defines learning and knowledge building as a co-evolution of cognitive and social systems. This model brings together Scardamalia and Bereiter's theory of knowledge building and Nonaka's knowledge creation theory. We demonstrate how learning and knowledge building may occur when people interact with each other, using shared digital artifacts such as tag clouds (that result from social-tagging activities) or wikis. For both technologies, we provide illustrating data from two pilot studies. As an example, we refer to the learning processes that take place while searching for information in tag clouds. In addition, we illustrate processes of knowledge building by referring to users working on a wiki. In conclusion, the differences and similarities between these technologies are assessed, regarding their potential for knowledge building.

Introduction

Recent developments of software technology have made new tools available, which are of great importance for computer-supported collaborative learning and knowledge building. They provide new opportunities for learning and knowledge building, because they are capable of facilitating the interplay between individual and collective processes. These technologies are associated with social-software systems. *Social software* is a term for software systems that support human communication, collaboration, and interaction in large communities (Kolbitsch & Maurer, 2006). They facilitate the establishment and maintenance of self-organizing communities and social networks (Köhler & Fuchs-Kittowski, 2005; Wasko & Faraj, 2005). Social software is mainly associated with Internet communities, but may also be applied in educational contexts (Notari, 2006; Wang & Turner, 2005). We believe that social software has a great potential in the field of learning and knowledge building.

For a long time, psychological and educational research have examined individual learning and collaborative knowledge building as two separate things (for an early systematic model of collaborative knowledge building cf. Stahl, 2000). We propose that software tools are now able to support "interdigitation" and, so to speak, a "merger" of individual and collective knowledge processes. This new development of software technology also calls for a new theoretical framework, in order to focus on the tight conjunction between individual learning and collective knowledge building, in the sense that the knowledge of individuals and of a community may cross-fertilize and mutually support the development of each other. The aim of this paper is to provide such a theoretical framework. For this purpose, we will present and bring together two theoretical approaches.

The first approach is Scardamalia and Bereiter's (1991) theory of knowledge building. It deals with the mechanism through which a community of learners will manage to develop knowledge jointly. This approach was already based on the use of computer technology, and it emphasized the impact of epistemic artifacts on knowledge building. So it appears to be quite a suitable theory to explain how social software can support the development of collective knowledge. The second approach is Nonaka and Takeuchi's (1995) knowledge creation theory. Its focus is on the building and transfer of tacit knowledge. This approach is very popular in literature on knowledge management, but has hardly received attention in educational research and the learning sciences. Although Nonaka's model does not explicitly mention computer support and the creation of artifacts, we believe that the major underlying ideas of this model are very useful to explain some details of knowledge building with social software.

We will finally present our own co-evolution model of cognitive and social systems. The model takes into account social processes that are facilitated by a collaboratively developed technical artifact and, at the same time, cognitive processes of the individual users. Our model demonstrates how these social and cognitive processes will mutually influence each other. It is a theoretical framework which integrates many of the processes that have been described by the theory of knowledge building and the theory of knowledge creation. After a more general description of what we mean by "co-evolution" of cognitive and social systems, we will provide two examples of social-software technologies, and present some empirical data to demonstrate how these technologies can support this process of co-evolution. For this purpose, we will describe the use of social-tagging systems and the application of wikis. Each of these technologies creates a unique kind of artifact, which

supports, in its own specific way, those processes of knowledge building which we have described. In conclusion, we will assess the differences and similarities between these technologies, regarding their potential for knowledge building.

Theories of Knowledge Building and Knowledge Creation

Scardamalia and Bereiter have proposed a theory of knowledge building (Bereiter & Scardamalia, 1996; Scardamalia & Bereiter, 1996, 1999, 2003). Knowledge building is defined as a socio-cultural process, which takes place in a community and aims "at producing something of value to the community – theories, explanations, problem formulations, interpretations, and so on, which become public property that is helpful in understanding the world" (Scardamalia & Bereiter, 1999, p. 276). Scardamalia and Bereiter consider knowledge building as a collective creation of public knowledge. They compare learning in classrooms to learning in knowledge-building communities, such as research laboratories (Bereiter, 2002), and conclude that knowledge building should be rendered possible in all communities. Educational software, such as CSILE (Computer-Supported Intentional Learning Environments) or Knowledge Forum, can support knowledge building. These environments provide shared databases as collaborative design spaces. Here, all participants may contribute their own theories, models, examples, visualizations, notes, and other epistemic artifacts. The design space supports mutual citing and referencing, in order to initiate a dynamic and self-organized process in which ideas are formulated, discussed, revised, or rejected. The design space visualizes this collective improvement of ideas. Accordingly, there is a set of requirements that have to be fulfilled to make successful knowledge building possible (Hewitt & Scardamalia, 1998; Scardamalia, 2002). All members of a community should contribute to the advancement of knowledge, and learners in a community should be concerned with authentic real-life problems. Advancing knowledge should be regarded as an improvement of ideas, not a search for a perfect or true solution. Learning is regarded as a discourse-oriented process, in the sense of common problem solving.

Nonaka's knowledge-creating theory (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995) is also concerned with innovation. This theory emerged from research on knowledge management, and it regards knowledge dissemination as one of the aims of any knowledge organization. But the authors assume that within an organization only little knowledge is available in the form of explicit knowledge. Most knowledge is contained in the experience of individuals, and as such it is *tacit knowledge* (Polanyi, 1966). Tacit knowledge can hardly be expressed verbally, so this type of knowledge is difficult to transfer to others. But effective knowledge creation requires such a transfer. In order to describe how a transfer of tacit knowledge takes place, the authors refer to four processes, which build on each other in a dynamic way: socialization, externalization, combination, and internalization. *Socialization* is a process in which the experience of an individual is shared. Tacit knowledge can only be communicated from one person to the other through direct experience. Experience may be transferred by observation and imitation, and, as a result of this transfer, the observer acquires new knowledge, but this remains tacit. So a process of *externalization* is necessary. It consists of the articulation of tacit knowledge and the transfer from tacit to explicit knowledge. At this stage, new concepts are formulated using tacit knowledge. When knowledge has been made explicit, then it can be combined, in order to develop new knowledge within an organization. So, *combination* refers to connecting and giving a new structure to explicit knowledge. Such combination is supported by interpersonal sharing of knowledge. Explicit knowledge will then, once more, become tacit knowledge through a process of *internalization*. This conversion is an individual process, in which explicit knowledge becomes part of that person's personal knowledge. Internalization will occur through learning by doing. Nonaka has formulated the idea of a *knowledge spiral* in which socialization, externalization, combination, and internalization succeed each other. The spiral allows the inter-individual transfer of knowledge and, at the same time, the creation of new knowledge, through a combination of externalized knowledge which was previously tacit.

Co-Evolution Model of Cognitive and Social Systems

The authors of this paper have introduced a theoretical model of individual learning and collaborative knowledge building (Cress & Kimmerle, 2007, 2008; Kimmerle, Moskaliuk, & Cress, 2009; Moskaliuk, Kimmerle, & Cress, 2008). In this model, collaborative knowledge building is described as an interplay between cognitive systems and a social system. Just like Scardamalia and Bereiter, we think that knowledge building is a central issue in modern knowledge societies. Consequently, our model is basically predicated on the ideas of Scardamalia and Bereiter. But our considerations go beyond those of these authors, as we focus equally on individual learning processes and on the collective development of knowledge. And as far as social software is concerned, epistemic artifacts are not only considered as a means to an end, but also as an end in itself, because we are convinced that collective knowledge manifests itself in shared digital artifacts. The model borrows, so to speak, from systemic and from cognitive approaches. Its main assumption is that knowledge building can only be understood if the interplay between individuals and the collective is taken into account. From a systems-theoretical point of view – in the sense of Luhmann (1995) – the cognitive systems of individuals are different from a social system, which is (in our theory) represented by a shared digital artifact (Cress & Kimmerle, 2008).

Cognitive systems and social systems have different kinds of operations. Due to their different modes of operation, both systems cannot simply merge. But one system can affect the other one in its development by irritating it. Each system can provide its own complexity for the development of the other.

The co-evolution model of cognitive and social systems (Cress & Kimmerle, 2008) is based on this systemic view, and it describes learning processes and knowledge-building processes as reactions of a system to irritations. Irritations are interpreted, in the sense of Piaget (1977), as cognitive conflicts, and the assumption is that cognitive systems will develop when people solve such cognitive conflicts. A cognitive conflict exists when people's prior knowledge and information which they receive from their environment are somewhat incongruent. Cognitive conflicts can be solved by processes of equilibration. There are two types of such equilibration processes: people will either assimilate information, i.e. they simply add new information to their prior knowledge; or they will accommodate their prior knowledge to new information. In either case, people will somehow have to internalize information from their environment. In this way, their cognitive system becomes more complex. This development of a cognitive system refers to what is traditionally called *learning*. These two processes represent two types of internalization from the social system, i.e. both *assimilation* and *accommodation* support the development of cognitive systems. The model states that processes which take place in a cognitive system by means of internalization will take place analogously in a social system by means of externalization. Through externalization, a cognitive system can bring that person's own individual knowledge into the shared artifact. People do not only internalize information from their environment into their cognitive systems, but also externalize their knowledge. This means, just as individuals can learn by internalizing new information, social systems can also learn by incorporating information, and social systems can develop new knowledge by assimilation or accommodation respectively. They can develop by just adding new content (assimilation) or by changing their own structure (accommodation). We propose that emergent effects usually occur through such accommodations of artifacts. This external accommodation leads to a higher complexity of the shared digital artifact and, accordingly, to new equilibration processes in other people's cognitive systems. Thus, the users' knowledge supplies the artifact's content, and the artifact itself provides its users with new information and releases new cognitive conflicts. What is important here is that the processes of internalization and externalization, or of individual learning and knowledge building respectively, are not independent from each other. It is always a matter of internalization *and* externalization, i.e. of continuous exchange processes between cognitive systems and the social system. In this way, there exists a mutual development of cognitive and social systems, and this is what we refer to as co-evolution (cf. Figure 1).

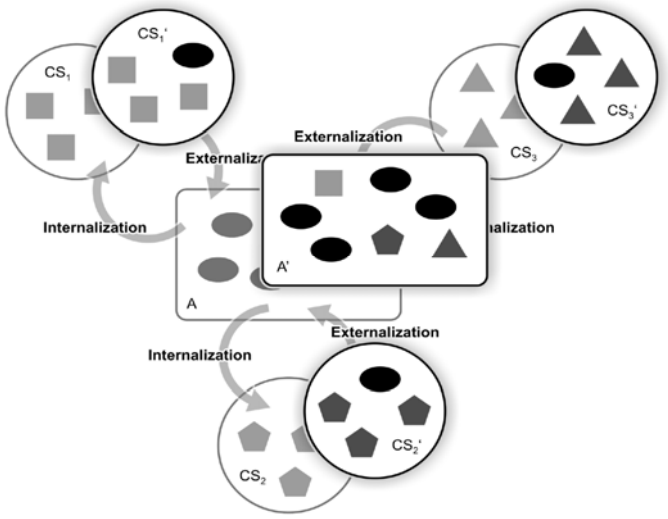

Figure 1. Co-evolution of cognitive systems ('CS') and a social system, i.e. an artifact ('A').

We can now apply the four processes, as they were described by Nonaka, to this model of knowledge building with shared artifacts. For this purpose, we translate the processes of making tacit knowledge explicit, and vice versa, into processes of externalization and internalization. This will help us to understand exchange processes between cognitive systems and the social system in more detail. Externalization can then be described by those processes which Nonaka has labeled *externalization* and *combination*. When people introduce their own knowledge into a shared digital artifact, they will have to articulate their knowledge, i.e. they need to couch their cognitive concepts in words. For this purpose, they have to translate their knowledge into a form that is generally understandable and intelligible to all. People have to consider the information which is already available in an artifact in order to integrate their own thoughts adequately. Internalization combines the two

processes which Nonaka calls *internalization* and *socialization*. When people incorporate information from a shared digital artifact, they "dig around" for information by browsing the artifact. In this way, they gather and collect relevant information, which they have to transfer into their own cognitive structures. In the following we will explicate these processes by referring to two concrete examples of shared digital artifacts. The first example – social tagging – considers the process of internalization, the second example – wikis – will take a closer look at externalization.

Examples of Social-Software Supported Knowledge Building

We present our notions by providing two examples that use new software technology. The first one will illustrate the interplay between individual and collaborative processes by analyzing *social-tagging activities* and the processes which may be supported by social tagging. Then, we will describe how *wikis* can contribute to knowledge building. For both technologies we point out their potential as learning environments, and demonstrate the processes of internalization and externalization. For this purpose, we provide some empirical data from two pilot studies: processes of internalization (individual learning) will be illustrated by a reference to searching for information in tag clouds; processes of externalization (knowledge building) will be demonstrated by quoting contributions of people who worked on a wiki.

Social Tagging

Social tagging has become a standard feature of many social-software tools, and it has potential to play a role in learning scenarios (Marlow, Naaman, Boyd, & Davis, 2006). The term tagging describes the annotation of digital resources with keywords (Golder & Huberman, 2006). These resources are primarily objects in virtual environments, like the Internet or intranets, and they may include web sites, photos, videos, research papers, or other pieces of digital information. The keywords (or tags) may be chosen by its users, and they represent the users' associations concerning the objects. Tagging is used on platforms which offer file sharing within a community, or which support users in organizing their own stored resources. The labeling of items with tags may facilitate search processes and the retrieval of information on these platforms, not only for individual users, but also for the benefit of others. The term *social* tagging refers to this social context in which tags are used, and in which all members of a community may benefit from them. Most of the social-tagging systems allow each user to tag all available resources individually and independently. In this way, all tags in a community that concern a particular object may be aggregated, and a large set of metadata for that resource may come together. This accumulated collection of tags (or metadata) represents the users' connections, concepts, or categorizations for items, and builds a jointly created artifact of keywords that refer to a specific resource. The World Wide Web provides loads of information and many opportunities for acquiring knowledge. This can take place as an individual and independent learning process, beyond formal educational settings. Users may browse through the information space of the Internet, and access information on virtually any topic of interest. Limitations lie mainly in the overwhelming amount and inconsistent quality of that information. Social-tagging systems can help to overcome these problems and provide a tool for structuring and filtering information.

When dealing with social-tagging systems, individuals have the opportunity to externalize their own knowledge and, at the same time, they also may internalize information. In the process of externalization, users add tags to specific resources and describe the object with their own set of keywords. For this activity of creating tags, users have to articulate their own cognitive concepts of an item, and transform them into keywords. When people add tags, they externalize their knowledge about a resource. They focus on the essential concepts of an item, and may, consequently, elaborate on the resource more thoroughly. The additional cognitive effort which is involved here will induce processing of information in such a way that individual learning takes place. The creation of tags and externalization of cognitive concepts can lead to knowledge building (Budiu, Pirolli, & Hong, 2009): the artifact of metadata develops in a step-by-step incremental process of individual tagging. All individual tags of a community are summed up in one accumulated artifact of keywords. A single user has only a marginal influence on the whole product. The artifact depends on the tagging activities of numerous people, and tag clouds will only emerge from a large quantity of added keywords. As the artifact grows, it represents the most important related concepts and connections that concern a resource or a keyword.

In the process of internalization, people integrate new information into their cognitive systems. In a social-tagging environment, users will browse a web site in order to explore relevant resources. For this purpose they may use tags as an orientation and searching device. The jointly created artifacts of metadata, typically visualized as tag clouds, help them to navigate through the information space and find relevant information related to the tags. In this process of browsing, the users of the system will become aware of the keywords that were annotated by other users. In this way, the users incorporate information about the concepts and categorizations of an object, and learn how other users have classified that resource. Moreover, the artifact of tags may show interconnections between resources and concepts that may previously have been unknown to the individual user. The information which is represented in the metadata of tags can lead to knowledge acquisition

and a change in the cognitive structures of individuals. People can be made aware of new information and incorporate the community's concepts and categories (Fu, 2008). These concepts and connections may differ from individual cognitive structures, and if they do, individual knowledge may increase and new understanding may develop. This process of learning may be defined as assimilation or accommodation of knowledge. Assimilation describes the process of merely adding new pieces of information to previously existing knowledge. This happens when people acquire additional facts about a subject, but do not significantly change the underlying structure of the cognitive concepts involved. For instance, when users learn new tags and related concepts which are in accordance with their prior knowledge about a certain resource, this will extend their factual knowledge, but they will not form a new concept of this subject. The following example will illustrate this process. The data are taken from a pilot study with university students. Participants had to find out what "EMDR (eye movement desensitization and reprocessing)" means, by searching and browsing for information only with the help of tag clouds and, at the same time, they had to think aloud. The following transcript from the thinking-aloud audio protocols (translated from German) is an example of assimilation:

> *"Yes, this is a form of psychotherapy, I know that, that's why I click on 'therapy' […] yes, exactly, and there is 'treatment', there I will get it in more detail […] okay, now, here is 'trauma', it has something to do with that […] and with 'anxiety' […] and it could also be about 'stress' […]".*

This participant expanded his knowledge, but he relied very much on his prior knowledge (that EMDR is a form of psychotherapy). So he specified his knowledge: later, he knew what this therapy is used for (the treatment of post-traumatic stress disorder). Previously existing knowledge was supplemented, but the knowledge structure did not have to be changed. In contrast to this process of assimilation, accommodation takes place when a qualitatively new understanding of a subject develops and prior knowledge is transformed. If other people use very different tags from those that this particular user would have applied, then it is obvious that specific resources or tags are related to very different concepts. So users may learn that their associations on a subject or topic were incorrect, and may change their cognitive concepts accordingly. Another sample from the thinking-aloud protocols of the pilot study will illustrate the accommodation process:

> *"I think it is about an eye movement disorder […] okay, here is 'movement', I click on that […] now there is 'desensitization' […] now 'reprocessing' remains as the biggest tag […] and, yes, 'treatment' […] and now it's about 'behavior' and eh? Hm, 'trauma'? Now I'm confused, somehow I can't see any connection. But I would click on that, on 'trauma', yes. It somehow stands out from the crowd […]".*

Even though this participant did not find out (in the given time) that EMDR is a form of psychotherapy, she did understand that her prior knowledge was not adequate, which is an important prerequisite for accommodation. Another participant had a similar experience, but her gain of knowledge went even further:

> *"[…] 'anxiety'? I'm irritated now […] I don't understand […] I just see that it has something to do with 'psychiatry' and with 'clinical' […] I see, it seems it is about psychology and psychotherapy, and, although I first thought it was an eye disease […]".*

The process of co-evolution of cognitive and social systems takes place when individuals use tags for browsing and navigating the Internet, and stumble across relevant information and resources. These cognitive processes of internalization and the retrieval of new information may prompt users to tag the discovered new resources themselves. In this way, the individuals' concepts and categorizations are externalized and incorporated into the artifact of metadata, and the whole system evolves (Fu, 2008). All members in a social-tagging community offer and obtain knowledge, and a continuous process of advancing knowledge takes place. The community constantly adds new resources and new tags to the artifact, in this way developing new information, new interconnections, and new ideas. Anyone can contribute and participate in this process of improvement, which takes up the viewpoints of many different people; the collective as a whole is responsible for the advancement of knowledge.

Wikis

A wiki is a web page that allows users to change its content online (Leuf & Cunningham, 2001). It is easily accessible and can simply be used by everyone (Désilets, Paquet, & Vinson, 2005). In a wiki, people may easily revise all parts of the text, add, change, or delete anything at their discretion (Raitman, Augar, & Zhou, 2005). In that way, people can form communities that work collaboratively on a certain topic and create new content (Köhler & Fuchs-Kittowski, 2005; Moskaliuk & Kimmerle, 2009). Wikis may be used in educational contexts (Notari, 2006; Wang & Turner, 2005) – schools, universities, but also informal learning settings. A wiki lends itself, for example, to collective work on a scientific topic in school or a university class, particularly if people tend to have controversial opinions on that topic. In a wiki, those involved can introduce their own points of view on equal terms. Participants may express opposing opinions, addressing each other, and they incorporate their own perspective into a coherent text. But such processes of knowledge acquisition and knowledge

exchange will not only take place in formal settings but also in informal contexts, for example, when people try to deal with and develop a topic through the Internet. This is a way for them to increase their own understanding, and they are able to acquire new knowledge. In addition to their individual learning, they also develop some collective knowledge.

Individuals may acquire new knowledge when they internalize information from the wiki. In order to incorporate information from the artifact, they will have to start off by browsing for information in a more or less target-oriented manner. When they have found some relevant information, they will have to transfer it into their own cognitive system. They will have to treat this information in some way or other to fit it into their own existing knowledge. So this internalization process allows people to increase their individual knowledge and gain new insights. This type of individual learning may, again, either take place in the form of assimilation or accommodation. When people assimilate information, they simply acquire knowledge without developing a different quality of understanding. Accommodation will occur when they incorporate new information in such a way that it modifies their prior knowledge. In an accommodation process, people transform knowledge with the aim of better understanding new information. In addition to this individual learning, as a result of internalization, there is also a supplementary form of knowledge generation: people will not only internalize information as it is, but also develop knowledge that is completely new, knowledge that was originally neither part of the digital artifact nor a component of their individual knowledge. This supplementary knowledge may develop when people have internalized new information, which will then, in turn, interact with their prior knowledge. This is the way in which a process of emergence is enabled. In such a situation, collaboration is a prerequisite for emergent knowledge. People on their own will not be able to develop this kind of knowledge; they need stimulation by other people. So knowledge processes enabled by a wiki are not simple knowledge-sharing processes, but collaborative processes of knowledge development.

When people want to contribute to a wiki, they will have to externalize certain aspects of their own knowledge. People who introduce their own knowledge to a shared digital artifact will have to put some effort into articulating that knowledge. That means they have to transform cognitive concepts into written language. Ideally, people will express their thoughts in a way that can easily be understood by others. They need to consider pre-existing information in the artifact to make sure that they integrate their own thoughts adequately. When people contribute to a wiki article, this will not only support the development of the wiki itself, but also its contributors' individual learning: people who externalize their knowledge will have to elaborate on it. This cognitive effort helps people to process their own knowledge more deeply, and this, in turn, will broaden their understanding (cf. the *self-explanation effect*; Chi, Bassok, Lewis, Reimann, & Glaser, 1989). When individuals have externalized their own knowledge, the resulting information continues to exist independently from its contributors. This information may, in turn, be picked up by other users, who may develop it further.

When people introduce knowledge into a wiki, there are two options for incorporating this information into the artifact. The information is either assimilated or accommodated. It is a matter of assimilation when information is simply attached to a text that already exists. In this case, new information is not connected to earlier information. Assimilation means that the previous arrangement of the artifact remains unchanged. An example will illustrate this process. The data are derived from another pilot study in which participants had to deal with a wiki text about causes of schizophrenia. The original wiki text was rather one-sided – only presenting biological causes, such as inheritance – and some participants only added information to the text that argued along the same lines, even though they had access to a variety of information sources; for example, the original text stated that an inherited disposition caused schizophrenia, and a participant wrote:

> *"This is supported by a study of the University of Göttingen about the genetic influence on suffering from schizophrenia. The results show that the probability of being afflicted with schizophrenia is increased when someone is consanguineous with a schizophrenic person. The probability of being afflicted with schizophrenia is 9.35 % for children. Another study with monozygotic twins shows that…".*

This contribution may be considered an essential addition, because it is important to provide empirical data for claims and statements. But it contains only supplementary information; it does not provide an alternative point of view. In a well-organized wiki, however, the process goes beyond such a simple assimilation of information. An efficient wiki community will endeavor to interpolate new information evenly. A wiki reflects accommodation if newly-introduced information is not just added to some existing text, but this text is also re-arranged in a new way. Accommodation has taken place if the article has been re-organized or new aspects have been integrated into existing information. A further example (by another participant) from the same study illustrates this accommodation process:

> *"Beyond biological causes, another potentially interesting reason is the interrelation of schizophrenia and the social environment. A study collected data about people's social class, their profession, education, income, and social situation (period of 2 years) as well as stress and personal living conditions that have negative psycho-social effects. The results were unambiguous: schizophrenic persons come from a low social class, have experienced inferior*

> *education, earn less money and are under considerable psycho-social strain. As a consequence, it may be concluded that a negative social environment contributes fundamentally to the onset of schizophrenia."*

People working on a wiki will not only improve their individual knowledge, but may also contribute to the development of collective knowledge at the same time. Thus, wikis support individual learning, and they may be an attractive tool for knowledge-building purposes, as described by Scardamalia and Bereiter. Collaboration with a wiki has the primary goal of advancing knowledge. Processes of externalization and internalization are going on all the time. In this way, both individual and collective knowledge are being developed constantly. The cognitive systems of individuals as well as the social system are continuously being enhanced and advanced, due to these processes of equilibration. All the people involved here can introduce information, and this information may be treated by each member of the community on an equal footing. A wiki community gets together when there is a need for jointly developing solutions to some problem which its members have in common. An idea that is introduced to the artifact will stimulate and inspire another community member to incorporate, develop, and improve this idea. In this way, concepts and ideas are developed, and the community and all the individuals involved can expand their knowledge.

Conclusion

In this paper, we have elaborated on a framework in which knowledge building is defined as a co-evolution of cognitive and social systems. New knowledge may develop when people interact with each other via shared digital artifacts. It is assumed that collective knowledge becomes manifest in these shared artifacts. In order to illustrate these processes, we have demonstrated how they work, referring to two examples of social-software technologies: social-tagging systems and wikis. These allow different degrees of influencing and manipulating artifacts. Social tagging gives individuals only little scope for manipulating the whole artifact and its content. They can only add some new keywords or add a tag which has already been used. If many users have participated, resulting in a tag cloud which is already rather large, one individual contribution will probably not change this tag cloud very much. In such systems, it is not each individual's tagging behavior that will directly define the artifact. Instead, the artifact represents the accumulation of all the tags, giving each user equal impact. Regarding wikis, there are many opportunities for individual users to influence the artifact's content. They may, at their discretion, revise, change, or delete any part of a wiki article. If a user deletes some content, it will not be part of the shared artifact any more. The current state of a wiki does not represent the sum total of all these activities, as is the case with tagging systems. Instead, a modified wiki represents only the most recent interventions. This means that one person who modifies content in a wiki has the opportunity to make the whole text coherent. So in a wiki, a user can directly deal with incongruities.

To what extent a certain tool is conducive to knowledge building, depends very much on the potential of that technology to induce cognitive conflicts. In social tagging, productive conflicts are primarily caused by differences between a person's internal conceptual structure and that provided by the artifact. Individuals may solve this conflict mainly by changing their own individual knowledge structure. Wikis provide a high potential both for the development of cognitive conflicts and for solving them. The content of a wiki may differ fundamentally from its users' previous knowledge and understanding. If they want to improve the wiki text, they need to connect new content by re-organizing and re-conceptualizing it in order to adapt it to the content that already exists. This course of action will necessarily lead to the development of the shared artifact and to knowledge building.

To sum it up, this paper shows the potential of social software for learning and knowledge building. Social-software tools open up specific opportunities to combine individual and collective learning processes. Such tools are particularly relevant for knowledge-building purposes when they provide opportunities to influence and manipulate shared digital artifacts and when they have the potential to induce cognitive conflicts. Future developments of such technologies may benefit from taking these considerations into account.

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