Understanding Learning – the Wiki Way

Joachim Kimmerle
University of Tuebingen
Konrad-Adenauer-Str. 40
72072 Tuebingen, Germany
+49 7071 979-346
j.kimmerle@iwm-kmrc.de

Johannes Moskaliuk
University of Tuebingen
Konrad-Adenauer-Str. 40
72072 Tuebingen, Germany
+49 7071 979-322
j.moskaliuk@iwm-kmrc.de

Ulrike Cress
Knowledge Media Research Center
Konrad-Adenauer-Str. 40
72072 Tuebingen, Germany
+49 7071 979-209
u.cress@iwm-kmrc.de

ABSTRACT
Learning "the wiki way", learning through wikis is a form of self-regulated learning that is independent of formal learning settings and takes place in a community of knowledge. Such a community may work jointly on a digital artifact to create new, innovative and emergent knowledge. We regard wikis as a prototype of tools for community-based learning, and point out five relevant features. We will present the co-evolution model, as introduced by Cress and Kimmerle [3][4], that may be understood as a framework to describe learning in the wiki way. This model describes collaborative knowledge building as a co-evolution between cognitive and social systems. To investigate learning the wiki way, we have to consider both individual processes and processes within the wiki, which represent the processes that are going on within a community.

This paper presents three empirical studies that investigate learning the wiki way in a laboratory setting. We take a look at participants' contributions to a wiki indicating processes within the wiki community, and measure the extent of individual learning at the end of the experiment. Our conclusion is that the model of co-evolution has a strong impact on understanding learning the wiki way, may be helpful to designers of learning environments, and serve as framework for further research.

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H.5.3 [**Group and Organization Interfaces**]: Collaborative computing, Web-based interaction
K.3.1 [**Computer Uses in Education**]: Collaborative learning

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Design, Human Factors, Theory

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Wiki, Knowledge Building, Co-evolution, Collective Knwoledge

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1. Introduction
It is assumed that changes of the Web will lead to new forms of collaboration and learning. Web 2.0 tools, such as wikis, weblogs, podcasts, folksonomies, file sharing and virtual online worlds, are changing their users' handling of data, information and knowledge, and lead to a "fundamental mind shift" [11]: User participation, collaboration and the opportunity to create one's own content are the relevant aspects of this technical development. Thus, learning – as defined by constructivism – is intensified by what is offered through the Web 2.0. Learning tends to become a self-regulated process, independent of formal learning settings, say, at school or university: Individual learning is performed in informal learning spaces by members of a community of knowledge. They may work jointly on shared digital artifacts [17] that were provided through the Internet or a local area network, say, of a university. This will not only lead to cumulation of knowledge, by which the knowledge of many individuals is brought together and made available to others, but also to emergence, the creation of new knowledge [10], a process that is being discussed under headings like "Wisdom of the crowds" [1], [16].

A wiki may be understood as a prototype of such a tool. It allows the joint creation of knowledge and leads to instant collaboration the wiki way [12]. In our opinion, five main features may be regarded as characterics of learning the wiki way:

(1) A community of learners is involved.

(2) They use a shared digital artifact to collaborate.

(3) Learning processes are self-regulated and often take place in an informal setting.

(4) Emphasis is on the collaborative product, the jointly created artifact (the wiki page, some object of a virtual environment).

(5) The community builds new knowledge or will gain some new expertise that had not been part of the community before.

Here we refer to Scardamalia and Bereiter [13] who introduced the concept of knowledge building. They define knowledge building as a socio-cultural process that takes place in a community. The goal of a knowledge building community is to create knowledge that supports members of the community in understanding their environment.

We should distinguish knowledge building from individual learning: The focus of the knowledge building concept is on processes within a community. Such a process of knowledge

building, represented through a wiki, may occur, say, if an individual has enriched a wiki page by adding new facts or arguments to existing concepts (quantitative contribution to the wiki), or if an individual re-structures the entire wiki page or adds new or conflicting aspects to it (qualitative contribution). The concept of individual learning focuses on the cognitive processes of an individual. It might be described as a process of acquiring new factual or conceptual knowledge.

So we have to consider two relevant entities: The wiki page that represents the knowledge building processes within a community, on the one hand, and the individual learner and his/her cognitive processes on the other.

Cress and Kimmerle [4] use the terms "social system" and "cognitive system" to describe learning as interplay between these two systems. The social system is the digital artifact (e.g. the wiki) and the corresponding knowledge building community. The cognitive system refers to processes like thinking, reasoning, remembering and so on, in the mind of an individual. Both systems develop in a dynamic way in the course of time, and become more and more complex. The cognitive system develops by internalizing new information from the social system wiki, and influences the social system by externalizing that person's own knowledge to the social system wiki. The same is true of the social system: It internalizes knowledge from, and externalizes information to the cognitive systems of its users.

Processes of individual learning and knowledge building are not separated from each other, but influence one another. To understand what learning the wiki way is about, we have to consider both individual processes and processes within the wiki (representing processes within a community). Learning the wiki way is a co-evolution of cognitive and social systems.

The co-evolution model assumes that incongruity between information contained in the wiki and the knowledge of an individual will lead to a cognitive conflict and trigger individual learning and collaborative knowledge building. A medium level of incongruity will lead to a greater extent of individual learning and collaborative knowledge building than a high or low level of incongruity.

The research presented in this paper refers to experiments in a laboratory setting. Their aim was to investigate which conditions lead to an increase of individual learning and knowledge building. Instead of only measuring cognitive learning results (as psychologists often do), processes within the wiki as a social system will also be considered. Even through the laboratory setting seems to be very different from real learning settings, an attempt was made to consider the main features of learning in the wiki way, by providing the following conditions:

(1) There was no real community of learners during the experiment, but participants worked in groups of three to ten people and were instructed that they had to work together on a shared wiki.

(2) The wiki was introduced to them as a "real" wiki for people with an interest in Clinical Psychology.

(3) The participants were not informed that they were actually involved in a learning experiment, but invited to improve a wiki and test its software.

(4) The only way in which users of the wiki page could communicate was by writing down their own point of view or editing text written by others.

(5) Relevant information was distributed between the wiki and its users, so the possibility was real to build new knowledge that had previously not been present in the community.

In other words, the experiment was based on a scenario that is comparable to a real world setting and allowed the investigation of learning the wiki way. At the same time, it was possible to control confounding variables and reduce the quantity of relevant aspects to dimensions of meaningful investigation.

This paper will present three experimental studies. It will, first of all, describe the method that was used for these studies (experimental setting, material, procedure, measures), and then describe how they were carried out, including some specific hypotheses, and the respective results. The concluding section, we will discuss our findings and some potential prospects for future research.

2. Method

In this section we will describe the experimental setting, the procedure adopted, and the measures that were applied in the three experiments. All three experiments dealt with different kinds of incongruity between the information in the wiki and the prior knowledge of its users.

2.1 Experimental Setting and Material

In the experiment, participants worked with a wiki that was introduced to them as a real wiki from Clinical Psychology. This was a wiki page that dealt with "causes of schizophrenia". The participants were made to believe that the content of this wiki had been contributed by other participants in previous sessions (but the wiki and its content were faked in that they had faked prior versions, faked previous authors and edit dates, in order to maintain a controlled experimental setting).

There are various different explanations of the causes of schizophrenia. One position suggests a genetic or biological sensitivity to schizophrenia; another position considers the social environment and psycho-social stress as main factors. And the so-called diathesis-stress model tries to integrate these two different positions into one explanation, saying that external stress may uncover an inherent vulnerability (diathesis). The experimental material consisted of ten arguments. Four of these arguments presented biological explanations as causes of schizophrenia, while four other arguments gave social explanations. Two further arguments were in line with the diathesis-stress model.

In order to provide participants with some prior knowledge of the topic, ten short texts (in the style of popular science newsletters) were provided. Each text contained one argument and was complemented by additional information that was irrelevant to the significance of the argument. Whether participants received newsletters (and how many), depended on the experimental condition to which they were allocated (see below). Each argument of a newsletter was identical with one that could also be found in the wiki, but the wiki texts were shorter and only contained the important points.

2.2 Procedure

We used mobile computers for presenting two questionnaires (one at the beginning for raising demographic variables, and one at the end of the experiment), for the instructions, and for a short tutorial which introduced the handling of the wiki. Before the participants started working on the wiki, they received the newsletters (except for those – in Study 2 – who did not receive any newsletters at all). After participants had made themselves familiar with the newsletters in order to acquire some prior knowledge, they started working on the wiki for 50 minutes. Regardless of where a specific item of information appeared, in the newsletters or in the wiki, it was ensured that each participant was exposed to each argument at least once. According to the instruction, the participants' assignment was to "contribute to the development of the wiki". The study was not announced as a learning experiment. Finally, the participants filled in a post-experimental questionnaire in order to measure knowledge acquisition (see next paragraph).

2.3 Measures

For measuring to what extent people externalized their prior knowledge, we detected modifications of the wiki, i.e. 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 quantity of contributions, we counted the number of words that participants had added to the wiki text. In order to measure quality of contributions, we counted the phrases which participants used to improve the text by connecting arguments and relating them to each other (this was rated by two independent experts).

To measure factual knowledge about causes of schizophrenia (in the post-experimental questionnaire), we used a multiple choice test with 21 statements about the causes of schizophrenia.

To measure conceptual knowledge (in the post-experimental questionnaire), we asked participants to provide the best argument to explain why schizophrenia occurs. Their answers were, again, rated by two independent experts to distinguish between different levels of conceptual knowledge (for more details on the method and the measures cf.[15]).

3. Study 1

Study 1 varies incongruity between the participants' prior knowledge and information contained in the wiki, by holding the participant's prior knowledge constant and manipulating the completeness of information in the wiki.

3.1 Hypotheses

Obviously it is difficult to contribute something useful from one's own knowledge, if all the relevant information is already available in the wiki, so we hypothesized the following effect:

People will write the more words the more information is missing in the wiki (Hypothesis 1).

What is much more interesting, however, is what the externalization of knowledge looks like in terms of quality, and how the opportunity to externalize own knowledge will influence the acquisition of factual and conceptual knowledge. We believe that a very high or very low incongruity between people's own knowledge and new information in the wiki is not helpful for the acquisition of factual and conceptual knowledge, because in these cases it is rather difficult to connect one's own knowledge to external information; it is more complicated to find points of contact. This is supposed also to have a negative effect on the quality of externalizations. Consequently, we assume that a medium level of incongruity is best to improve the quality of contributions and to facilitate learning (cf. [2], [9], [14]).

There will be a higher quality of contributions in the medium-incongruity condition (*Hypothesis 2*).

People will acquire more factual knowledge in a situation with a medium level of incongruity between prior knowledge and new information in the wiki (*Hypothesis 3*).

People will acquire more conceptual knowledge in a situation with a medium level of incongruity between prior knowledge and new information (*Hypothesis 4*).

3.2 Participants

This study was carried out with 61 participants. 43 of these were women, 17 men (and one person with undisclosed gender). The participants' mean age was 24.64 years (SD=10.58). The participants were randomly assigned to one of the three experimental conditions. 18 participants were assigned to the low-, 22 to the medium-, and 21 to the high-incongruity condition.

3.3 Experimental Design

The experiment represented a 1x3-factorial design with incongruity (low vs. medium vs. high) as between-factor. In the three experimental conditions, the amount of information a user possessed a priori was kept constant (all participants received all ten newsletters). The (in)congruity between a participant's knowledge and the wiki information was manipulated by the amount of information that was contained in the wiki.

In the medium-incongruity condition, only the four arguments of one position were provided in the wiki. So there were two versions of the medium-incongruity wiki: one providing the four biological arguments (A), and the other providing the four social arguments (B). Both versions might be labeled as one-sided content. In the condition with low incongruity, the wiki contained all ten arguments, and in the high-incongruity condition the wiki was empty at the beginning of the experiment. Figure 1 shows the four different wiki versions on causes of schizophrenia, representing the three conditions.

As dependent variables we measured quantity and quality of people's contributions to the wiki (i.e. their externalization of prior knowledge), as well as the acquisition of factual and of conceptual knowledge.

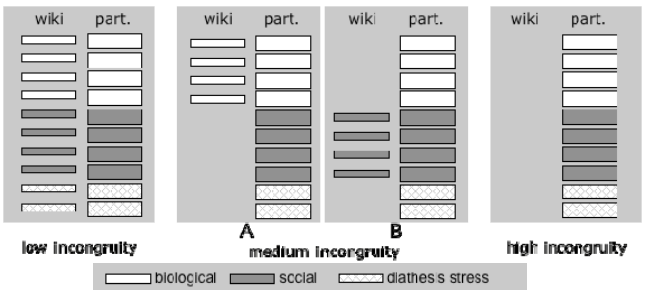

Figure 1: Three experimental conditions varying incongruity in Study 1.

3.4 Results

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

Quantity of contributions: In the medium-incongruity condition, participants contributed significantly more words to the wikis than in the low-incongruity condition: M_{med}=210.00 (*SD*=124.98) vs. M_{low}=78.78 (*SD*=64.17), $t(38)=4.03$, $p<.01$, $d=1.32$. 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), $t(40)=-1.67$, $p>.05$.

Quality of contributions: In the medium-incongruity condition, the quality of contributions was significantly higher than in the low-incongruity condition: M_{med}=3.29 (*SD*=2.70) vs. M_{low}=1.78 (*SD*=1.70), $t(37)=2.04$, $p=.02$, $d=0.67$. And it was higher in the medium-incongruity condition than in the high-incongruity condition: M_{med}=3.29 (*SD*=2.70) vs. M_{high}=2.05 (*SD*=0.94), $t(39)=1.93$, $p=.03$, $d=0.61$. Figure 2 shows the differences between the three conditions for the variable quality of contributions.

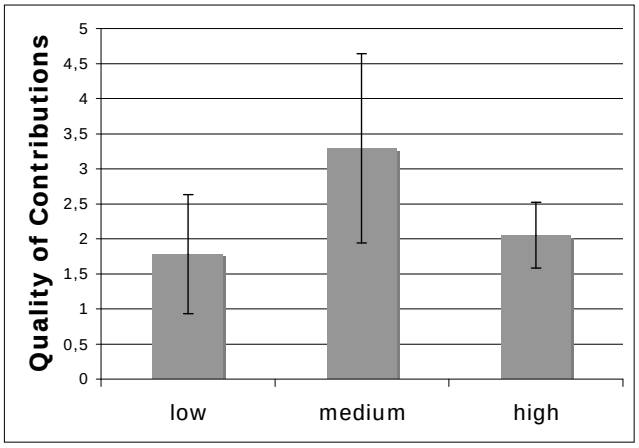

Figure 2: Quality of contributions in the three conditions.

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}=13.78 (*SD*=2.82), $t(38)=2.13$, $p=.02$, $d=0.67$. 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}=14.24 (*SD*=1.92), $t(41)=1.95$, $p=.03$, $d=0.59$.

Conceptual knowledge in the medium-incongruity condition was higher than in the low-incongruity condition: M_{med}=3.04 (*SD*=1.13) vs. M_{low}=2.29 (*SD*=1.16), $t(37)=2.03$, $p=.02$, $d=0.65$. Conceptual knowledge in the medium-incongruity condition was also higher than in the high-incongruity condition: M_{med}=3.04 (*SD*=1.13) vs. M_{high}=2.43 (*SD*=1.03), $t(41)=1.87$, $p=.03$, $d=0.56$.

3.5 Discussion

The quantity of contributions was smaller with low incongruity than with medium and high incongruity. There was no significant difference between medium and high incongruity. This finding seems trivial, because participants could, of course, contribute more words to a blank or a one-sided wiki. But it also showed that there was no simple relationship between the sum total of written words and the quality of contributions or the extent of individual learning. As expected, the quality of contributions was highest in the medium-incongruity condition.

Medium incongruity between people's knowledge and the wiki information led to a higher increase of factual knowledge. Participants could also acquire more conceptual knowledge with medium incongruity, if compared to low and high incongruity.

In this study, people's knowledge was kept constant, and we manipulated various levels of incongruity by using different wiki pages on schizophrenia. In the following study, however, we manipulated the participants' prior knowledge by providing them with different amounts of information (newsletters with information on causes of schizophrenia) before working with the wiki. Participants in the high incongruity condition would then receive no prior information, participants in the medium incongruity condition only one half of the newsletters, and participants in the low incongruity condition all newsletters. All pieces of information would be available in the wiki in all conditions.

4. Study 2

The second experiment was, so to speak, a mirror-inverted replica of the previous one.

4.1 Hypotheses

We expect people to write the least number of words in the high-incongruity condition (*Hypothesis 5*), because it will be very difficult to write down anything if one has no prior knowledge.

As in the previous study, we expect the highest quality of contributions in the medium-incongruity condition (*Hypothesis 6*).

The acquisition of factual knowledge depends on the amount of prior knowledge participants receive at the beginning of the experiment. We assume that people will acquire more factual knowledge in the low incongruity condition than in the medium and high incongruity conditions (*Hypothesis 7*).

We assume, again, that people will acquire more conceptual knowledge (*Hypothesis 8*) in a situation with a medium level of incongruity between prior knowledge and new information.

4.2 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 randomly assigned to one of the three experimental conditions. 25 participants were assigned to the low-, 25 to the medium-, and 22 to the high-incongruity condition.

4.3 Experimental Design

Again, the experiment represented a 1x3-factorial design with *incongruity* (low vs. medium vs. high) as between-factor. While in the experimental conditions of the previous study participants' prior knowledge was kept constant and the wiki differed in the information it contained, the artifact in the second experiment contained the same information in all conditions, and variation concerned the knowledge of the participants.

In all three experimental conditions, all of the arguments were presented in the wiki. Here, however, the wiki only provided the four social and the four biological arguments. Participants were not provided with arguments on the diathesis-stress model,

because we wanted to examine if they were able to find out these arguments on their own (this was considered a more valid test for the development of conceptual knowledge). Variation in the experimental conditions concerned the extent of participants' prior knowledge (see Figure 3).

In the low-incongruity condition, the participants knew all eight arguments, in the high-incongruity condition they had no prior knowledge at all. In the medium-incongruity condition, the participants only knew the arguments of one position on causes of schizophrenia, i.e. either the four social (A) or the four biological arguments (B).

As in Study 1, we measured quantity and quality of people's contributions to the wiki as well as the acquisition of factual and of conceptual knowledge as dependent variables.

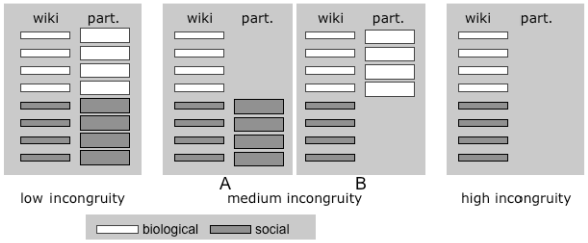

Figure 3: Three experimental conditions varying incongruity in Study 2.

4.4 Results

Again, we conducted independent sample t-tests in order to test the hypotheses.

Quantity of contributions: Participants contributed significantly more words in the medium- than in the high-incongruity condition: M_{med}=84.00 (*SD*=64.92) vs. M_{high}=11.71 (*SD*=26.09), $t(44)=4.78$, $p<.01$, $d=1.46$. There were also more contributions in the low- than in the high-incongruity condition: M_{low}=89.00 (*SD*=63.38) vs. M_{high}=11.71 (*SD*=26.09), $t(43)=5.21$, $p<.01$, $d=1.59$. Figure 4 shows the quantity of contribution in the three conditions.

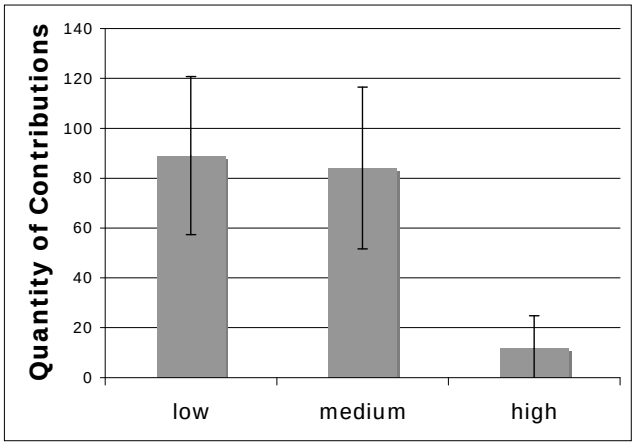

Figure 4: Quantity of contribution in the three conditions

Quality of contributions: In the medium-incongruity condition, the quality of contributions was significantly higher than in the low-incongruity condition: M_{med}=2.04 (*SD*=1.79) vs. M_{low}=0.58 (*SD*=0.93), $t(47)=3.55$, $p<.01$, $d=1.02$. And it was higher in the medium- than in the high-incongruity condition: M_{med}=2.04 (*SD*=1.79) vs. M_{high}=0.29 (*SD*=0.46), $t(44)=4.36$, $p<.01$, $d=1.34$. Figure 5 shows the quality of contributions in the three conditions.

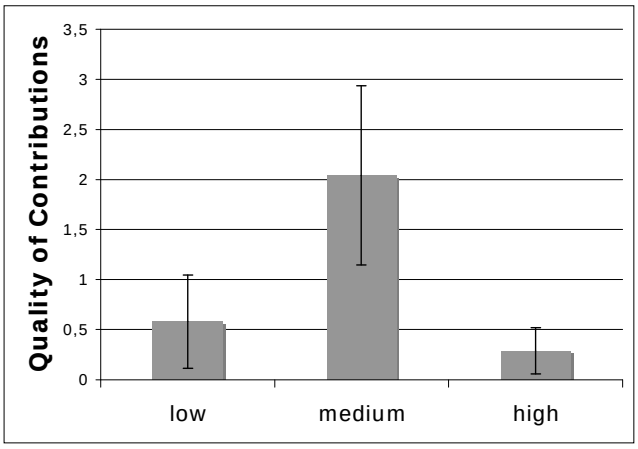

Figure 5: Quality of contributions in the three conditions.

Factual knowledge: In the low-incongruity condition, the participants acquire more factual knowledge than in the medium-incongruity condition: M_{low}=14.72 (*SD*=2.01) vs. M_{med}=13.68 (*SD*=2.34), $t(48)=1.69$, $p=.05$, $d=0.48$. And participants in the medium-incongruity condition also acquire more factual knowledge in the medium than participants in the high-incongruity condition: M_{high}=11.82 (*SD*=3.17) vs. M_{med}=13.68 (*SD*=2.34), $t(45)=2.31$, $p=.01$, $d=0.67$.

Conceptual knowledge: Participants acquire more conceptual knowledge in the medium- than in the high-incongruity condition: M_{high}=1.05 (*SD*=0.58) vs. M_{med}=1.48 (*SD*=0.82), $t(45)=2.07$, $p=.02$, $d=0.61$. There is only a marginal significant difference between the medium- and the low-incongruity condition: M_{low}=1.20 (*SD*=0.65) vs. M_{med}=1.48 (*SD*=0.82), $t(48)=1.34$, $p=.09$, $d=0.38$.

4.5 Discussion

As expected, the quantity of contributions was smaller with high incongruity than with medium and low incongruity. The quality of contributions is higher in the medium-incongruity condition than in the low- and the high-incongruity condition. Low incongruity between people's knowledge and wiki information led to a higher increase of factual knowledge than medium incongruity. Medium incongruity led to higher increase of factual knowledge than high incongruity.

And participants in this condition acquired more conceptual knowledge than participants in the high-incongruity condition. The expected difference between the medium- and the low-incongruity condition is only marginally significant.

In Study 1 and 2 there was some intermixture between two aspects of incongruity. In the medium-incongruity condition in Study 1, the wiki contained one-sided information and the participants possessed some prior knowledge that partly contradicted the information in the wiki. And in the medium-incongruity condition in Study 2 they possessed one-sided prior knowledge and had to deal with partially new and contradictory information in the wiki. So, incongruity may refer to the quantity of identical information (which we will refer to as "redundancy")

or to the allocation of information to different content-related concepts (referred to as "dispersity").

Study 3, then, tried to keep these two aspects – number of redundant arguments and the tendency of these arguments (biological or social) – apart. So, using the medium-incongruity conditions of the previous studies as a starting point, we manipulated redundancy and kept dispersity constant in Study 3: in each condition, the wiki contained information that was contrary to the participants' prior knowledge. In addition to this contradictory information, the wiki contained either no, two, or four arguments that were in line with the participants' prior knowledge.

5. Study 3

5.1 Hypotheses

It is expected that people will contribute more words in the low redundancy condition than in the medium- and the low-redundancy condition (*Hypothesis 9*), corresponding to the information that is still missing in the wiki. The quality of contribution will be higher in the medium-redundancy condition than in the other conditions (*Hypothesis 10*). The acquisition of factual knowledge (*Hypothesis 11*) and the acquisition of conceptual knowledge (*Hypothesis 12*) will be higher in the medium-redundancy condition than in the low- and the high-redundancy condition.

5.2 Participants

This study was carried out with 82 participants. 57 of these were women, 21 men (and four people with undisclosed gender). Their mean age was 24.92 years (*SD*=5.42). The participants were randomly assigned to one of the three experimental conditions. 29 participants were assigned to the high-, 26 to the medium-, and 27 to the low-redundancy condition.

5.3 Experimental Design

The experiment represented a 1x3 factorial design with redundancy (low vs. medium vs. high) as between-factor. In the low-redundancy condition, the wiki contained four arguments that contradicted the participants' prior knowledge (if a participant had previously been made familiar with four biological arguments, the wiki contained four social arguments, and vice versa). In the medium-redundancy condition the wiki contained four contrary and two consistent arguments, and in the high-redundancy condition the wiki contained all arguments (four contrary and four consistent).

The amount of prior knowledge was kept constant in all conditions (four social or four biological arguments). In order to take into account potential qualitative differences between social and biological explanations, we provided varying versions in each condition, i.e. the configuration of arguments was permuted. Figure 6 shows examples of the three experimental conditions with different degrees of redundancy.

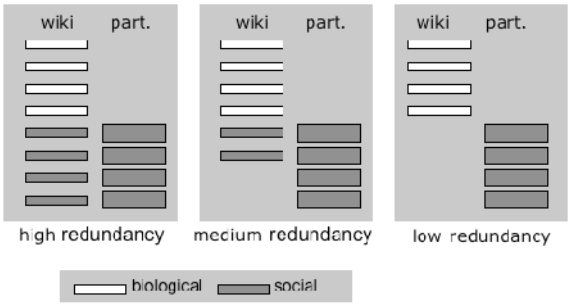

Figure 6: Three experimental conditions varying redundancy in Study 3.

As dependent variables we measured, again, quantity and quality of people's contributions to the wiki (i.e. their externalization of prior knowledge) and the acquisition of factual and of conceptual knowledge.

5.4 Results

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

Quantity of contributions: In the low-redundancy condition, participants wrote significantly more words than in the medium-redundancy condition: M_{low}=176.93 (*SD*=129.61) vs. M_{med}=72.38 (*SD*=59.77), t(36.88)=3.75, p<.01, d=1.04. And they wrote significantly more words than in the high-redundancy condition: M_{low}=176.93 (*SD*=129.61) vs. M_{high}=77.14 (*SD*=83.81), t(45)=3,45, p<.01, d=0.91. Figure 7 shows the quantity of contributions in the three conditions.

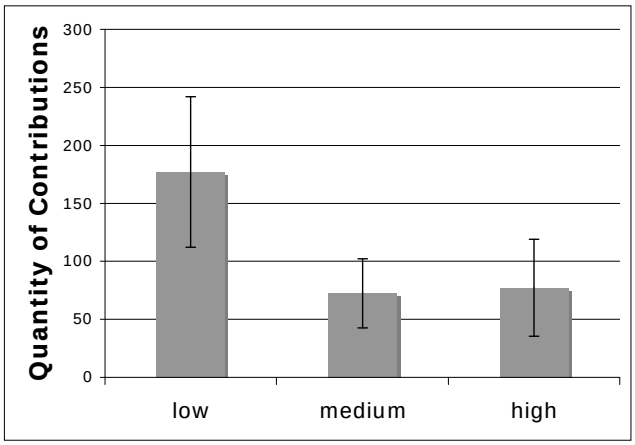

Figure 7: Quantity of contributions in the three conditions of study 3.

Quality of contributions: In the medium-redundancy condition the quality of contributions was higher than in the high-redundancy condition: M_{med}=3.28 (*SD*=1.79) vs. M_{high}=1.44 (*SD*=1.45), t(50)=4.08, p<.01, d=1.13. And it was higher in the medium- than in the low-redundancy condition: M_{med}=3.28 (*SD*=1.79) vs. M_{low}=1.04 (*SD*=1.12), t(50)=5,45, p<.01, d=1.50. Figure 8 shows the quality of contributions in the three conditions.

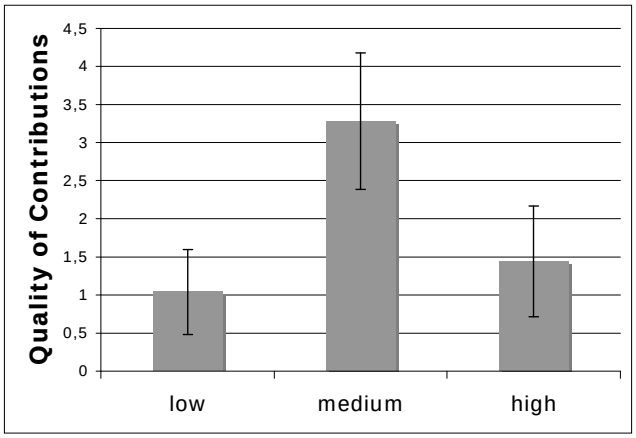

Figure 8: Quality of contributions in the three conditions of study 3

Factual knowledge in the medium-redundancy condition was higher than in the high-redundancy condition: M_{high}=11.52 (*SD*=3.30) vs. M_{med}=13.03 (*SD*=2.32), $t(53)=1.95$, $p=.03$, $d=0.52$. There was no significant difference between the medium- and the low-redundancy condition: M_{med}=13.03 (*SD*=2.32) vs. M_{low}=13.30 (*SD*=2.58).

Conceptual knowledge: There were no significant differences between the three conditions: M_{low}=1.81 (*SD*=0.96) vs. M_{med}=1.57 (0.84) vs. M_{high}=1.69 (*SD*=0.86).

5.5 Discussion

As expected, Study 3 shows that medium redundancy leads to better contributions to the wiki, the quantity of contributions depends simply on the extent to which the provided wiki was complete. If there were no shared arguments beforehand (low redundancy), participants could not link their prior knowledge to the external source. Factual knowledge was higher in the medium- than in the low-redundancy condition. But there are no other differences between the conditions for factual knowledge and conceptual knowledge.

6. General Discussion

The results of Study 1 and Study 2 clearly show a higher quality of contributions and acquisition of more conceptual knowledge in a state of medium incongruity between prior knowledge and external information than with low and high incongruity. Incongruity on a medium level seems to be beneficial for the quality of both the externalization of one's own knowledge and the acquisition of new knowledge.

The quantity of contributions simply depends on the amount of prior knowledge and the completeness of the wiki. If the wiki contains all relevant points, participants can complete the task by writing fewer words than if the wiki has left out some important arguments (Study 1). If participants had no prior knowledge, they could contribute less to the wiki than in a situation when they had four or eight argument as prior knowledge (Study 2). The acquisition of factual knowledge depends on the experimental operationalization of incongruity. If the prior knowledge of the participants is the same in all conditions, then medium incongruity leads to more factual knowledge at the end of the experiment (Study 1). If participants start with differential prior knowledge at the beginning, and the content of the wiki is constant in all conditions, these differences of prior knowledge remain constant during the experiment (Study 2).

In Study 3 we could show that redundancy (as one aspect of incongruity) only had an influence of the quantity and quality of contributions. The results for the acquisition of factual and conceptual knowledge are ambiguous. We might conclude that dispersity – as one aspect of incongruity – has a stronger impact on processes of learning, while redundancy has a stronger influence on externalization. So, in a follow-up study we will keep redundancy at level zero in all three experimental conditions. Variation will only concern dispersity.

In addition, we will focus on the relevance of the topic of the wiki (the learning domain) to the individuals involved. When individual relevance is high, incongruity is expected to have a greater influence on learning than in the case of low relevance. Another important factor is the significance and validity of the wiki. If participants perceive the wiki as the work of experts or other authorities this will probably influence the interplay between an individual's prior knowledge and the information that is available from an external source.

Regarding our propositions at the beginning of the paper, the results of the present studies have demonstrated, in our view, that the model of co-evolution does indeed have a great impact on understanding learning "the wiki way". It is necessary to consider both sides – processes in a shared digital artifact, indicating knowledge building in a community, and the cognitive processes of individuals, indicating their individual learning. Our experiments are one possible method to investigate these processes: by transferring them into an artificial (laboratory) setting where we can try to control all confounding variables.

The experiments which were presented here are, so to speak, one piece of the puzzle: It highlights the aspect of *incongruity* between people's knowledge and the information in the wiki as relevant condition for knowledge building and learning. Other aspects, like the devolvement of the wiki and the community of authors over time (e.g. [8]), the role of the wiki's audience for learning (e.g. [5], [7]) or the wiki as tool for constructing text [6], to name only a few, will have to be considered as well. Here, the model of co-evolution provides a framework for further research.

Keeping the two separate processes of knowledge building and individual learning in mind, it is obvious that a variety of multiple methods and disciplines will be needed to really understand learning the wiki way.

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