Using Wikis for Learning and Knowledge Building: Results of an Experimental Study

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ABSTRACT

Computer-supported learning and knowledge building play an increasing role in online collaboration. This paper outlines some theories concerning the interplay between individual processes of learning and collaborative processes of knowledge building. In particular, it describes the co-evolution model that attempts to examine processes of learning and knowledge building by working on wikis. We report an experimental study that aimed at testing some predictions of this model empirically. The results support the assumption that accommodative knowledge building and a development of conceptual knowledge takes place particularly when there is incongruity at a medium level between people’s knowledge and the information contained in a digital artefact. In contrast, assimilative knowledge building and the development of factual knowledge depends largely on people’s prior knowledge. Concluding, the consequences of these findings on educational uses of wikis are discussed.

Keywords

Learning, Knowledge building, Wiki, Experiment

Introduction

In the last few years, various technologies and tools have been developed that provide opportunities for computer-supported knowledge exchange (Cress, Kimmerle, & Hesse, 2006; Kimmerle, Cress, & Hesse, 2007), as well as for computer-assisted learning and collaborative knowledge building (Bryant, 2006). Technologies that support people in communicating, interacting, and collaborating in large communities are referred to as “social software” (cf. Kolbitzsch & Maurer, 2006). The collaborative development of knowledge that is enabled by social software illustrates quite nicely what Scardamalia and Bereiter (1994, 1996, 2003) describe in their theory of knowledge building. Knowledge building in the web is virtually scaled up from smaller groups (e.g., a class or a team in an organization) to large communities of users. Wikipedia, the Online Encyclopaedia, is one of the most frequently cited examples of this phenomenon (cf. Baytiyeh & Pfaffman, 2010; Goldspink, 2010): 13.8 million registered and many other unregistered users have contributed more than 3.5 million articles to the English version of the Wikipedia (figures of January 2011). This success story of social software on the Internet has convinced many people to apply social-software tools in educational contexts as well (Evans, 2008; Fessakis, Tatsis, & Dimitracopoulou, 2008; Kim, 2008). It is assumed that social software has a great potential in the context of learning and knowledge building, both in formal and informal learning situations (Bryant, 2006; Parker & Chao, 2007; Wang & Turner, 2004).

Wikis are particularly interesting for learning purposes (Reinhold, 2006; Shih, Tseng, & Yang, 2008; Wang & Turner, 2004; Yukawa, 2006). Wikis may be characterized as collections of websites on intranets or the Internet. Such websites cannot only be read by users, but may also be edited by any participant (Leuf & Cunningham, 2001). In a wiki, people may generate content and link it to other content, using hyperlinks. Users are allowed to change text, insert new text, or even delete the whole text of a wiki or parts of it. In this way, a community of wiki users can work together in order to create one shared digital artefact. Thus, working on a wiki enables a collaborative development of knowledge (Köhler & Fuchs-Kittowski, 2005) and leads to knowledge building as the creation of new and innovative knowledge. Users can use a wiki to share their knowledge, create a joint artefact, discuss and integrate different opinions, develop innovative ideas. This may, at the same time, lead to individual learning. Thus, wikis may be considered as powerful tools for learning and knowledge building in educational contexts.

The initial enthusiasm has settled down, however. Some practitioners report on the pitfalls of social software in educational contexts (cf. Cole, 2009). Often, students use wikis as a read-only-source. They will not change any content and seem not to be motivated to construct knowledge together with others. It seems that the success of a real social web (e.g., Wikipedia) cannot directly be transferred into classroom (Forte & Bruckman, 2006). Using wikis in
educational contexts will not per se lead to learning and knowledge building. So the main issue of this paper is to examine the process of individual learning and collaborative knowledge building with wikis and specify the circumstances under which these processes may be successful. The first part of the paper gives a short survey of psychological and educational approaches that are helpful to understand individual learning and collaborative knowledge building with wikis. In the second part of the paper, we report on an experimental study that focused on incongruity between the knowledge of individuals and the information contained in a wiki, as an important trigger for processes of learning and knowledge building. The final part of the paper aims at integrating theoretical assumptions and empirical results, and suggests further implication for the use of wikis and other social software in educational contexts.

**Individual learning and collaborative knowledge building**

When looking at theories and research about computer-supported collaborative learning and knowledge building (cf. Tsiatsos, Andreas, & Pomportsis, 2010), it is noticeable that we often find two categories of theoretical approaches: on the one hand, theories that primarily deal with individual results of learning processes, and, on the other hand, theories that are mainly interested in collective processes. What is needed, however, to really understand learning and knowledge building with social software is theories or models that look in more depth into the interplay between the individual and group level of learning. We will now present some of these approaches that aim at examining both levels and their interplay.

**Knowledge building**

As a theoretical term (Hewitt & Scardamalia, 1998; Scardamalia, 2002; Scardamalia & Bereiter, 2003) describes the creation of new knowledge and innovative ideas as a socio-cultural process that takes place within a community. It aims at creating “… 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). The term knowledge building refers to the collective creation of public knowledge. This collective effort is in the main focus of that theory. This approach is aware that a collective is composed of individuals, but the main focus is on what occurs within the community. The group is considered as more than an assemblage of individual people. From this perspective, individual learning is always considered as well, but the main interest is not directed onto this process. Individual learning is, so to speak, rather a by-product of the constructive process of collective knowledge building.

The knowledge creation model (Nonaka, 1994; Nonaka & Takeuchi, 1995; Nonaka & Toyama, 2003) considers knowledge dissemination as the aim of any knowledge organization. In this model, however, most of the knowledge that exists in an organization is part of the experience of individuals; it is tacit knowledge (Polanyi, 1966). This tacit knowledge can hardly be expressed verbally and transferred to others without own experience. The authors describe a dynamic process of socialisation, externalization, combination, and internalization that is necessary to share tacit knowledge.

Another approach that tries to combine the perspectives of individual learning and collaborative knowledge building is group cognition (Stahl, 2006, 2009). Its focus is on interaction between individuals and the group. In this theory, learning is constituted in a context of interaction with others, and small groups of learner are considered as the engines of knowledge construction. A shared digital artefact serves as mediator between individual knowledge and knowledge of the group, and it is a tool for knowledge construction at the same time.

Activity theory (Engeström, 1987, 1990, 2001) puts learning in a cultural context. Individuals use cultural artefacts such as tools, symbols, or language to solve problems and fulfil tasks. Activity theory is interested in cognitive competences of individuals, but it assumes that it does not make much sense to consider individuals as isolated entities, because human cognition and learning are always part of a society or community, based on interaction between individuals and some (cultural and social) context. Therefore, human cognition should always be considered as socially embedded and its analysis needs to take this aspect into account. Various other theories have focused on this aspect of cultural, situational, or physical context of individual learning, e.g., the distributed cognition approach (Hutchins, 1995a, 1995b), the situated cognition approach (Greeno, 1998), and the concept of embodied cognition (Clark, 1997; Gibbs, 2006).
What becomes clear from this short survey is that it is widely accepted that we have to consider three dimensions in this context: cognitive processes of individuals, social processes inside a community, and interaction between individuals and a community. The theories presented here are very heterogeneous, and they were originally not developed for research on wikis. Research on learning and knowledge building in the social web requires a theoretical framework that considers these seminal theories, but that focuses on the tight conjunction between individual learning and collaborative knowledge building and that permits, at the same time, the formulation of concrete hypotheses about conditions for successful learning and knowledge building with wikis. In the following, we will present a model that is, in our opinion, suitable for that purpose.

**The co-evolution model**

The co-evolution model by Cress and Kimmerle (2007, 2008; Kimmerle, Cress, & Held, 2010) aims at describing and explaining how individual learning and collaborative knowledge building with social software – with wikis in particular – may take place (cf. also Kimmerle, Moskaliuk, Cress, & Thiel, 2011). This model adopts a systems-theoretical perspective by referring to the work of Luhmann (1990, 2006). It differentiates between the cognitive systems of users and the social system established by the wiki community. These systems differ in their mode of operation: whereas cognitive systems are based on cognitive processes (thinking, reasoning, consciousness), social systems operate via communication (Luhmann, 1995). In order to describe processes of individual learning in the cognitive systems of individuals, Cress and Kimmerle borrowed some ideas from Piaget’s model of equilibration (Piaget, 1970, 1977). In addition, they take up Piaget’s considerations and translate them into processes that occur within social systems in order to describe collaborative knowledge building.

Piaget’s model of equilibration (1985) assumes that people take up new information from the environment and integrate it into their existing knowledge. If new information is not in line with prior knowledge, this will lead to cognitive conflicts. Individuals have two options to deal with such cognitive conflicts: in simple terms, they may either assimilate new information or accommodate their existing knowledge. In the process of assimilation, people utilize their prior knowledge, as it is, in order to understand the new information. Accommodation, however, is a process in which people modify their existing knowledge as a result of handling new information. So in this accommodation process, individuals will qualitatively change their prior knowledge, not only assimilate additional information into their existing knowledge.

Cress and Kimmerle (2007, 2008) suppose that accommodation and assimilation will not only occur in cognitive systems, but also in social systems. In the case of wikis, assimilation is characterized by purely adding information, without explicitly connecting it to any previously existing information. The organization of the wiki remains unaffected; the wiki simply “assimilates” this new information. Accommodation is characterised by re-arranging the existing information in that wiki. This is the case, for example, when sections are rewritten, the arrangement of pages is re-organized, or previously existing and new information are combined and incorporated into each other (cf. also Majchrzak, Wagner, & Yates, 2006). This leads to four processes of individual learning and collaborative knowledge building: assimilative learning, accommodative learning, assimilative knowledge building and accommodative knowledge building.

This model integrates individual and collaborative aspects. It describes individual learning as internalization of information from the social system into the cognitive system, and collaborative knowledge building as externalization of individual knowledge from the cognitive system into the social system. These two systems are not independent, but influence each other (Kimmerle, Moskaliuk, Harrer, & Cress, 2010). Their development is a mutual progress, a **co-evolution**. Besides, the co-evolution model specifies the conditions under which individual learning and collaborative knowledge building may take place. The authors states that incongruities between people’s knowledge and the information contained in a wiki can lead to cognitive conflicts in the sense of Piaget. They specify their assumption by saying that the **extent** of incongruities has an impact on the extent of the cognitive conflict, which in turn affects learning and knowledge building. Incongruities **at a medium level** are supposed to be particularly conducive to both individual learning and collaborative knowledge building.

The benefit of the co-evolution model is the fact that it offers an integrative point of view and considers cognitive and social systems at the same time. Apart from that, it specifies the configuration of both systems that leads to an
increase of individual learning and collaborative knowledge building at the same time. The experimental study that we present in the following section will examine these aspects and test the predictions of the model.

Experimental study

Moskaliuk, Kimmerle, and Cress (2009) were able to demonstrate in their study that incongruities at a medium level do indeed support individual learning and collaborative knowledge building to a higher extent than high or low incongruities. This study worked with participants who were supplied with a high level of prior knowledge, and the authors operationalized incongruities by making their participants work on wikis that were either completely filled with information (low incongruity), half-filled with information (medium incongruity), or completely empty (high incongruity).

Concerning assimilative knowledge building, Moskaliuk et al. (2009) found an equally high level in the medium- and the high-incongruity condition. This is not surprising, because in both conditions participants had enough room to write things down. In the low-incongruity condition, however, with a virtually full wiki, they did not have this opportunity. Despite the fact that participants in the medium-incongruity condition did not add more words to the wiki (assimilative knowledge building) than in the high-incongruity condition, there was still more accommodative knowledge building, and participants also learned more (developed more factual and more conceptual knowledge). The authors concluded that simply writing down many words will not necessarily lead to more learning. What is more important in this context is the opportunity to link one’s own knowledge to existing information (in the wiki), which is not the case in the low- and the high-incongruity conditions. In order to be able to link one’s own knowledge to existing information, there has to be a certain degree of agreement between knowledge (in the individuals’ minds) and information (in the wiki), but this agreement should not be exhaustive. In the study by Moskaliuk et al. (2009), participants had the opportunity to externalize their own knowledge (except for the low-incongruity condition). The results of this experiment suggest that some opportunities should exist to externalize one’s own knowledge, and that this is an important precondition for learning and knowledge building.

The question arises, however, what will happen in such a knowledge-building situation if this opportunity for externalizing one’s own knowledge is extremely reduced? We assume that people will then still develop conceptual knowledge and participate in accommodative knowledge building – as long as there is a sufficient “overlap” between individual and collective knowledge, as it is the case with medium incongruity. This is because in such a situation people have the opportunity to elaborate on their prior knowledge, as it will be stimulated and inspired by novel input. These processes are supposed to lead to improved understanding. The same is true for information in the wiki, which is also challenged and stimulated in this process, and this, in turn, may also lead to qualitative improvement.

Assimilative processes, however, are supposed to be primarily depending on people’s individual prior knowledge: if they only have little prior knowledge, they will hardly be able to add new information to a wiki (assimilative knowledge building), and if they know a great deal in advance, they will still possess more factual knowledge afterwards. These considerations lead to concrete hypotheses that will be presented in detail in the next paragraph. Subsequently, we will describe how we managed to remove the opportunity to externalize one’s own knowledge in the study reported here.

Hypotheses

In our opinion, the superiority of a medium degree of incongruity between people’s knowledge and information contained in a wiki refers particularly to accommodative processes. The impact of incongruity on assimilative processes, however, is supposed to depend on the respective operationalization of incongruity. In order to examine these specifying assumptions and come to more differentiated conclusions, we conducted a pivotal modification compared to the study by Moskaliuk et al. (2009): we decided not to keep the individuals’ prior knowledge constant (it was kept at a constantly high level in that study) and vary the information in the wiki, but instead operationalize incongruity the other way round: information in the wiki was kept constant (at a high level) and people’s prior knowledge varied (Figure 1).
**Hypothesis 1.** We expect the lowest degree of assimilative knowledge building in the high-incongruity condition (if people have no prior knowledge, it will be very difficult for them to write down anything). In more concrete terms, we expect more assimilative knowledge building in the medium-incongruity condition than in the high-incongruity condition (Hypothesis 1a). And we expect more assimilative knowledge building in the low- than in the high-incongruity condition (Hypothesis 1b).

**Hypothesis 2.** We expect the highest degree of accommodative knowledge building in the medium-incongruity condition, because this situation is most suitable when the point is to dispute and challenge existing information, i.e. when it comes to processes which are supposed to lead to qualitative improvement of that information. In more concrete terms, we expect more accommodative knowledge building in the medium- than in the low-incongruity condition (Hypothesis 2a). And we expect more accommodative knowledge building in the medium- than in the high-incongruity condition (Hypothesis 2b).

**Hypothesis 3.** We expect that people will possess more factual knowledge, the higher their respective knowledge was in the first place (i.e. the more facts they were familiar with in advance). In more concrete terms, we expect people to develop more factual knowledge in the low- than in the medium-incongruity condition (Hypothesis 3a). And we expect people to develop more factual knowledge in the medium- than in the high-incongruity condition (Hypothesis 3b).

**Hypothesis 4.** We expect that people will develop more conceptual knowledge in the medium-incongruity condition, because this condition is supposed to be optimal for elaborating on prior knowledge and gaining new insights. In more concrete terms, we expect that people will develop more conceptual knowledge in the medium- than in the low-incongruity condition (Hypothesis 4a). And we expect that people will develop more conceptual knowledge in the medium- than in the high-incongruity condition (Hypothesis 4b).

**Method**

In order to test these hypotheses empirically we performed an experimental study under controlled laboratory conditions. In this section, we will describe the experimental setting, the procedure adopted, and the measures that were applied.

**Experimental setting.** The experiment was conducted in groups with five to ten participants. Going through the complete experiment took about two hours. The wiki was introduced to the participants as a real wiki about Clinical Psychology, currently under development in order to inform patients or other interested people. The participants were made to believe that the other participants had to deal with a different part of the same wiki, i.e., on a different topic (paranoia, depression...), but in fact, each participant worked, independently from the others, with the same simulation of a wiki page (with faked prior versions, faked previous authors, faked edit dates) on the “causes of schizophrenia”. We used nearly the same experimental material as in the study of Moskaliuk et al. (2009): eight different arguments (four “social” and four “biological” arguments) were used to build the wiki page about causes of

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*Figure 1. Distribution of information provided in the wiki and participants’ prior knowledge (“part.”) in three experimental conditions. B1 to B4 are arguments that describe biological causes of schizophrenia, S1 to S4 arguments that describe social causes.*
schizophrenia – Moskaliuk et al. (2009) had used ten arguments; apart from social and biological arguments they had also used two integrative arguments. We decided to omit these integrative arguments, because we wanted participants to arrive at an integrative approach on their own, because we think that this is a very good indicator of accommodation (see below). The eight arguments were the same in all conditions, keeping the information in the wiki constant. In order to manipulate incongruity between prior knowledge and information in the wiki, participants in the different experimental conditions received a different number of short texts in the look-and-feel of scientific newsletters before they started working on the wiki. Each newsletter text contained one argument (either social or biological). These newsletters dealt with the same eight arguments that were also part of the wiki page, but they were complemented by additional information that was irrelevant to the significance of the argument.

Participants in the low-incongruity condition received all eight newsletters in order to guarantee high prior knowledge. Participants in the medium-incongruity condition received either four newsletters with social arguments on causes of schizophrenia or four newsletters with biological arguments (in order to take into account potential qualitative differences between the social and the biological arguments, we provided two versions of the medium-incongruity condition). Participants in the high-incongruity condition received no newsletters. Consequently, their prior knowledge was low. Figure 1 shows the three experimental conditions.

Procedure. We used mobile computers for presenting two questionnaires (at the beginning and end of the experiment), for the instructions, and for a short tutorial that introduced the handling of the wiki. Before the participants started working on the wiki, they received the newsletters (except in the high-incongruity condition). The time that participants could spend reading the newsletters (learning phase) was determined, depending on the condition that they had been assigned to (see below).

Measures. Corresponding to the four processes of learning and knowledge building, there were four different dependent variables. For measuring modifications in the wiki, we made a log-file analysis for each participant, to compare the initial version of the wiki page to the last version at the end of the experiment. To measure assimilative knowledge building, we counted the number of words that participants had added to the wiki text. In order to measure accommodative knowledge building, we developed an index as follows: we counted those phrases that participants either used to refer to interaction between social and biological causes of schizophrenia (integrative arguments) or which they used to connect arguments (e.g., “on the one hand … on the other hand”, “in contrast”, “however”).

To measure factual knowledge about causes of schizophrenia (in the post-experimental questionnaire), we used the multiple choice test from Moskaliuk et al. (2009) with statements about the causes of schizophrenia. To measure conceptual knowledge, we asked participants to provide the best argument to explain why schizophrenia occurs. Their answers were rated by experts to distinguish between different levels of conceptual knowledge. An answer that contained a simple explanation (biological or social) was rated with one point. Two points were assigned when participants named both biological and social causes. They received three points if they pointed out to some kind of interaction between social and biological factors. And participants received four points if they were able to explain that it is external stress (social) that can uncover an inherent (biological) vulnerability. The number of points attained was taken to represent the degree of conceptual knowledge.

Experimental design. The experiment represented a between-subjects design with incongruity as between-subjects factor with three levels (low vs. medium vs. high). To distinguish clearly between the conditions, we varied the time that participants were able to spend on the development of prior knowledge by reading the scientific newsletters. In the low-incongruity condition they had 20 minutes (for eight newsletters); in the medium-incongruity condition they had 10 minutes (for four newsletters). Participants in the high-incongruity condition were not supposed to have any prior knowledge, so they were not given any learning time before working on the wiki. Assimilative and accommodative knowledge building as well as development of factual and conceptual knowledge served as dependent variables.

Participants. This study was carried out with 72 participants. 55 of these were women, 17 men. Their mean age was 22.06 years (SD=3.48). The participants were students from a local university. Students of Psychology were not allowed to participate, because of their potential prior knowledge on schizophrenia. The participants were randomly assigned to one of the experimental conditions. 25 participants were assigned to the low-, 25 to the medium-, and 22 to the high-incongruity condition.
Results

In order to test the hypotheses, we conducted independent sample t-tests for comparing the experimental conditions for each dependent variable.

H1a assumed more assimilative knowledge building in the medium- than in the high-incongruity condition. The data supported this hypothesis: \( t(44)=4.78, p<.01, d=1.46 \). There was more assimilative knowledge building in the medium-incongruity condition: \( M_{\text{med}}=84.00 (SD=64.92) \) vs. \( M_{\text{high}}=11.71 (SD=26.09) \).

H1b assumed more assimilative knowledge building in the low- than in the high-incongruity condition. The data supported this hypothesis: \( t(43)=5.21, p<.01, d=1.59 \). There was more assimilative knowledge building in the low-incongruity condition: \( M_{\text{low}}=89.00 (SD=63.38) \) vs. \( M_{\text{high}}=11.71 (SD=26.09) \).

H2a assumed more accommodative knowledge building in the medium- than in the low-incongruity condition. The data supported this hypothesis: \( t(47)=3.55, p<.01, d=1.02 \). There was more accommodative knowledge building in the medium-incongruity condition: \( M_{\text{med}}=2.04 (SD=1.79) \) vs. \( M_{\text{low}}=0.58 (SD=0.93) \).

H2b assumed more accommodative knowledge building in the medium- than in the high-incongruity condition. This hypothesis was also supported: \( t(44)=4.36, p<.01, d=1.34 \). There was more accommodative knowledge building in the medium-incongruity condition: \( M_{\text{med}}=2.04 (SD=1.79) \) vs. \( M_{\text{high}}=0.29 (SD=0.46) \). Figure 2 presents the results of H2.

H3a assumed that people would possess more factual knowledge in the low- than in the medium-incongruity condition. The data supported this hypothesis: \( t(48)=1.69, p=.05, d=0.48 \). Participants in the low-incongruity condition had more factual knowledge: \( M_{\text{low}}=14.72 (SD=2.01) \) vs. \( M_{\text{med}}=13.68 (SD=2.34) \).

H3b assumed more factual knowledge in the medium- than in the high-incongruity condition. The data supported this hypothesis: \( t(45)=2.31, p=.01, d=0.67 \). Participants in the medium-incongruity condition possessed significantly more factual knowledge: \( M_{\text{high}}=11.82 (SD=3.17) \) vs. \( M_{\text{med}}=13.68 (SD=2.34) \).

H4a assumed that people would develop more conceptual knowledge in the medium- than in the low-incongruity condition. The data tended to support this hypothesis; this is, however, only a marginal effect: \( t(48)=1.34, p=.09, d=0.38 \). Participants in the medium-incongruity condition tended to develop more conceptual knowledge: \( M_{\text{low}}=1.20 (SD=0.65) \) vs. \( M_{\text{med}}=1.48 (SD=0.82) \).

H4b assumed more conceptual knowledge in the medium- than in the high-incongruity condition. The data supported this hypothesis: \( t(45)=2.07, p=.02, d=0.61 \). Participants in the medium-incongruity condition developed significantly more conceptual knowledge: \( M_{\text{high}}=1.05 (SD=0.58) \) vs. \( M_{\text{med}}=1.48 (SD=0.82) \). Figure 3 shows the results of H4.
Discussion

The results of this study show a higher extent of assimilative knowledge building in the low- and in the medium-incongruity condition than in the high-incongruity condition. Moreover, individuals possessed more factual knowledge in the low- than in the medium-incongruity condition and more factual knowledge in the medium- than in the high-incongruity condition. As expected, participants possessed, after the experiment, the more factual knowledge the higher their prior knowledge had been in the first place. These results are not too surprising and arise predominantly from the way incongruity was operationalized in this study: there is a simple linear relationship between the quantity of available learning material and the availability of factual knowledge.

But as far as accommodative processes are concerned, the results are rather revealing: in the medium-incongruity condition, more accommodative knowledge building occurred than in the other two conditions. And we found that people developed more conceptual knowledge in the medium-incongruity condition than in the low- and the high-incongruity condition (even though the difference between medium and low was only marginally significant). What is important here is the finding that people participated more in accommodative knowledge building and developed more conceptual knowledge in the case of medium incongruity; this cannot be explained with the length of learning time: allocating more learning time did not lead to a greater extent of accommodative knowledge building and development of conceptual knowledge. The relevant factor here is incongruity between information in the wiki and the individuals’ knowledge, and the results indicate clearly that a medium level of this incongruity is particularly conducive to knowledge building and individual learning in terms of quality.

As compared to the study by Moskaliuk et al (2009), the present study aimed specifically at enabling processes of internalization of knowledge. In the high-incongruity condition, participants were able, while working on the wiki, to internalize all arguments from the wiki. In the medium-incongruity condition, it was only possible to internalize those parts of the arguments that had not previously been available in the newsletters. In the low-incongruity condition, participants found no new information in the wiki and would hardly have been able to develop any new knowledge by working on the wiki.

The experimental manipulation of opportunities for the internalization of knowledge had the consequence that opportunities provided for externalization were very low in all three conditions, because the wiki contained all the relevant information and participants could practically only add minor details. So this study is a mirror-inverted replica of the study by Moskaliuk et al. (2009), where opportunities for internalization were kept constantly low in all three conditions and those provided for externalization of knowledge were manipulated. Participants in this study had received all newsletters in all three conditions (low, medium, and high incongruity) and it was the different degrees of completeness of the wiki that made the difference between the three conditions. A comparison of the
results of the present study with the results from Moskaliuk et al. (2009) supports the assumption that it is mainly construction processes of externalization that act as catalysts of knowledge development.

To sum up, the experiment reported here support the assumptions of the model by Cress and Kimmerle (2008). Although in all experimental conditions users always had access to all information – it was only distributed differently between the newsletters and the wiki – the experimental conditions differed, in line with theory, in the extent to which they facilitated learning and knowledge building.

Conclusion

What are the implications of these findings for the use of wikis in educational contexts? Based on our own research and the theoretical approaches discussed in the first section of the paper, we can point out that an integrative point of view is essential to understand learning and knowledge building. We have to focus on the individual and individual learning processes on the one hand, as well as on the group or community and its knowledge-building processes on the other. In schools and universities often only individual achievement is considered. In other contexts (e.g., in enterprises or in a scientific community), however, knowledge is very often built jointly. So a broader understanding of learning and knowledge building needs both perspectives.

It is necessary to specify these processes of learning and knowledge building. The co-evolution model presented here describes accommodation and assimilation as two ways of integrating own knowledge and new information in a wiki. Besides, the model postulates that medium incongruity between one’s own knowledge and new information leads to a greater cognitive conflict than low and high incongruity and to a greater extent of learning and knowledge building in terms of quality.

Concerning the use of wikis in educational contexts, we would like to make some practical suggestions (even though we are aware that a transfer of findings from laboratory studies to real world contexts will always need to be handled with care):

- One factor that triggers learning and knowledge building is the interaction between a person’s individual knowledge and new information in the environment. A central catalyst here is a perceived cognitive conflict that may lead to accommodation and assimilation. So educators should allow cognitive conflicts. They should provide educational settings in which such conflicts may occur and may actively be solved by learners.
- So educators need to find an adequate level of incongruity. Starting with an empty wiki disables the possibility of linking one’s own knowledge to available content, and a complete wiki with all relevant information may demotivate students from participating. A partly filled, but still incomplete wiki provides the opportunity to consider new information, but still add one’s own knowledge, settle controversies, and integrate different positions.
- Educators need to specify their learning goals. Working with a wiki seems to have a lower impact on the development of factual knowledge and assimilative knowledge building than on the development of conceptual knowledge and accommodative knowledge building. If the aim is merely to impart facts, then wikis are not necessarily the first choice. But if the goal is to discuss and integrate different aspects of one topic, or to develop mutual understanding of complex issues, a wiki seems to be an appropriate tool.

A conclusion of the theoretical background and the study reported here is that wikis seem to be suitable instruments to encourage and facilitate processes of individual learning and collaborative knowledge building at the same time. Wikis are more than a piece of software technology – they stand for a constructivist view on learning, one that defines knowledge building as a socio-cognitive process between individuals and groups. So, this tool and the underlying principles (cf. Moskaliuk & Kimmerle, 2009) may be used on a broader scale, both in informal and institutionalized learning arrangements. The underlying theoretical paradigm, however, cannot only be applied to wikis. It may also be transferred to situations in which people deal with other types of shared digital artefacts. We conclude that it is an adequate approach to consider both the processes in the cognitive systems of individuals and in the social system in order to understand individual learning, collaborative knowledge building, and their interplay – regardless of which particular social software tool people may use.
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