

A Theoretical Framework of Collaborative Knowledge Building with Wikis – a Systemic and Cognitive Perspective

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Abstract: Wikis provide new possibilities for collaborative knowledge building with artifacts. This paper presents a theoretical framework for describing and understanding the processes which lead to collaborative knowledge building. The model borrows from the systemic approach of Luhmann as well as from Piaget's theory of equilibration. It describes people's learning activities as processes of externalization and internalization. Individual learning happens through internal processes of assimilation and accommodation, whereas changes in a wiki's information space are due to activities of external assimilation and external accommodation. All these equilibration activities are caused by subjectively perceived differences between an individuals' knowledge space and the wiki's information space. Differences of medium level are considered to cause cognitive conflicts which activate the described processes of equilibration.

Computer-Supported Knowledge Building with Wikis

Recently, a variety of new tools fostering computer-supported collaborative learning (CSCL) and computer-supported cooperative working (CSCW) appeared and established themselves on the WWW. On the one hand, the term Web 2.0 describes a set of new interactive technologies and services on the internet. On the other hand, Web 2.0 refers to a modified utilization of the internet. What is of particular importance in the web 2.0 context for CSCL researchers is the integration of so-called social software (Kolbitsch & Maurer, 2006). Social software refers to systems which facilitate human communication, interaction, and collaboration. These systems support the constitution and maintenance of self-organizing social networks and communities. Weblogs (blogs), file-sharing communities, and especially wikis loom large in this social-software context. Blogs are websites which are used as online diaries. They contain new entries periodically. Usually, blogs are produced by a single author or by a small group of users. But they are open to the public for reading (Blood, 2002; Maurer & Tochtermann, 2002). File-sharing web pages provide private spaces where users can store their documents and a public space where files can be shared with other users. Popular examples of file-sharing communities are services like flickr (a photo sharing website), or youtube (a video sharing website) (Rodriguez, Tan, & Gkantsidis, 2005).

Whereas blogs and file-sharing systems are mainly used for pooling information, wikis have special potential for computer-supported collaborative knowledge building. Wikis are web sites which allow users not only to have access to its content but also to change the content online (Leuf & Cunningham, 2001). Wikis are mostly used to write texts. Their special feature is that people can do all kinds of revision of the text: they can create hyperlinks and fill them with text, they can revise texts by adding, deleting or changing any text parts they want to. This way, large groups of like-minded people are able to work collaboratively on one and the same text about a certain topic. In wikis all users collaboratively create one hypertext. An example which illustrates the potency of wikis is the online encyclopedia Wikipedia. Here, users mutually develop the world's largest encyclopedia. Every internet user is allowed to take part in this undertaking. The Wikipedia example will be applied throughout the whole article in order to make our theoretical analysis more concrete. In a wiki people work mutually on one common artifact (cf. Stahl, 2002 for the relevance of artifacts in CSCL). And a multitude of people around the world are able to participate in this process anywhere, anytime. In this article we will ask what makes wikis especially attractive for learning purposes and knowledge building. To examine this question, we will consider several fundamental perspectives on learning and knowledge building. We presuppose that a person's individual knowledge is a resource for other peoples' learning (Kafai, 2006; Scardamalia & Bereiter, 1994). We base our arguments on findings as to how people make use of each others' knowledge through collaborative knowledge building with artifacts (cf. Bruckman, 2006). We rely on Papert's approach of

constructionism (e.g. Papert, 1980, 1987, 1993, 1997; cf. also Kafai, 2006) and point out that our perspective is grounded in a tradition that emphasizes the learner's activity in the learning process (cf. Greeno, 2006)

In the remainder of this article we will present our model of collaborative knowledge building with wikis by taking a systemic perspective and by distinguishing between the processes of externalization and internalization. We will clarify these processes by continuously applying the Wikipedia example to our model. We will then describe the four processes of knowledge building that result from the distinction between external and internal (cognitive) processes on the one hand and between assimilation and accommodation on the other hand. Finally, we will describe the motivational aspects of collaborative knowledge building. We are aware that, in the strict sense, the motivational aspects are the foundation of the processes of knowledge building. The cognitive and socio-cognitive processes cannot be separated from the motivational ones. However, we decided to present our model in an order which would make clear that the cognitive and socio-cognitive processes can help to explain the motivational processes.

A Model of Collaborative Knowledge Building with Wikis

In the model presented here we consider from a systemic point of view the components and the processes necessary for the exchange of knowledge and for collaborative knowledge building with wikis. For this purpose we borrow perspectives from systemic approaches (cf. Luhmann, 1984, 1995, 1997; von Bertalanffy, 1950, 1968). Based on these perspectives, a wiki can be seen as a *social system* which operates through the communication of people sharing information and creating artifacts. We have to make clear here that according to Luhmann, the people themselves are not part of the social system. With respect to a wiki, this is obvious because the wiki and its content exist as an artifact even if all users are absent. *Cognitive systems* operate through cognitive processes like retrieval of knowledge from long-term memory (Baddeley, 1986, 1992), elaboration of knowledge (Craik & Lockhart, 1972), or externalizing and internalizing information. According to Luhmann (1984) it is the social system's border and the difference between system and environment which defines a system. The difference between a system and the environment is determined by the system's way of operating. Thus, clearly delineating the "border" between the social system (the wiki) and cognitive systems (the users) is crucial for understanding how collaborative knowledge building with wikis works.

In this section we will first of all outline the functionality of the social system, then we will address the functionality of the cognitive systems. After that we will describe the processes responsible for transitions between the social system and the people's cognitive systems. Here, we distinguish the process of externalization from the process of internalization.

Social and the Cognitive Systems

According to Luhmann (1995) a social system operates via communication. With respect to Wikipedia the community of users establishes itself through the interaction of its participants who use their knowledge and write encyclopedia articles. The wiki articles comprise the information people share. For example one user might know something about George Washington's childhood and contribute this information to a Wikipedia article about George Washington. Another user might contribute something about Washington's attitude towards slavery and so on. This way, the George Washington article develops out of provided information and becomes more and more complete. The articles are traceable in the internet. There they are accessible for all members of the community. Each member of the community can contribute to an article. On the one hand, she or he can extend or diminish an article by adding or deleting information (e.g. adding references about George Washington). On the other hand a participant can change the artifact's structure by revising an article (e.g. removing biographical information about George Washington at the opening of the article and moving the references to the end). The information which is embedded in the wiki builds the wiki's "information space". It consists of all information units (definitions, descriptions etc.) and relations or links between these units. Information units and relations between them belonging together make the structure of a wiki.

Turning to the cognitive systems, we analogously describe each group members' individual knowledge as his/her individual "knowledge space". This knowledge space contains all the schemas a person possesses (Bartlett, 1932; Piaget, 1970; Schank & Abelson, 1977). A schema is made up of knowledge units and relations

between these units belonging together. For a person contributing to a Wikipedia article about George Washington, knowledge units might be Washington's birthplace, birthday, the name of his mother, and so on. What processes are going on, when people share their knowledge by creating wikis? What happens when people work parallel on one common artifact, thereby building new knowledge collaboratively? Here, two processes are relevant which describe the "crossing of the border" between the social and the cognitive system (a process which Luhmann terms *structural coupling*): we refer to these processes as "externalization" and "internalization" respectively.

Externalization

For contributing to the development of a wiki a person first has to externalize his/her knowledge. He/she does this by writing information down in the wiki which reflects parts of his/her own knowledge space. For it, knowledge units of one's own knowledge space have to be conveyed into a wiki article which maps the person's knowledge. For describing these processes of externalization we refer primarily to an individual's declarative knowledge in her/his memory's semantic system (Tulving, 1985).

This artifact, then, exists independently from the person who created it, and it contains information units which follow from the person's knowledge units. The information units in the wiki's information space relate to the knowledge units of the contributor's individual knowledge space: therefore, the person's cognitive schemas are represented by the wiki's structure. E.g. if a Wikipedia user writes something about George Washington's military career, he/she can only write down something which was in his/her knowledge space before. The person's knowledge about George Washington's military career precedes the information about George Washington's military career in the wiki's information space. In this way, information about the military career is significantly related to the person's knowledge about the career. Of course, the information in the wiki and the knowledge in a person's mind are not identical, but they are equivalent to a certain degree. After the process of externalization, the artifact's information space exists independently from the person's knowledge space.

Contributing to an article does not only allow the creation of an artifact, it can also lead to an individual learning process of the contributor. The mental effort necessary for the externalization of knowledge can extend the person's individual knowledge space, because externalization requires deeper processing and clarification. This aspect is addressed by the work of Flower and Hayes (1980) as well as Webb (1982). So, normally the person who produces a wiki article cannot externalize some of his/her own knowledge units without some changes of his/her own individual knowledge space. Through the externalization process one often deepens one's own knowledge and might even acquire new knowledge which can improve an existing schema. So externalization can lead to individual learning processes, and a contributor to a wiki article can expand his/her individual knowledge space through acquiring new knowledge units which were not part of the individual's knowledge space before. With respect to the Wikipedia article about George Washington one can imagine that a person who writes something about George Washington's military career is forced to restructure her or his own knowledge in order to make it more comprehensible for others. This way some issues become clearer to her-/himself and he/she acquires deeper knowledge and comes to new insights about George Washington's military career.

In Figure 1 this kind of learning is shown by the grey symbols which expand the individual knowledge space K to K' . In this figure each symbol represents another knowledge unit. Each of the three people externalizes knowledge by contributing to the wiki, but only Person 1 and Person 3 acquire new knowledge units by this activity.

If a person has contributed to a wiki, then each individual group member can have access to the wiki's information space. This is shown by the symbols in the wiki's information space in Figure 1. For the time being, this process of externalization does not require the interaction with other people in a narrow sense. A person can externalize her/his own knowledge (and thereby extend one's own knowledge space) without necessarily addressing other people. However, with respect to the process of internalization, which will be described in the next section, a participation of other people is indispensable.

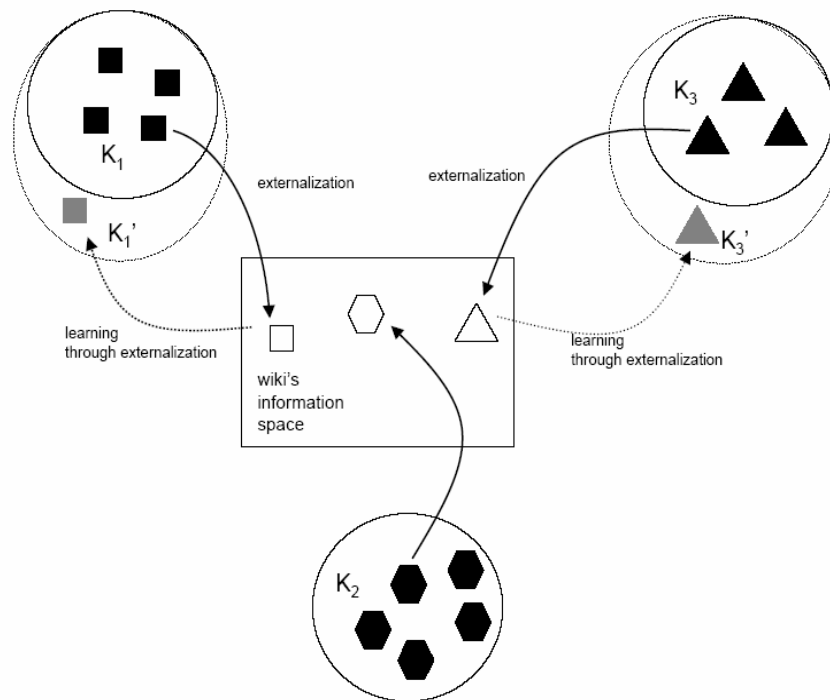


Figure 1: Three people with different individual knowledge spaces K_1 to K_3 interacting with a wiki. The grey symbols show novel knowledge units as a result of learning through externalization, K_1' and K_3' represents the extended knowledge spaces correspondingly.

Internalization

Interindividual knowledge transfer and collaborative knowledge building takes place when people have the opportunity to work with a wiki and to internalize the information the wiki contains. So people have to decode the information captured in a wiki, and then they have to integrate the information units in the wiki's information space into their individual knowledge spaces. Through this internalization a person acquires new knowledge units and relations between knowledge units, i.e. a person uses the wiki's information space to expand his/her own knowledge space. In Figure 2 the results of an internalization is indicated by the striped symbols. Through internalization the individual knowledge spaces are expanded to K'' . For example, if a person reads something about George Washington's first election as president and this person did not know beforehand that George Washington became president in 1789, then the person expands his/her own knowledge space by adding this new knowledge unit to his/her schema about George Washington.

Besides this interindividual knowledge transfer resulting from the internalization of information in a wiki, an additional kind of knowledge-acquisition process can occur: If a person internalizes information units from the wiki which did not belong to his/her personal knowledge space before, knowledge units can develop which were neither part of his/her personal knowledge space nor part of the wiki. Such additional knowledge acquisition can happen if a new knowledge unit that a person internalized from a wiki interacts with his/her individual knowledge space in a way that enables the person to create new knowledge. This kind of knowledge building can happen if a person is able to infer new knowledge units out of the knowledge units he/she internalized through the work with the wiki and the knowledge units he/she had in his/her individual knowledge space before. This knowledge can be described as "emergent knowledge". A person would not have been able to create this knowledge if it had not been internalized from the artifact before. This emergent knowledge is a product of the collaboration and as such represents the result of a form of collaborative knowledge building which is more than mere knowledge sharing (something qualitatively new is developed). Emergent knowledge has not been part of the individual's knowledge spaces before (for a detailed elaboration on the phenomenon of emergence cf. Holland, 1998 or Johnson, 2001). This process can also be clarified with the Wikipedia example:

if a person comes to know that George Washington became president in 1789 by reading the corresponding Wikipedia article, and if this person previously knew that the U.S. declared independence in 1776 and also knew some facts about the American Revolutionary War, he or she can draw conclusions with respect to certain developments in American history. In Figure 2 person 3 has created such emergent knowledge.

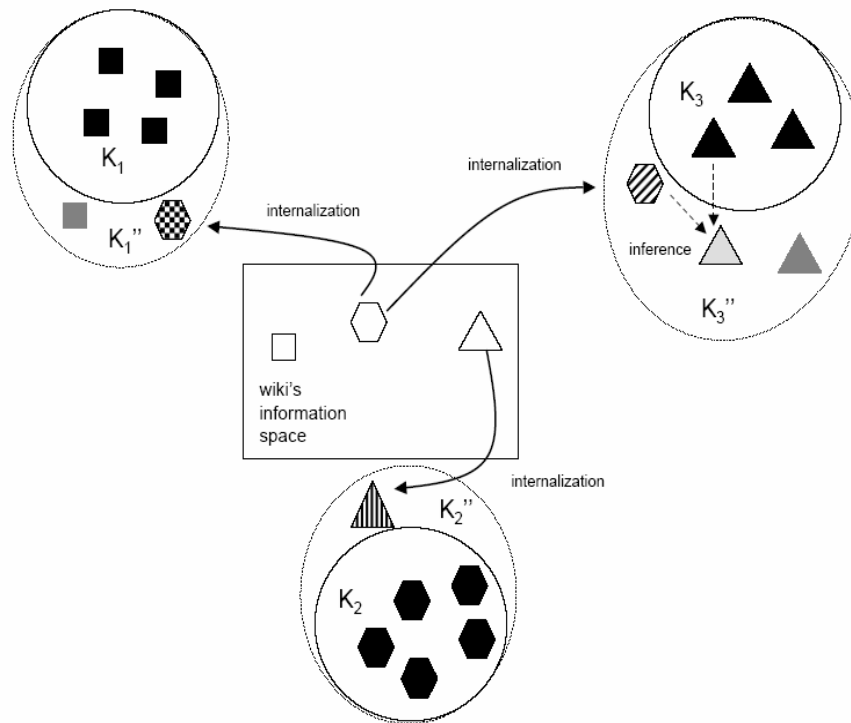


Figure 2: Process of internalization: Each of the three individuals internalizes one concept (striped symbols). Person 3 additionally creates a new knowledge unit (light-grey) through a process of inference from an internalized knowledge unit and from another one belonging to the person's knowledge space previously. The occurrence of such knowledge units shows an emergent process.

Four Processes of Knowledge Building

- The model so far has described different kinds of individual learning. Individual learning occurs
- as a result of externalization (due to processes of deeper processing and elaboration which are activated by the externalization process),
 - as a result of internalization (due to the simple adding of new knowledge units) and
 - as a result of inferences (due to the expansion of a person's individual knowledge space through internalization and, arising from that, an opportunity to interconnect old and new knowledge units, i.e. inferences of knowledge units that were unknown until then).

All forms of learning take place when people interact with the artifact in a way that information and knowledge are transferred between the individual's knowledge space and the wiki's information space. So, to refer back to Luhmann's perspective, learning occurs by the transgression of the border between the individual's knowledge spaces and the wiki's information space. The processes of internalization and externalization cause these individual learning processes. But in the model as described so far, learning primarily is considered as quantitative increase of knowledge units in an individual's knowledge space. And up to this point, expansion of the wiki's knowledge space has been described, but not yet qualitative changes within the wiki. These aspects will be addressed systematically in this section.

For considering this qualitative aspects we take up Piaget's model of equilibration (Piaget, 1977a, 1977b). This model also describes how people deal with new information from their environment and how they perceive and encode this information from outside and integrate it into their own cognitive schemas. The equilibrium theory describes the way people try to maintain a balance between the environmental information on the one hand and their cognitive schemas on the other hand. If information is new and leads to knowledge that was not part of the individual's knowledge space before, it cannot be promptly decoded and integrated into an existing cognitive schema. Thus, people have to adapt to this new environment. There are two possibilities of adaptation: people can *assimilate* the new information or they can *accommodate* their internal cognitive schema (in order to match it with the information). Assimilation describes a process where an individual understands new information on the basis of an existing cognitive schema and then integrates it into this cognitive schema. This means that information coming from the environment is perceived and modified in a way that makes it fit into the individual's cognitive schemas. Assimilation describes more a *quantitative* aspect of individual learning. The mental schemas of an individual remain the same and only additional concepts are acquired which fit to these schemas.

The other process of adaptation which Piaget describes is the process of accommodation. Here a person interacts with new information in a way that changes a cognitive schema. In this case, a person does not simply integrate new information into an existing cognitive schema, but actually changes this schema in order to better understand the environment and its information. We consider the creation of new schemas as an indicator of learning in a more qualitative manner.

We apply this distinction between assimilation and accommodation to our model of people's interaction with wikis described in our model. When interacting with the wiki, people can learn as a result of externalization, or as a result of internalization (with or without inferences). This learning can take place by assimilation or by accommodation respectively: people can acquire new information without changing their cognitive schemas, or they can modify schemas or create new schemas.

For collective knowledge building with wikis, we state that accommodation and assimilation do not only take place internally (in people's individual knowledge spaces) but also externally (in the wiki's information space). A wiki can accommodate or assimilate as well. If people contribute information to the wiki without linking it to previously existing information units, they only extend the wiki by adding some information. If people contribute this way, the information space of the wiki assimilates the new information, which means that the structure of the wiki remains the same, only some information is added. For example, if a user adds some references about George Washington in the Wikipedia article, this is only an assimilation of the wiki. But the wiki can also accommodate. This happens when people do not only attach new information to the existing information space, but they also structure the information of the wiki in a new way. For example, in Wikipedia this would happen if a user revises an existing article by arranging and configuring the information of the article, by separating an article into different articles, or by linking an article to another one and describing the relation between both. In Wikipedia such organization processes often occur. The application of a history flow diagram is a visual method developed by an IBM research group which makes such activities visible (Viegas, Wattenberg & Dave, 2004). Such visualizations of Wikipedia articles show that sometimes people only add new information to in existing article, and sometimes people completely restructure an article.

In sum, in collaborative knowledge building with wikis we can distinguish four different forms of knowledge building: Internal assimilation (quantitative individual learning), internal accommodation (qualitative individual learning), (quantitative) external assimilation, and (qualitative) external accommodation. The first two are processes of individual learning, the latter two are processes of a collaborative knowledge building with respect to the wiki.

Motivational Processes in Knowledge Building

What motivates people to engage in this collective process of knowledge building? We know from many scenarios where shared databases, forums, or blogs are used for knowledge exchange that people often are reluctant to contribute their own knowledge (Ardichvili, Page & Wentling, 2003; Huber, 2001; Jian & Jeffres, 2006) because of the costs of the contribution: People have to write down information, they fear embarrassing themselves through publishing information which might contain mistakes, or they may be afraid of losing power

if they share information, which only they have (Cress & Hesse, 2004). All these problems are described in knowledge-exchange settings, where the main aim is to pool information and to make it accessible (Cress & Hesse, 2006). In knowledge building scenarios like Wikipedia this seems to be different. The success and quality of this encyclopedia shows that people take part in this collaborative process of knowledge building voluntarily and with plenty of effort and enthusiasm. What motivates people to do this?

Following Piaget's model of equilibration we propose that people engage in knowledge building by contributing new information to wikis and by restructuring existing articles because of a *social-cognitive conflict*. We propose that when people work with a wiki they have to match their own individual knowledge space with the information space the wiki provides. This matching process can lead to different results: If an individual feels that the wiki's information space is congruent to his/her individual knowledge space then there is no need for equilibration and people do not accommodate or assimilate, either internally or externally. In contrast, if people feel that the wiki's information space differs from their own knowledge space, there is a need for equilibration, which people can satisfy by processes of internal or external assimilation or accommodation. If an individual realizes that concepts which are part of the individual's knowledge space are missing in the wiki he/she perhaps will externalize these and add them to the wiki (external assimilation). If she/he feels that the wiki's information space describes concepts which are not part of the individual knowledge space she/he will acquire new knowledge by internal assimilation. If she/he feels that both spaces are structurally different he/she will accommodate the cognitive schema (internal accommodation) or revise the wiki's structure (external accommodation).

We further propose that the motivation for the described activities of equilibration is a function of two features: The amount of dissonance between the individual knowledge space and the wiki's information space, and the *valence* which the topic has for a person. According to the valence we propose a linear relation: the higher an individual rates the valence of the topic, the higher the perceived cognitive conflict is and the more interest (Krapp, 1999) a person feels. According to the *objective difference* between the individual knowledge space and the wiki's information space we propose an inverted u-shaped relation between the difference between both spaces and the cognitive conflict people perceive which is displayed in Figure 3. If the difference between both spaces is very small, there is no need for equilibration. If the difference is very large, the concepts of the wiki and the individual knowledge space will not be perceived as describing one and the same topic. This will reduce the need for making both consistent. We propose that only a medium-level discrepancy causes a cognitive conflict which motivates people to engage in one of the knowledge building processes described above.

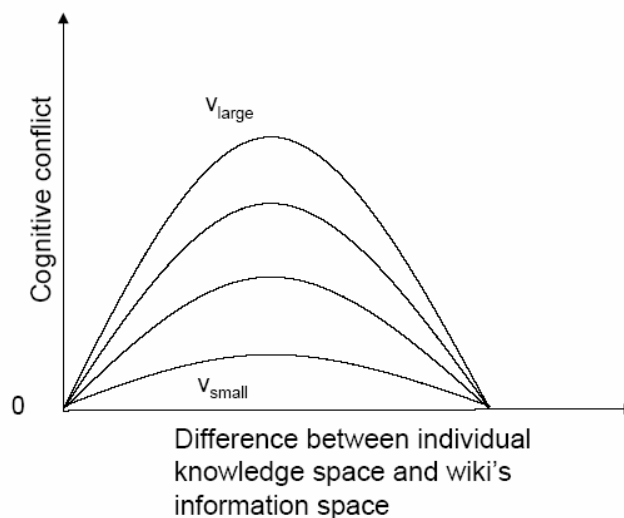


Figure 3: The inverted u-shaped relation between cognitive conflict and difference between an individual's knowledge space and the wiki's information space. The Figure provides this relation for four different levels of v , ranging from a low level of v to high level of v .

In this model the dissonance between people's individual knowledge space and the wiki's information space is the motor of the system's development. In a process of mutual development people learn and enhance their individual knowledge space and the artifact improves, becomes more exhaustive and more and more consistent. And according to Luhmann (1986) this is the base of the autopoietic processes which can be observed in all social systems (for a detailed elaboration on the phenomenon of Autopoiesis cf. Varela, Maturana, & Uribe, 1974 or Luhmann, 1990). Through processes of equilibration the wiki tends to incorporate more and more knowledge from the individual knowledge spaces of the users. Through external assimilation the wiki consists of more and more information units, and through accommodation processes it enables new understandings and transports new and emergent information.

Conclusion

In this article we develop a model which helps us to better understand collaborative knowledge building with wikis. For this purpose we combined Luhmann's system theory with Piaget's cognitive theory. Luhmann's approach is very thorough with respect to social systems, and Piaget's theory primarily focuses on the development of cognitive structures. Our model attempts to demonstrate the interplay of the social system wiki and individuals' cognitive systems. This consideration of the structural coupling of social and cognitive systems illustrates collaborative knowledge building with artifacts and might be a fertile approach for CSCL research. Our next steps will be to test the model empirically in various contexts in order to further elaborate on this approach and to make it more sophisticated.

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