Collaborative Knowledge Building with Wikis: The Impact of Redundancy and Polarity

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Abstract

Wikis as shared digital artifacts may enable users to participate in processes of knowledge building. To what extent and with which quality knowledge building can take place is assumed to depend on the interrelation between people’s prior knowledge and the information available in a wiki. In two experimental studies we examined the impact on learning and knowledge building of the redundancy (Study 1) and polarity (Study 2) between participants’ prior knowledge and information available in the wiki. Based on the co-evolution model of cognitive and social systems, external assimilation and accommodation were used as dependent variables to measure knowledge building. The results supported the hypotheses that a medium level of redundancy and a high level of polarity foster external accommodation processes. External assimilation was stimulated by low redundancy and a high level of polarity. Moreover, we found that individual learning was influenced by the degree of external assimilation.

Keywords: Cooperative/collaborative learning; Interactive learning environments; Teaching/learning strategies
Collaborative Knowledge Building with Wikis: The Impact of Redundancy and Polarity

1. Introduction

Recently, the online encyclopedia *Wikipedia* celebrated its tenth anniversary as a provider of knowledge on a myriad of topics (Kubiszewksi, Noordewier, & Constanza, 2011). Countless volunteers work together, share their knowledge within the community of *Wikipedians* and create millions of entries in different languages. The Wikipedia is a popular example of how social software changed the relations between producers and users of information, writers and readers, experts and novices, teachers and students. Wikis, the underlying technology, are collections of web-sites that cannot only be read, but also edited by every user (Leuf & Cunningham, 2001; Moskaliuk & Kimmerle, 2009). Users can generate content (insert, change, delete text) and they can link it to other related texts with the help of hyperlinks.

The transformation of the web to a social web was assumed to have an impact on how people work with information in general (cf. Kolbitsch & Maurer, 2006). The use of wikis (Cole, 2009; Shih, Tseng, & Yang, 2008), blogs (Chong, 2010; Deng & Yuen, 2011; Kim, 2008), social networking sites (Mazman & Usluel, 2010) and other social software tools influences methods of learning in schools, universities, companies and organizations, and in informal learning settings (Forte & Bruckman, 2006, 2010). In the age of social software and online collaboration (cf. Tsai, 2010) learning can no more be described as an individual process of mere internalization of information. Externalization of one’s own knowledge into a shared digital artifact is also important in this context and enhances the mutual development of knowledge (Köhler & Fuchs-Kittowski, 2005).
The wiki technology enables users to become an active part of a knowledge-building community by sharing their own knowledge with others (cf. Conole & Culver, 2010; Trentin, 2009). ‘Learning the wiki way’ (Kimmerle, Moskaliuk, & Cress, 2009) takes place during the process of writing and adding one’s own knowledge to existing information. Others can take up this information, integrate it into their own store of knowledge and add new information again. This collaboration with other learners leads to individual learning, and at the same time the knowledge of a learning community develops. This is on the one hand an effect resulting from self-explanation (Atkinson, Renkl, & Merrill, 2003; Chi, Bassok, Lewis, Reimann, & Glaser, 1989): collaboration with other learners requires explaining one’s own knowledge, which leads in turn to deeper elaboration, better understanding and the development of individual knowledge.

On the other hand, the collaboration also results in emergent learning processes (Kimmerle, Moskaliuk, Cress, & Thiel, 2011). The externalization of one’s own knowledge and the integration of prior knowledge into the information presented enable both processes of collaborative knowledge exploration (Lee & Tsai, 2011) and also processes of knowledge building within a community. Scardamalia and Bereiter (2003; 2006) describe knowledge building as a socio-cultural process that takes place within a community and 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; cf. also Schrire, 2006; So, Seah, & Toh-Heng, 2010; Van Aalst & Chan, 2007). Individual learning is, so to speak, only a by-product of this constructive process of collective knowledge building. This idea highlights the relevance of externalization for collaboration within a community as well as for individual learning. If learning is understood not only as an internalization process, it is also relevant to examine which
factors influence and foster the externalization of individual knowledge into a shared digital artifact.

Wikis are well-suited tools to support this process of learning through externalization (cf. Bocconi & Trentin, 2011). We argue for two mechanisms for successful externalization of individual knowledge into a shared wiki text.

1.) Users try to find connection points between what they know and information in the wiki. If there is no redundancy between their own knowledge and information in the wiki, it is difficult for users to find a way to externalize their own knowledge. If their own knowledge and information in the wiki are too redundant, there is no need to add their own knowledge. Thus it appears that redundancy on a medium level should provide an optimal condition to connect one’s own knowledge to existing information.

2.) Users are motivated to externalize their own knowledge, if they perceive a polarity between their own knowledge and information in the wiki. This polarity is supposed to activate users to add their own knowledge into the wiki, because in such a situation they consider their own knowledge to be relevant for the community, thinking it would lead to a more balanced and unbiased presentation of arguments.

This reasoning is in line with the co-evolution model (Cress & Kimmerle, 2007, 2008) that describes the incongruity (cf. Hunt, 1963) between individual knowledge and information in a wiki as a catalyst for learning and knowledge building. In our considerations, however, we will go more deeply into the concept of ‘incongruity’ by differentiating between two aspects: the redundancy and the polarity of individual knowledge and information in a wiki.
The following subsections will introduce the co-evolution model as a framework for describing learning and knowledge building with wikis by addressing the interplay between internalization and externalization processes (subsection 1.1). We will then discuss the impact of incongruity on learning and knowledge building (subsection 1.2) and explain our distinction between redundancy and polarity (subsection 1.3). Subsequently, we will present the method that was applied (section 2) and the results of two experimental studies that examined the impact of redundancy (Study 1, section 3) and the impact of polarity (Study 2, section 4) on the externalization of individual knowledge into a wiki. Concluding, we will discuss the implications of our findings (section 5).

1.1 Co-evolution of individual and collective knowledge

The co-evolution model of cognitive and social systems (Cress & Kimmerle; 2007, 2008; Kimmerle, Cress, & Held, 2010) describes the interplay between the externalization of one’s own knowledge into a shared digital artifact (i.e., knowledge building) and the internalization of information from an artifact (i.e., individual learning). The model focuses on wikis as collaboration tools that support the mutual development of individual knowledge and information available in the text (representing the knowledge of the involved community). The co-evolution model posits learning as an active construction of knowledge. People’s individual learning processes are mutually influenced if people exchange their knowledge using shared digital artifacts (cf. also Kafai, 2005; Scardamalia and Bereiter, 1994). A wiki, as a shared digital artifact, is well suited for encouraging and supporting a kind of mutual use and development of knowledge (cf. also Bruckman, 2006; Norman, 1991). The co-evolution model explicitly addresses internalization and externalization as two relevant processes. Externalization is the
activity by which people introduce their own knowledge into the shared digital artifact. On the one hand externalization leads to the development of artifacts (texts, documents, etc.); on the other hand it can induce individual learning, because this externalization process may activate a deeper elaboration of knowledge. Internalization is an activity by which people take in information from the shared digital artifact. This may expand a person’s individual knowledge and lead to learning. Thus, externalization and internalization describe how knowledge and information are interchanged between an individual and a shared digital artifact.

Applying Piaget’s (1977) ideas, Cress and Kimmerle (2008) specified the processes of externalization and internalization in more detail. According to Piaget, individual learning can occur as assimilation or accommodation—people may either assimilate information which is new to any prior knowledge, or they may modify some existing knowledge to accommodate new insights. The co-evolution model transfers this distinction to the process of externalization. *External assimilation* occurs when information is introduced into a wiki without being connected to previously existing information. In this process, the wiki text becomes longer, but its organization remains unchanged, and from the perspective of the wiki, it merely assimilates this new information. But a wiki may also accommodate. Such *external accommodation* takes place when information in the wiki is re-arranged by rewriting paragraphs, re-organizing pages, or integrating new and existing information which modify, improve or correct the wiki text (cf. also Majchrzak, Wagner, & Yates, 2006). Figure 1 summarizes the theoretical assumptions of the co-evolution model.

--Insert Figure 1 about here--
1.2 Incongruity as a trigger for externalization

Following our reasoning—that successful externalization of individual knowledge into a shared digital artifact is a crucial part of collaborative learning—we have to focus on triggers for this externalization. Cress and Kimmerle (2008) discuss the incongruity between an individual’s prior knowledge and information in the wiki as key factor to incite externalization. Incongruity causes an individual to want to resolve the resulting cognitive conflict (cf. Piaget, 1977) either by individual learning, or by externalizing own knowledge into the shared wiki—which, in turn, is the basis for knowledge building within a community.

Research on *conceptual change* often describes learning and development as a continual process of adjusting and changing existing conceptions (for an overview of the role of conceptual change in educational settings cf. Vosniadou, 2007a). The fundamental conditions for conceptual change are dissatisfaction with an existing conception, and intelligible, plausible new conceptions (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992; cf. also Lee, 2010a; Trundle & Bell, 2010). Thus, comparing learners with scientists, learning could be described as adapting existing concepts to new information. As a result, conceptual change is not only a cognitive process, but is also influenced by situational and socio-cultural factors (Vosniadou, 2007b). This leads to the idea of knowledge building as a platform for conceptual change (Lee, 2010b) and highlights the relevance of externalization. Individuals have to externalize their own concepts and ideas to enable the other members of the community to experience cognitive conflicts. So the externalization of one’s own knowledge and the resulting cognitive conflicts between an individual’s knowledge and a community’s knowledge are precious factors in understanding human development. From an educational perspective it is of
great interest not only to know *that* cognitive conflicts can trigger learning and knowledge building, but to understand *how* the incongruity should be designed to trigger externalization.

1.3 Two aspects of incongruity

The co-evolution model hypothesized that it is particularly a medium level of incongruity between knowledge and information that makes individuals externalize their own knowledge and connect it to the information available in the wiki. Previous experiments (Kimmerle, Moskaliuk, & Cress, *in press*; Moskaliuk, Kimmerle, & Cress, 2009) have supported this hypothesis. We argue, however, that the medium incongruity in these experiments consisted of two confounded aspects: the *redundancy* of the information in the wiki with respect to what the individual already knows, and the *polarity* of the ideas contained in the knowledge and the information.

The conditions with medium incongruity in these previous studies provided content with 50 percent redundancy between individual knowledge and information in the wiki. We argue that a medium level of redundancy encourages participants to externalize individual knowledge into the wiki. If there is no redundant content, participants will not be able to find a point of contact for connecting their own knowledge to the information in the wiki. In this case, participants would have to write down their own prior knowledge without any connection to the existing text, and they would not be likely to do so. In a situation in which there is only redundant content, in contrast, participants will perceive no need either to add their own prior knowledge or to integrate it with existing information.

Moreover, the conditions with medium incongruity in the previous studies consisted of a high polarity of individual arguments and arguments within the wiki. We assume that such a high polarity motivates users to revise information that contradicts their own knowledge and fosters
the integration of their own prior knowledge with information available in the wiki. Our reasoning refines the assumption that medium incongruity will lead to individual learning and collaborative knowledge building: we will elaborate on ‘redundancy’ and ‘polarity’ as two separate aspects of incongruity. With this approach the aim is to override the confounding of redundancy and polarity in the studies by Moskaliuk et al. (2009) and Kimmerle et al. (in press) and to consider independently from each other their impact on the externalization of knowledge.

Therefore we conducted two experimental studies. In Study 1, we held constant the polarity of content between prior knowledge and information in the wiki and manipulated the amount of redundancy. In Study 2, in contrast, we held constant the level of redundancy and manipulated the polarity of content between prior knowledge and information in the wiki.

2. General method

2.1 Overview

The two studies presented in this paper examined collaborative knowledge building and focused on the process of externalization. Our methods were based on the studies of Moskaliuk et al. (2009) and Kimmerle et al. (in press) and aimed at disentangling the two confounded aspects of incongruity. Study 1 examined the impact of redundancy on external assimilation, external accommodation, and individual learning, and compared three conditions (low vs. medium vs. high redundancy). Study 2 examined the impact of polarity on external assimilation, external accommodation, and individual learning, and compared two conditions (low vs. high polarity). Figure 1 shows the experimental conditions of the two studies and the distribution of
arguments among participants (“part.”) and wiki. The bright and dark boxes represent the contradicting arguments (see also below).

--Insert Figure 2 about here--

2.2. Material

The topic which participants had to deal with was the mental disorder *schizophrenia*. Based on two different explanations for the causes of schizophrenia (biological predisposition vs. social influences) we built contradicting pieces of arguments. Four arguments presented biological (e.g., genetic) explanations as causes of schizophrenia, while the other four arguments presented social explanations (e.g., psycho-social stress) as causes of schizophrenia. These arguments were used to build a text about the causes of schizophrenia that was provided as one website of our experimental wiki.

In order to provide participants with prior information of the topic, they were given short texts in the style of popular science newsletters. Each text contained one argument and was complemented by additional information that was irrelevant for the significance of the argument (e.g., information about the scientist who had made a certain statement or an example to illustrate it). Each text consisted of about 170 words. The participants could use all texts during their work with the wiki. So the experimental situation was comparable to a real wiki setting where people may read other sources about the relevant knowledge domain, extract relevant information, give it a structure, and use what they know to edit a wiki article.

2.3 Measurements
In order to measure external accommodation, we examined all the edits in the wiki by a log-file analysis. We compared the version on the page with which a participant had started and the last version of the wiki at the end of the experiment. We adopted the accommodation index of Moskaliuk et al. (2009). Two independent raters evaluated the amount of external accommodation for each sentence and built the mean score of both ratings. The inter-rater reliability for the accommodation index between the two independent raters measuring external accommodation for Study 1 was $r = .85, p < .01$, for Study 2 the inter-rater reliability was $r = .88, p < .01$.

As an indicator for external assimilation we measured the number of words that each participant had contributed.

Individual learning during the work with the wiki was measured with a post-experimental knowledge test. This test was based on the questionnaire of Moskaliuk et al. (2009) and comprised 16 statements about the causes of schizophrenia (e.g., “The double bind hypothesis is an empirically sound theory about the causes of schizophrenia”). The participants had to decide whether a statement was correct or not. They could also choose an ‘I don’t know’ option. In measuring the number of correct responses the ‘I don’t know’ option was counted as a wrong answer in order to reduce the probability of guessing the right answer.

All these dependent variables were measured after the participants had completed their work on the wiki. In addition, we measured as a control variable the participants’ prior knowledge about schizophrenia. We asked the participant to self-report on a 4-point scale ranging from no prior knowledge to much prior knowledge how much prior knowledge on the topic “causes of schizophrenia” they had before the experiment.
2.4 Procedure

The experiments were conducted in small groups. Completely going through each of the experiments took participants about two hours. The wiki was introduced to them as a real wiki about Clinical Psychology, currently under development in order to inform patients, relatives and other interested people about mental disorders. The participants were made to believe that others who participated in the experiment at the same time had to deal with another topic of the wiki (e.g., on paranoia, depression, etc.). In actual fact, each participant worked with a simulated wiki about the causes of schizophrenia. We instructed the participants to “complement or improve the wiki-text” and formulated as goal of the wiki “to provide interested readers a short overview about the relevant information”. All participants within an experimental condition started to work with the same initial wiki. The initial wikis differed only between the experimental conditions. The participants could not see the others’ monitors. All instructions and a short tutorial which explained the function of the wiki tool were presented on a mobile computer. The post-experimental questionnaire that measured individual learning was also presented on the computer screen. The experimenter only welcomed the participants briefly and, at the end of the experiment, made a debriefing about the aims of the study. The three conditions were assigned by chance by the experimental software.

3. Study 1

Study 1 examined the impact of redundancy on the externalization of individual knowledge. We postulated that redundancy on a medium level would support participants to connect their own knowledge to the existing wiki text which is supposed to lead to more external accommodation.
3.1 Method

3.1.1 Design

We used a 1x3 between-subject design and manipulated the amount of redundant information available in the wiki (low, medium, and high). The polarity of prior information and information in the wiki was the same in all conditions: there were always four ‘counter-arguments’ presented in the wiki (see Figure 1). The prior information the participants got before they worked with the wiki was held constant. Whether the participants received the four ‘biological’ or the four ‘social’ arguments was randomly assigned. Which two of the four ‘counter-arguments’ were presented in the wiki in the medium-redundancy condition was equally permuted across participants. As dependent variables we measured external accommodation, external assimilation and individual learning.

3.1.2 Participants

Experiment 1 was carried out with 81 participants. 57 of these were women, 20 men, and four did not indicate their sex. Their mean age was 21.97 years (SD = 4.63). The participants were randomly assigned to one of the three experimental conditions. 28 participants were assigned to the high-, 26 to the medium-, and 27 to the low-redundancy condition.

3.2 Hypotheses

Hypothesis 1 (H1): Medium redundancy leads to a higher degree of external accommodation than high and low redundancy.
The amount of information in the content of the wiki was supposed to influence how much people were able to write down. In the condition with low redundancy the wiki contained four arguments, in the condition with medium redundancy six arguments, and in the condition with high redundancy eight arguments (cf. left hand side of Figure 1). Therefore, we stated the following hypothesis:

H2: There is more external assimilation in the low- than in the medium-redundancy condition and there is more external assimilation in the medium- than in the high-redundancy condition.

Individual learning, in turn, was assumed to depend on how much people write—as the externalization of own knowledge is supposed to foster a deeper elaboration of the arguments. This should lead to better scores in the post-experimental knowledge test. Therefore, we stated the following hypothesis:

H3: There is more individual learning in the low- than in the medium-redundancy condition and there is more individual learning in the medium- than in the high-redundancy condition.

3.3 Results

The analytic procedure for H1 followed the suggestions made by Niedenthal, Brauer, Robin, and Innes-Ker (2002, see also Abelson & Prentice, 1997). This hypothesis corresponds to the contrast A (-1 2 -1, for low, medium, and high redundancy), meaning that we expected more external accommodation in the medium-redundancy condition than in the low- and the high-redundancy condition. Given that there were three experimental groups, one additional orthogonal contrast captured the residual systematic variance between the groups (B: -1 0 1). A
result was considered consistent with the theoretical predictions when the following two conditions were satisfied: (1) contrast A was statistically significant, and (2) contrast B was not statistically significant. The second condition was meant to test whether there was any difference between the other two conditions (because they were expected to be equal). Both contrasts were entered into a multiple regression analysis.

H1 was supported by the results: a multiple regression analysis in which external accommodation was regressed on both contrasts revealed that contrast A was statistically significant, $F(1, 81) = 20.61, p < .01, R^2_{\text{change}} = .24$. In contrast, the other conditions did not significantly differ among each other, $F(1, 81) = 0.03, p = .86, R^2_{\text{change}} < .01$. As expected, there was more external accommodation in the medium-redundancy condition ($M_{\text{med}} = 3.07, SD = 1.66$) than in the low- ($M_{\text{low}} = 1.34, SD = 1.29$) and the high-redundancy condition ($M_{\text{high}} = 1.45, SD = 1.22$). This result is shown in Figure 2.

H2 was supported only partially by the results. The test of the main effect of redundancy on external assimilation was statistically significant: $F(2,81) = 11.31, p < .01, \eta^2 = .25$. Post-hoc tests (Scheffé) showed differences between low ($M_{\text{low}} = 193.82, SD = 130.13$) and medium redundancy ($M_{\text{med}} = 76.43, SD = 61.00$) and between low and high redundancy ($M_{\text{high}} = 77.92, SD = 84.16$). There was, however, no significant difference between medium and high redundancy.

H3 was not supported by the results. There was no significant main effect of redundancy on individual learning: $F(2,81) = 1.84, p = .17, \eta^2 = .05$. We argued that the externalization of the participants’ own knowledge would lead to a deeper elaboration and expected that participants who contributed more words to the wiki would acquire more knowledge. One reason
that our manipulation did not elicit effects on individual learning could be that external assimilation and accommodation have influenced each other: even if the use of a higher number of written words in the condition with low redundancy led to more learning, the higher amount of external accommodation in the condition with medium redundancy had probably overlaid this effect. This might have inhibited the direct influence of redundancy and could explain the missing effects of redundancy on individual learning. Our post-hoc analysis supported this line of argument: external assimilation significantly predicted individual learning, $\beta = .34$, $t(81) = 2.38$, $p < .05$. External assimilation also explained a significant proportion of variance in individual learning, $R^2 = .08$, $F(1, 81) = 5.66$, $p < .01$.

3.4 Discussion

The central result of Study 1 was that a medium level of redundancy did indeed lead to a higher degree of external accommodation than high and low redundancy. The medium redundancy supported participants in connecting their own prior knowledge to the information available in the wiki. Moreover, we found that the amount of text contained in the wiki influenced how much participants contributed to the wiki (external assimilation): the less ‘complete’ the wiki (i.e., the less arguments it contained overall), the more external assimilation there was as a result. Finally, we found that external assimilation was a significant predictor for individual learning.

This study highlighted redundancy separately as one aspect of incongruity. Redundant arguments acted as connectors between prior knowledge and information available in a wiki. This redundancy is considered as one crucial cause of the results of the studies by Moskaliuk et
al. (2009) and Kimmerle et al. (in press) in which medium incongruity supported knowledge building and individual learning more than low or high incongruity.

The second aspect of incongruity to be analyzed separately was the polarity of the arguments. As explained above, we assumed that it was the high polarity of biological and social arguments in the condition with medium incongruity in the previous studies that activated participants to add contradicting information and integrate it into a balanced text. We examined this aspect in Study 2.

4. Study 2

Study 2 examined the impact of polarity on the externalization of individual knowledge. We postulated that polarity would incite participants to contribute their own knowledge and add their own contradicting arguments in order to reach a balanced line of argument within the wiki text.

4.1 Method

4.1.1 Design

We used a two-group between-subject design and manipulated the polarity between participants’ prior knowledge and the information available in the wiki (low vs. high). There were no redundant arguments in either condition. Whether the participants received the four ‘biological’ or the four ‘social’ arguments in the high-polarity condition was randomly assigned. Which two of the four ‘biological’ and ‘social’ arguments respectively were assigned to the wiki and which to the participant was equally permuted across participants in the low-polarity
condition. Again, as dependent variable we measured external accommodation, external assimilation and individual learning.

4.1.2 Participants

Experiment 2 was carried out with 50 participants. 37 of these were women, 13 men. Their mean age was 24.52 years \((SD = 3.70)\). As in study 1 we asked the participant to self-report how much prior knowledge on the topic “causes of schizophrenia” they had before the experiment. Three participants were excluded from further analysis because they indicated that they had much prior knowledge about schizophrenia. The participants were randomly assigned to one of the two experimental conditions. 24 participants were assigned to the low- and 23 to the high-polarity condition.

4.2 Hypotheses

H4: High polarity leads to more external accommodation than low polarity.

In both conditions the wiki contained four arguments (cf. right hand side of Figure 1). So, in contrast to Study 1, the amount of information in the wiki was supposed to have no influence on the number of written words. We assumed, however, that a high level of polarity would make participants write down their own (contradicting) knowledge into the wiki. Participants were supposed to rectify the one-sided presentation in the high-polarity condition by adding their own contradicting prior knowledge. In the low-polarity condition the wiki contained two biological and two social arguments, that is, its arguments were balanced, even if there were some missing arguments. Therefore, we stated the following hypothesis:

H5: There is more external assimilation in the high- than in the low-polarity condition.
Individual learning was supposed to depend on how much people write down. Based on our line of argument regarding the post-hoc analysis in Study 1 we stated the following hypothesis:

H6: Participants who contribute more words to the wiki acquire more knowledge.

4.3 Results

H4 was supported by the results as there was more external accommodation in the condition with high polarity than in a condition with low polarity: $M_{\text{high}} = 2.93$ ($SD = 1.88$) vs. $M_{\text{low}} = 2.07$ (1.68), $t(46) = 1.68, p = .05$ (one-tailed), $d = 0.48$. This result is shown in Figure 3.

--Insert Figure 4 about here--

H5 was supported as there was more external assimilation in the condition with high polarity than in a condition with low polarity: $M_{\text{high}} = 203.75$ ($SD = 116.08$) vs. $M_{\text{low}} = 142.52$ (112.43), $t(46) = 1.84, p < .05$ (one-tailed), $d = 0.54$.

Finally, H6 was supported as well. External assimilation significantly predicted individual learning, $\beta = .31, t(46) = 2.22, p < .05$. External assimilation also explained a significant proportion of variance in individual learning, $R^2 = .10, F(1, 47) = 4.92, p < .05$.

4.4 Discussion

The central result of Study 2 is that a high polarity of arguments led to a higher degree of external accommodation than low polarity. Polarity activated participants to integrate their own prior knowledge into the information available in the wiki in order to reach a balanced line of argument. We could also show that the high polarity led to more external assimilation and that external assimilation predicted individual learning. This study highlighted polarity as the second
relevant aspect of incongruity. Polarity between prior knowledge and information available in a wiki supported knowledge building in both quantitative and qualitative respects.

5. General discussion

Processes of externalizing personal knowledge into shared digital artifacts are of high relevance for both individual learning and knowledge building. In this paper we have argued that online collaborative learning should not merely be described as an internalization process. Therefore we have examined in detail one factor that has in previous studies been shown to have a significant impact on how people externalize knowledge when working with wikis: the incongruity between information within a shared digital artifact and the users’ prior knowledge. In the experiments reported here we have studied two aspects that were ‘intermingled’ in the incongruity concept, that is, redundancy and polarity between information in an artifact and prior knowledge. The aim of these studies was to disentangle these two confounded aspects of incongruity and to show their impact on learning and knowledge building independently from each other.

We examined these two aspects of incongruity in two studies under laboratory conditions. In the first experiment we manipulated redundancy while we held constant the polarity between information available in the wiki and participants’ prior knowledge; in the second experiment we manipulated polarity while we held constant redundancy. Our results suggest an explanation for why medium incongruity in the previous studies by Moskaliuk et al. (2009) and Kimmerle et al. (in press) was well suited for individual learning and collaborative knowledge building. A certain degree of redundancy supports users in finding connecting points between prior knowledge and information available in a wiki, helps them to validate their own
knowledge, and fosters the integration of arguments. A high level of polarity activates people to add their own arguments in order to reach a balanced text.

These findings are not only relevant from a theoretical point of view, in terms of a conceptual and empirical differentiation of the incongruity concept (cf. Hunt, 1963; Schaffer, 1966). They are also relevant from an applied perspective, that is, for example, for the design of knowledge building environments. Other researchers have concluded from their findings with collaborative knowledge building environments that students are “able to improve their initial understanding and to correct misunderstandings by reading, connecting, and questioning ideas in the online environment” (So et al., 2010, p. 488). There are many studies that have examined under which circumstances these processes of understanding and correcting misunderstandings are particularly successful—both for individual and collective knowledge. But the relation between people’s prior knowledge and information in an online environment has hardly been taken into account in this context. When educators want learners to contribute to the development of collective knowledge, however, they need to know which interrelations between people’s prior knowledge and information in a digital artifact are beneficial for that purpose. Our results suggest that a medium level of redundancy combined with a high level of polarity is particularly conducive to better quality in people’s contributions.

Our studies—in their capacity of controlled laboratory experiments—did not take into account, however, all those aspects that also play important roles when it comes to implementing knowledge building in settings outside the laboratory. For instance, what aspects would foster a knowledge building culture (So et al., 2010) which includes students’ willingness and ability to participate in knowledge building processes (cf. Shell, Husman, Turner, Cliffel, Nath, & Sweany, 2005) or includes use of their scientific literacy (Norris & Phillips, 2003).
There are also further aspects of collaborative knowledge building with wikis that could be addressed by using different methods, e.g. the networking analyses, to visualize the evolution of a wiki over time (Kimmerle, Moskaliuk, Harrer & Cress, 2010), or content detection methods, to track the users’ interaction with the wiki as indicator for external accommodation (Moskaliuk, Rath, Devaurs, Weber, Lindstaedt, Kimmerle & Cress, 2011). What our studies did, in contrast, was to take a detailed look at potentially beneficial combinations of information in a digital artifact on the one hand and people’s individual knowledge on the other. Future studies should aim at integrating these aspects and try to examine the impact of redundancy and polarity in elaborate real-life settings of collaborative learning and knowledge building.
References


Figure captions

Figure 1. The Figure summarizes the central ideas of the co-evolution model.

Figure 2. The Figure visualizes the experimental conditions in the two studies and the distribution of information between wiki and participant.

Figure 3. External accommodation depending on the level of redundancy (low vs. medium vs. high)

Figure 4. External accommodation depending on the level of polarity (low vs. high)
Figure 1
Figure 2

**Study 1: redundancy**

- **wiki part.**
  - low
  - medium
  - high

**Study 2: polarity**

- **wiki part.**
  - high
  - low
Figure 3

![Bar chart showing external accommodation vs. redundancy. The chart indicates that medium redundancy has the highest external accommodation, followed by low and high redundancy.](image)
Figure 4