# Learning and Knowledge Building with Wikis: The Impact of Incongruity between People's Knowledge and a Wiki's Information

Johannes Moskaliuk, Joachim Kimmerle, University of Tuebingen, K. Adenauer 40, 72072 Tuebingen
Email: j.moskaliuk@iwm-kmrc.de, j.kimmerle@iwm-kmrc.de
Ulrike Cress, KMRC, K. Adenauer 40, 72072 Tuebingen, u.cress@iwm-kmrc.de

**Abstract:** The study reported in this article aims at empirically testing a theoretical model of collaborative knowledge building with wikis which was recently introduced by Cress and Kimmerle (2007; in press). This model assumes that individual learning and collaborative knowledge building are based on the interplay between people's knowledge and the information available in the wiki. This interplay takes place in the form of externalization and internalization respectively. Individual learning is considered as happening through internal processes of assimilation and accommodation. Collaborative knowledge building happens through activities of external assimilation and accommodation. This study demonstrates these four processes in an experimental setting. As postulated by Cress and Kimmerle, the results show that a medium level of incongruity between people's knowledge and a wiki's information supports individual learning. A medium level of incongruity also leads to more external accommodation processes, despite the fact that high and medium levels of incongruity result in the same amount of text complements.

## Introduction

Wikis are compilations of web-sites on the internet or on an intranet. They cannot only be read by users but they can also be edited online (Leuf & Cunningham, 2001). Wikis can be employed without special software, they are very easily accessible and simple to use (Désilets et al., 2005). Usually wikis are used for writing and revising text. Users can create content and hyperlink it with other contents, they can add, delete, and change any part of the text if they want to (Raitman et al., 2005). This way, a group of users can jointly create one artifact and this activity facilitates the collaborative development of knowledge (Fuchs-Kittowski & Köhler, 2005; Köhler & Fuchs-Kittowski, 2005). These characteristics of wikis make them a precious technology for many purposes, especially in an educational context (Bruns & Humphreys, 2005; Chong & Yamamoto, 2006; Notari, 2006; Wang & Turner, 2005). Some researchers have pointed out to wikis' potential for collaborative learning: Chong and Yamamoto (2006) refer to wikis' ability to facilitate debate-based learning. Reinhold (2006) assumes that wikis support the shaping of knowledge. Wikis are considered as supporting processes of learning since they facilitate collaboration (Kim et al., 2006; Notari, 2006). They have been associated with an enhanced inventiveness (Guzdial et al., 2001), with design-based learning (Rick & Guzdial, 2006), or with the co-construction of knowledge and inquiry learning (Yukawa, 2006).

### Wiki-supported knowledge building

Cress and Kimmerle (2007) assume that wikis are supportive of learning and knowledge building. The theory of knowledge building addresses how a community of learners manages to jointly create knowledge (Scardamalia & Bereiter, 1994). This approach focuses very much on using computer technologies and emphasizes the impact of epistemic artifacts for knowledge-building purposes. Thus, knowledge building plays an important role in the context of CSCL (Hewitt & Scardamalia, 1998; Kali, 2006; Lee et al., 2006; Oshima et al. 2006; Scardamalia & Bereiter, 1996). Cress and Kimmerle (2007) presume that people's individual knowledge can be used as a supply for learning processes of other people (cf. also Kafai, 2006; Scardamalia & Bereiter, 1994). The authors argue that a wiki as an artifact is perfectly dedicated to support this kind of mutual use and development of knowledge (cf. also Bruckman, 2006; Norman, 1991).

Cress and Kimmerle (2007) argue that wiki-supported knowledge building can be considered from a systemic point of view. They distinguish the cognitive systems of the users from the social system wiki (the corresponding wiki *community* respectively). It is assumed that individual learning and knowledge building is facilitated by the interplay between people's knowledge and the information available in the wiki. This interplay allows a mutual development of a social system and cognitive systems. This so-called co-evolution is enabled by various basic processes. These processes arise from the distinction of *externalization* and *internalization* on the one hand and from the distinction of *assimilation* and *accommodation* on the other hand. Externalization is an activity in which people introduce their own knowledge to the wiki. This can lead to individual learning since this externalization process might activate deeper elaboration of knowledge. Internalization is the activity in which people take up information from a wiki. This can lead to individual learning since this internalization

process might expand people's individual knowledge. Thus, externalization and internalization describe how knowledge and information are interchanged between the individual's cognitive system and the wiki.

In order to explain the processes in the cognitive systems and the social system respectively Cress and Kimmerle (2007) refer to Piaget's model of equilibration (Piaget, 1970). This model describes how people take up novel information from the environment and how they integrate it into their own knowledge. People try to keep equilibrium between their existing knowledge and the information from the environment. New information which is not in line with prior knowledge causes *cognitive conflicts*. Such a cognitive conflict can result in new knowledge. If information cannot be easily integrated into prior knowledge, people have to process this new information somehow. There are two ways to deal with this incongruity and to solve cognitive conflicts. People can either assimilate new information or they can accommodate prior knowledge. Assimilation is the process in which individuals use their prior knowledge in order to comprehend new information. In the process of accommodation people change their knowledge by dealing with new information. Here, people truly change existing knowledge instead of simply assimilating new information into prior knowledge.

## Four processes of knowledge building

People who interact via wikis can learn by externalisation or internalization respectively. This learning can occur as assimilation or accommodation since people can simply add new information to their prior knowledge or they can change their knowledge and develop new understandings. It is assumed that equilibration does not merely occur in cognitive systems but also externally in wikis. Therefore, assimilation and accommodation are not merely processes of individual learning but also of collaborative knowledge building. It is a matter of external assimilation when information is simply added, i.e. when it is introduced to a wiki without being explicitly connected to formerly existing information. In this process the wiki's organization remains unchanged. With other words, the wiki assimilates this new information. However, a wiki can also accommodate. This external accommodation takes place when the information in a wiki is newly-arranged by rewriting paragraphs, by reorganizing pages, or by integrating new and existing information (cf. also Majchrzak et al., 2006).

Altogether, the co-evolution of cognitive systems and the social system which in turn allows for individual learning and collaborative knowledge building is based one four different processes: 1. Internal assimilation which represents the (quantitative) acquisition of factual knowledge. 2. Internal accommodation which represents the (qualitative) acquisition of conceptual knowledge. 3. External assimilation which represents quantitative knowledge building. 4. External accommodation which represents qualitative knowledge building. Internal assimilation and internal accommodation are processes of individual learning. External assimilation and external accommodation present processes of a collaborative knowledge building in reference to the wiki.

The description of these four processes is the starting point for our empirical investigations. Cress and Kimmerle (in press) observed external assimilation and accommodation in Wikipedia. They did not focus examining internal processes of assimilation and accommodation. Our first research question is whether there is empirical evidence for all the four processes of learning and knowledge building. We want to examine whether these four processes can be adequately observed and documented in an experimental setting.

The second research question aims at empirically testing concrete hypotheses derived from the model of Cress and Kimmerle. These authors do not only describe incongruities between people's knowledge and the information in the wiki. In this context they also address people's motivation to participate in knowledge-building processes. They assume that people's motivation for externalization and internalization is determined by (in)congruities between people's knowledge and the information in the wiki. While working with a wiki people are continuously checking whether the information provided by the wiki fits into their own individual knowledge. With a very low incongruity there is no need for a wiki user for equilibration. People then do neither assimilate nor accommodate, neither externally nor internally. With a very high incongruity people have no point of contact for any processes of equilibration. Cress and Kimmerle conclude that individual learning and collaborative knowledge building are most successful with incongruities between people's knowledge and the information in the wiki on a medium level (cf. Hunt, 1965). In the following we aim at examining this prediction.

## Hypotheses

Concretely, these theoretical considerations and the according research questions presented above lead us to the following hypotheses:

1.) Incongruities between people's knowledge and the information in the wiki on a medium level lead to more knowledge building compared to low and high incongruities. More precisely:
    a. Incongruities on a medium level lead to higher quantitative increases of information in the wiki (external assimilation) compared to low and high incongruities.

b. Incongruities on a medium level lead to higher qualitative increases of information in the wiki (external accommodation) compared to low and high incongruities.

2.) Incongruities between people's knowledge and the information in the wiki on a medium level lead to more individual learning compared to low and high incongruities. More precisely:
   a. Incongruities on a medium level lead to a higher increase of factual knowledge (internal assimilation) compared to low and high incongruities.
   b. Incongruities on a medium level lead to a higher increase of conceptual knowledge (internal accommodation) compared to low and high incongruities.

## Method

To test the hypotheses presented above, we ran an experiment in a laboratory setting. In the following we present the sample, the material, the measures, and the procedure we applied in this study.

### Participants

61 university students participated in this study. 43 of them were women, 17 were man (and 1 missing value). The participants' mean age was 24.6 years (*SD*=10.6).

### Material

For conducting the experiment a wiki was provided, which informed about the mental disorder schizophrenia. In order to guarantee the comparability with real wikis the welcome page of the experimental wiki presented an overview about all mental and behavioral disorders described in the ICD 10. However, participants were asked to work on the area on the *causes of schizophrenia* first. The other areas were technically blocked.

There are different positions about the causes of schizophrenia. One position suggests a genetic or biological sensitivity for schizophrenia; the other position considers the social environment and psychosocial stress as main factors. The diathesis-stress model tries to integrate the two different positions into one explanation: external stress can uncover an inherent vulnerability (diathesis). The experimental material for the wiki entry about the causes of schizophrenia consisted of ten arguments. Four arguments were assigned to the position that a genetic or biological tendency causes the disorder, four arguments were assigned to the position that considers the social environment and psychosocial stress as causal. Two arguments were assigned to the diathesis-stress model. An example for an argument according to the biological position is: "Schizophrenia is a hereditable disorder." An example for an argument according to the social position is: "Double-bind communication in a person's family leads to a higher probability to come down with schizophrenia."

The ten arguments were used to build four different entries about the causes of schizophrenia from which three conditions resulted. The entry in the low-incongruity condition contained all arguments; it can be described as a complete entry. Taking into account potential qualitative differences between the two positions, the medium-incongruity condition was build with two versions of the entry: One version contained the four genetic/biological arguments and the other version contained the four social arguments. It can be labeled as one-sided content. The entry about the causes of schizophrenia in the high-incongruity condition did not contain any content.

In order to make sure that prior knowledge of the participants was evenly low, we asked them for their knowledge about the causes of schizophrenia. It was found that all participants indicated low prior knowledge. To guarantee a basis for the work with the wiki ten short texts (in the style of popular science newsletters) were provided to the participants. Each text contained one argument and was complemented by additional information which was irrelevant for the significance of the argument (information about the scientist/institution who postulated/researched the statement and a scientific survey or an example to illustrate it). The newsletters were introduced as info alert for researchers or practitioners adapted to the look and feel of a scientific webpage. So the experimental setting was comparable to real learning settings: people read other sources about the relevant domain, extracted the relevant information and structured it with the goal of editing a wiki article.

Since each participant was provided all newsletter texts we ensured that all participants had the same prior knowledge about the causes of schizophrenia before they started working with the wiki. The three experimental conditions differed only in the information available in the wiki. This resulted in different incongruities between a wiki's information and people's knowledge in the three conditions. Figure 1 shows the four different entries about the causes of schizophrenia and the three conditions.

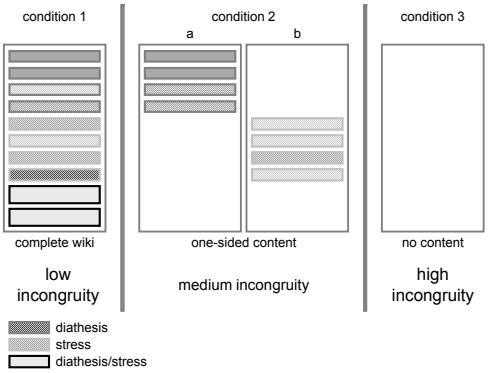


Figure 1. Four different wiki entries to manipulate incongruity between people's knowledge and the wiki's information. In all conditions the participants were aware of all arguments in advance.

The other entries about schizophrenia in the wiki contained information about the different kinds and states of the disorder, or about diagnostics and therapy. Since participants were instructed to edit the entry about the *causes* of schizophrenia, there were only very few changes on the other entries.

## Measures

We measured external processes which represent knowledge building in the artifact and internal processes which represent individual learning. As indicator for external assimilation we measured quantitative changes in the wiki: this is the case if a person simply adds new information to the wiki's entry without changing prior information or connecting new information with the existing content. Assimilation in people's cognitive system can be described as quantitative learning: learners add new facts to their prior knowledge, however, without restructuring or rebuilding their mental models. In contrast, accommodation is indicated by qualitative processes. Qualitative changes in the wiki are represented by reorganizations of the text or by phrases like "on the other hand…" or "against this…" which clarify or explicate different positions. Qualitative individual learning is indicated by a deeper understanding of the subject area and by more complex conceptual knowledge. Correspondingly, there are four dependent variables which are shown in Table 1.

Table 1: The dependent variables of the experiment.

| | **Wiki's information** | **People's knowledge** |
|---|---|---|
| **Quantitative changes** | Sum of added words | Factual knowledge |
| **Qualitative changes** | Accommodation index | Conceptual knowledge |

Changes in the wiki were examined with the aid of log-file analyses. We compared the version of the entry which a participant had started with to the last version of the entry at the end of the experiment. As indicator for quantitative processes we simply counted the number of words which participants had added to the wiki text.

In order to measure the qualitative processes we developed an accommodation index. For this purpose we analyzed every sentence which the participants had added. We counted the phrases, which contained an allusion to the diathesis-stress-model or to an interaction between both causes. Besides, we considered the structure of the arguments. For example, we accepted sentences with phrases like "on one hand… on the other hand…", "in contrast…", "nevertheless…", or "however…".

Factual knowledge is represented by the number of facts the participant have learned about the subject area. In the process of this quantitative individual learning new facts complement the prior knowledge of a person. Factual knowledge is measured with a test of 21 statements about the causes of schizophrenia (e.g. "The double bind hypothesis is an empirically proven theory about the causes of schizophrenia."). Participants had to decide, whether the statement is correct or not. They could also choose the option "I don't know". The number of correct responses was measured; the option "I don't know" was counted as wrong response.

The degree to which participants developed conceptual knowledge represented qualitative changes in their cognitive systems. In order to measure this qualitative individual learning, participants were asked to provide the best argument with respect to the causes of schizophrenia. The answers were categorized as simple

or complex answers. It was counted as a complex answer if participants referred to both causes (biological and social), presented the diathesis-stress model, or if they referred to an interaction between different causes. A simple answer only presented one cause or was characterized by a lack of coherent argumentation.

All dependent variables were measured after the work with the wiki. Additionally, we measured two control variables: the total time of editing the wiki (in relation to reading the wiki) and the prior knowledge about schizophrenia.

### Procedure

The experiment was conducted in groups with 5 to 10 participants. Passing the complete experiment took about 2 hours. Participants were led to believe that everybody had to deal with another part of the same wiki with various topics (paranoia, schizophrenia, …). In fact, every participant worked independently from the others with a simulated wiki with respect to the same topic. Participants could not see each others' monitors. In order to allow for realistic situations, we provided information on prior versions of an entry, on alleged previous authors, and on the date/time when the version was created allegedly. All instructions and a short tutorial, which explained the function of the wiki tool were presented on a mobile computer. The questionnaires which measured the dependent variables *factual knowledge* and *conceptual knowledge* as well as the control variables were also presented on the computer. The experimenter only took a short welcoming and, at the end of the experiment, a debriefing about the goals of the study. The assignment to the three conditions followed by chance and was carried out by the experimental software.

## Results

The next paragraph reports the results of the experiment. First we describe the results according to individual learning in person's cognitive system (hypothesis 1). Second we describe the result according to knowledge building in the wiki's social system (hypothesis 2). At least we describe the results of the collected control variables.

### Results Hypothesis 1

*Sum of added words.* For each participant we compared the first version of the entry about the causes of schizophrenia with the last entry. In the medium-incongruity condition participants added significantly more words than in the low-incongruity condition: $M_{med}$=210.00 (*SD*=124.98) vs. $M_{low}$=78.78 (*SD*=64.17), $t(38)=4.03$, $p<.01$. But there was no difference between high and medium incongruity: $M_{med}$=210.00 (*SD*=124.98) vs. $M_{high}$=268.70 (*SD*=99.35), $t(40)=-1.67$, $p>.05$.

*Accommodation index.* We calculated an accommodation index for each participant. We found significantly more qualitative knowledge building in the medium-incongruity condition than in the low-incongruity condition: $M_{med}$=3.29 (*SD*=2.70) vs. $M_{low}$=1.78 (*SD*=1.70), $t(37)=2.04$, $p=.02$ and than in the high-incongruity condition: $M_{med}$=3.29 (*SD*=2.70) vs. $M_{high}$=2.05 (*SD*=0.94), $t(39)=1.93$, $p=.03$. Figure 2 presents these effects.

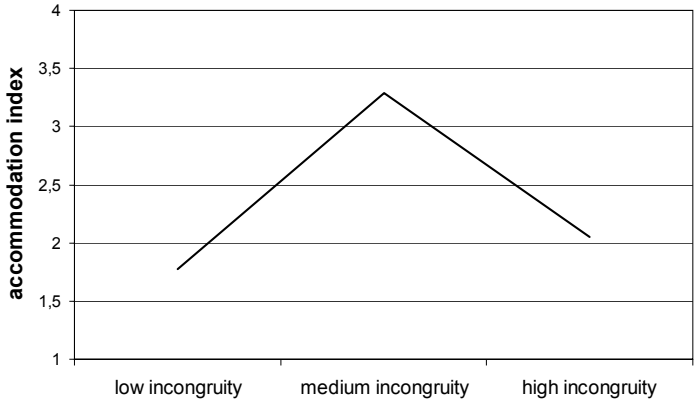


Figure 2. Qualitative knowledge building in the three conditions.

### Results Hypothesis 2

*Factual knowledge.* The factual knowledge acquired through the work with the wiki was compared among the three conditions. As expected, there was a significant difference: the factual knowledge in the medium-incongruity condition was higher than in the low-incongruity condition: $M_{med}$=15.50 (*SD*=2.30) vs. $M_{low}$=13.70 (*SD*=2.98), $t(37)=2.16$, $p=.02$. Factual Knowledge in the medium-incongruity condition was also

higher than in the high-incongruity condition: $M_{med}$=15.50 (*SD*=2.30) vs. $M_{high}$=14.20 (*SD*=1.96), *t*(37)=1.96, *p*=.03. Figure 3 shows the difference between the three conditions.

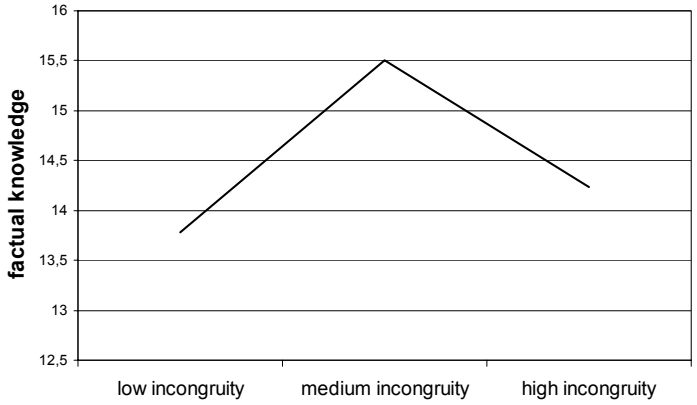


Figure 3. Factual knowledge in the three conditions.

*Conceptual knowledge.* We compared the frequency of participants' simple and complex responses to the question about the causes of schizophrenia. Chi-square tests show a no-chanced distribution of complex and simple answers between the high-incongruity condition and the medium-incongruity condition: $\chi^2$(1, *N*=43)=5.23, *p*=.02. There is also a no-chanced distribution of complex and simple explanations between the low-incongruity condition and the medium-incongruity condition: $\chi^2$(1, *N*=40)=4.55, *p*=.03. Figure 4 presents the percentage of complex explanations for the three conditions.

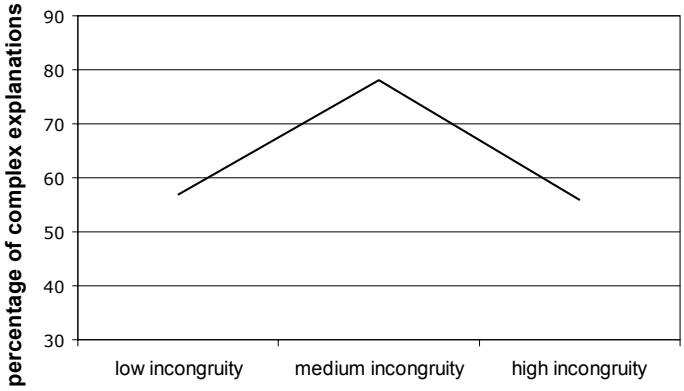


Figure 4. Percentage of complex explanations in the three conditions.

## Control variables

The total time of editing the wiki is higher in the high-incongruity condition than in the low-incongruity condition: $M_{high}$=86.6% (*SD*=12.87) vs. $M_{low}$=75.3% (*SD*=16.64), *t*(36)=2.34, *p*=.025. The total time of editing the wiki in den medium-incongruity condition was $M_{med}$ =83.4% (*SD*=17.52). At first sight, this seems to be a trivial result since a complete entry such as in the low-incongruity condition does not require many edits. But it is illuminative that there is no simple correlation between the time spent editing and the increase of knowledge.

## Discussion

The postulated processes of internal and external accommodation and assimilation can be adequately observed in an experimental setting. Using a Diff-Tool, like the function "compare documents" of MS Word in order to compare two version of a wiki entry, we can document the described processes. There is evidence for two different processes, as postulated above: assimilation as addition of new information without editing the existing content and accommodation as rebuilding or restructuring of existing content to make new information compatible.

As postulated in hypothesis 1, we found more qualitative knowledge building for a medium incongruity between people's knowledge and the wiki's information than for high or low incongruity. This means that there is more external accommodation with medium incongruity. The sum of added words is smaller with low incongruity than with medium and high incongruity. There is no significant difference between medium and high incongruity. This finding seems trivial, because participants can of course add more words in a blank or a one-sided wiki. But it shows that there is no simple correlation between the sum of written words and the amount of individual learning: in accordance with hypothesis 2 incongruities between people's knowledge and the information in the wiki on a medium level lead to more individual learning compared to low and high incongruity. Medium incongruity between people's knowledge and the wiki's information leads to a higher increase of factual knowledge. This can be described as internal assimilation. We also found more complex explanations for the causes of schizophrenia with a medium incongruity compared to a low and high incongruity. We consider this increase of conceptual knowledge as evidence for internal processes of accommodation. The study displays empirical evidence for the theoretical model of collaborative knowledge building with wikis (Cress & Kimmerle, 2007, in press): a medium level of incongruity between people's knowledge and a wiki's information supports individual learning (internal accommodation and assimilation) and leads to more qualitative knowledge building (external accommodation).

In the study described here, we held people's knowledge constant and manipulated various levels of incongruity by using different wiki entries about schizophrenia. In a subsequent study we will manipulate the prior knowledge of the participants by giving them different information (newsletters with information about the causes of schizophrenia) before working with the wiki. Participants in the low incongruity condition will receive no prior information, participants in the medium incongruity condition will receive four newsletters with only genetic/biological or social factors, and participants in the high incongruity condition will receive 2 newsletters with genetic/biological and 2 with social factors. The entry about schizophrenia in the wiki will always contain 8 arguments, the 4 genetic/biological and the 4 social arguments. The two arguments, addressing the diathesis-stress model will be neither contained in the wiki nor in the newsletters. The goal of the following study is on the one hand to replicate the findings, on the other hand to use an additional measurement of external and internal accommodation. This future study will address the question whether the participants will combine the two different positions about the causes of schizophrenia by postulating an interaction or a diathesis-stress model. This would be perfect evidence for accommodation processes.

Further research should consider additional factors like the participant's interest in the subject area, the motivation to acquire new knowledge, the personal involvement, or the goal and audience of the wiki. Social factors like the perception of others' expertise or the sympathy for others are also relevant for further research.

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