The Role of Inconsistencies in Collaborative Knowledge Construction

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Abstract: When learners use shared digital artifacts for purposes of knowledge construction, they may be confronted with different types of inconsistencies. We present a study in which physiotherapy students had to handle two types of inconsistencies: Inconsistencies within a wiki text and inconsistencies between the text and their own attitude toward health and therapy. We conducted both a quantitative and a qualitative analysis of the students' contributions. We found that students modified inconsistencies within a text by changing the text, sometimes even by changing scientific facts. When learners revised inconsistencies between the text and their own attitude they did not change their personal therapeutic health concept, but transformed the text to fit their own perspective. Finally, we found that students rearranged scientific facts to a higher degree if the text was not in line with their attitudes. We discuss the implications of our findings for understanding knowledge construction.

Introduction

Shared digital artifacts play an increasing role in computer-supported collaborative learning and collaborative knowledge construction. This applies both to environments that are explicitly intended for purposes of knowledge building (such as Knowledge Forum; see Fujita, 2013; Hong & Scardamalia, 2014; Zhang, Scardamalia, Reeve, & Messina, 2009) as well as to tools that allow for a rather casual and incidental way of learning and knowledge construction (such as social tagging tools, for example; Cress, Held, & Kimmerle, 2013; Golder & Huberman, 2006). Shared artifacts allow their users to make individual contributions and to introduce their own knowledge to the community of all users. But different types of shared digital artifacts vary in the degree in which they can be influenced and modified. Tools that are particularly convenient for users to make comprehensive modifications are wikis (Kimmerle, Cress, & Held, 2010). In wikis users have the opportunity to drastically influence the content of the shared artifact (Leuf & Cunningham, 2001; Moskaliuk & Kimmerle, 2009).

When people use shared digital artifacts for purposes of knowledge construction, they are confronted with different types of inconsistencies. There may be inconsistencies within a shared artifact itself. This is the case, for example, when contradictory words or definitions are used to refer to the same object in a social tagging environment or when different statements contradict each other within a wiki article (e.g., Kimmerle, Cress, Held, & Moskaliuk, 2010). Inconsistencies within texts and their implications for cognitive information processing have been examined in text comprehension research for more than two decades (see Graesser, McNamara, Louwerse, & Cai, 2004; McNamara, Kintsch, Songer, & Kintsch, 1996). McNamara et al. (1996) argued, for example, that a poorly composed text may support skilled readers in elaborating on its content, since they have to cognitively compensate for imprecise or ambiguous information. When using wikis for knowledge construction, however, the collaborative handling of inconsistencies within the shared text should also be given attention, in addition to the individual cognitive processing of information (see Cress & Kimmerle, 2007, 2008; Kimmerle, Moskaliuk, & Cress, 2011), in particular since the selective handling of information may have implications for the collective construction of knowledge. So far there has not been enough investigation into how such inconsistencies affect the collaborative production of a shared text. Another type of inconsistency may occur between the knowledge, beliefs, or attitude of an individual user and the information contained in the artifact. It is an empirically well-supported finding that such contradictions may lead to some kind of cognitive dissonance (Festinger, 1964) or to socio-cognitive conflicts (Berlyne, 1960; Piaget, 1977). When this occurs, individuals then have to deal with the contradictions in order to reduce the dissonance and re-equilibrate their cognitive structures. If learning scientists want to implement collaborative learning settings that support an unbiased handling of information, they need to understand learners' strategies of dealing with contradicting attitudes. A particularly relevant question for the learning sciences is how people deal with these inconsistencies in situations where they are not limited to a purely cognitive processing of the inconsistencies. What happens when they have the opportunity to modify the content of a shared digital artifact—as in the case of wikis? How strongly are they bothered by inconsistencies within a wiki text? How do they act or react to content that does not suit their view of the world? And what is the impact of particular combinations of inconsistencies? That is, do users react differently to inconsistencies within a wiki text when its general message is in line with their attitude, compared to a text that contradicts their opinion?

Bientzle, Cress and Kimmerle (2013) reported that inconsistencies within a wiki text per se did not provoke wiki users to conduct more modifications than in a situation without such inconsistencies in the text. But in texts that expressed a point of view contradictory to that of the users, those with inconsistencies were modified more frequently than texts without inconsistencies. It is apparent that people tolerated logical inconsistencies to a much lesser degree when they appeared in the wrapping of a contradictory point of view. This selective handling of information in the collaborative construction of knowledge is relevant for the learning sciences. If researchers aim to support learners in contributing to a preferably open-minded and unbiased knowledge construction process, then they need to comprehend how learners act when they have to deal with inconsistencies. So it is worthwhile to take a much closer look at how the findings of Bientzle et al. (2013) came about. Previous literature has not sufficiently described the underlying processes and the strategies that learners apply in such situations. Therefore, we provide in this article a detailed qualitative analysis of people's contributions. First, we describe the procedure of the experiment. Then we present a variety of exemplary findings of how the participants dealt with various constellations of inconsistencies. Finally, we discuss the implications of our results for future research in learning and education.

Method

In order to better understand how learners handle different types of inconsistencies, we analyzed their contributions, deletions, and modifications in a wiki text. On the basis of Bientzle et al.'s (2013) data set, we examined under which conditions learners applied particular strategies for dealing with inconsistencies in a wiki text. Since medical information is particularly concerned with inconsistencies (Kienhues, Stadtler, & Bromme, 2011; Kravitz, Duan, & Braslow, 2004; Sniderman & Furberg, 2009), a health-related topic was chosen for this study, and physiotherapy students were recruited as participants.

Inconsistencies were incorporated into the text by adding logical contradictions into statements about the effectiveness of stretching. To establish inconsistencies between the text and a learner's attitude, we used a pre-test to measure the therapeutic health concept of the participants. Based on this measurement, we then provided a text that was either consistent with or contradictory to the therapeutic health concept of the participants. We constructed four different versions of texts by combining these two types of inconsistencies.

Participants

Seventy-six students (M_{age} = 21.99, SD = 4.28; men: n = 24, women: n = 50, 2 did not indicate their gender) of a state-approved school of physiotherapy (PT Academy) participated in the study. The students were in the first, second, or third (final) year of their vocational training. They were randomly assigned to one of the four versions of the text, which they edited individually at a laptop in a classroom setting.

Inconsistencies within a Text

The fluctuating quality of health knowledge and inconsistencies in health information are challenges for health-related knowledge construction. Health information is not only based on scientific facts, but very frequently also on practical and anecdotal knowledge. In many cases, however, anecdotal knowledge is not supported by scientific evidence at all. As a consequence, inconsistencies within health knowledge occur.

In the health care sector, especially in sports and physiotherapy, stretching is an established and widely used treatment. It is used to improve mobility and flexibility, to prevent injuries and aching muscles, and to foster a quicker regeneration. At the same time many scientific investigations disclose inconsistent and controversial effects of stretching (Small, Mc Naughton, & Matthews, 2008; Taylor, Dalton, Seaber, & Garrett, 1990; Weppler & Magnusson, 2010). Thus, this topic seemed to be particularly suitable to investigate what happens when students are confronted with relevant but inconsistent information in a situation where they have the opportunity to modify the content.

Inconsistencies between a Text and a Learner's Attitude

To investigate the effect of inconsistencies between content in a shared artifact and people's attitude, we chose to use people's therapeutic health concept. This is a central and well examined concept in the health sciences (Alonso, 2004; Laffrey, 1986). There are various perspectives on what health is considered to be. It is known that health professionals and patients differ in their individual understanding of health (Patel, Arocha, & Kushniruk, 2002), and that even among healthcare professionals no common understanding of the concept exists (Engel, 1977; Larson, 1999; Roberts, 1994).

In the health care sector two different classification systems coexist. The International Classification of Diseases (ICD; World Health Organization, 1992) promotes a *biomedical therapeutic health concept*, whereas the International Classification of Functioning, Disability and Health (ICF; World Health Organization, 2001) promotes a *biopsychosocial perspective*. The biomedical therapeutic health concept implies a scientific perspective on therapy and health that can be described by keywords like 'scientific', 'evidence-based', or 'standardized'. The biopsychosocial therapeutic health concept implies a more holistic perspective that can be

described by keywords like 'individualized', 'social participation', or 'functioning in everyday life'. In order to evoke inconsistencies between the text and a learner's attitude, we presented texts that were either consistent with participants' health concept or that contradicted their attitude toward therapeutic principles.

Experimental Material

By systematically combining inconsistencies, four different versions of the text were constructed: (1) text with consistent information and a therapeutic health concept that was congruent with the learners' health concept; (2) text with inconsistent information and a congruent health concept; (3) text with consistent information and a health concept that contradicted that of the learners; and (4) text with inconsistent information and a contradicting therapeutic health concept.

A text with inconsistent information included five statements that illogically connected a *scientific fact* with practical or *anecdotal knowledge*. An example of an inconsistent statement was: *"Temporary stretching resulted in no structural extension of the muscle fiber. This seems to be a reason for a better mobility after a stretching intervention."* In physiotherapy, stretching is widely used to increase the range of motion (ROM), in particular if muscle contractures are identified to be caused by a restriction of mobility. It is frequently assumed that a structural extension of the muscle fiber occurs via stretching, which is then supposed to be the reason for the positive effect on mobility. But the anatomic fact is that no structural extension of the muscle fiber occurs. This scientific finding diametrically opposes the anecdotal knowledge that an increase of the ROM would be due to the structural length of a muscle fiber. The discrepancy between these two statements is obvious to students of physiotherapy (manipulation check measures indicated that students estimated such text sections as more inconsistent; for details see Bientzle et al., 2013).

The therapeutic health concept of the text was operationalized by including either five statements congruent with the student's concept or five statements contradictory to the student's concept. As already known from the literature, the biopsychosocial perspective is common and popular in physiotherapy (Jorgensen, 2000; Stenmar & Nordholm, 1994). According to the pre-test of the health concept, this was also true of the participating sample of physiotherapy students. To take this into account, the text with a contradicting health concept included five biomedical statements, whereas the text with a congruent health concept included five biopsychosocial statements. An example of a contradicting (i.e., biomedical) statement was: *"Since stretching has various effects, patients benefit most from standardized examination and the use of evidence-based treatments."* An example of a congruent (i.e., biopsychosocial) statement was: *"Since stretching has various effects, patients benefit most from individualized examination and the use of treatments suited to the individual's needs."*

We conducted a qualitative analysis (Mayring, 2000) and a statistical frequency analysis in order to gain deeper insights into how students handle inconsistencies when they have the opportunity to modify the content of the text. We focused on those text sections that provided logical inconsistencies within the text and represented either a biomedical (contradicting) or a biopsychosocial (congruent) therapeutic health concept.

Results

In the following sub-sections we present the participants' strategies for handling inconsistencies within a text as well as inconsistencies between a text and learner's attitude (see Table 1 for an overview). We also discuss the effects of the interaction of these two types of inconsistencies.

Table 1: Strategies for handling inconsistencies.

Type of inconsistency	Strategy	Frequency (percentage)
Inconsistencies within a text	No modification	83 (46.7%)
	Deletion of the entire section of the text	32 (16.8%)
	Resolving the inconsistency reasonably	44 (23.2%)
	Modifying the scientific fact	31 (16.3%)
Inconsistencies between a text and learner's attitude	No modification	102 (53.7%)
	Revising without changing the perspective of the text	9 (4.7%)
	Deletion of the entire section of the text	21 (11.1%)
	Transforming into own perspective	28 (14.7%)
	Integrating contradicting attitude with the own attitude	30 (15.8%)

Inconsistencies within a Text

Over all conditions and participants, 190 sections represented inconsistencies within the text. Eighty-three (43.7%) sections were not modified at all. There were 11 students who modified five out of five inconsistencies and six students who never modified any inconsistencies. This quite large range of behavior indicates that the pure existence of logical inconsistencies does not guarantee active participation in knowledge construction in order to solve these discrepancies. In the following, we provide a deeper analysis of the remaining 107 (56.3%) text sections in which the students did modify logical inconsistencies.

Thirty-two (16.8%) text sections with logical inconsistencies were completely deleted. Students who deleted the entire section made an effort to create a coherent text by trying to get rid of these confusing segments. They were obviously able to identify those specific sections of the text that were a source of inconsistency. But they did not make the effort to look into the problem more deeply.

Forty-four (23.2%) logical inconsistencies were reasonably resolved with respect to content. In most of these cases students presented a solution to the inconsistency in that they deleted the inference that was incorrectly drawn from the scientific finding. This is illustrated by the modification made to the following example: *"It is already known that stretching fosters the range of motion. Temporary stretching resulted in no structural extension of the muscle fiber. ~~This seems to be a reason for a better mobility after a stretching intervention.~~"*

The selective deletion of an illogical inference needs—in contrast to deleting an entire section—a deeper understanding of the content. Students who performed such selective deletions had to be aware of the quality of information: It seems they considered scientifically evaluated information as more trustworthy than practical or anecdotal knowledge. They were able to identify the anecdotal knowledge as the source of inconsistency and accordingly drew the conclusion that it was this part that needed to be removed in order to achieve a coherent text.

Another approach to resolving an inconsistency was to adapt the anecdotal knowledge. The following example demonstrates this strategy. This was the original text: *"It is commonly considered that after temporary stretching the flexibility of the musculature is improved. A hint of this assumption is that the stress-strain curve of the muscle is left unchanged after stretching."* This inconsistency was adapted by simply inserting the word *"not"*: *"... that after temporary stretching the flexibility of the musculature is <u>not</u> improved. A hint of this assumption ..."*.

The adaptation of the anecdotal knowledge showed that students who applied this strategy apparently reflected about the inconsistency and were thus even able to incorporate the anecdotal knowledge in a modified way. It seems they were familiar with scientific reasoning to such a degree that they demonstrated the ability to interpret a scientific fact correctly.

An additional, even more demanding strategy to resolve an inconsistency reasonably was to adapt the anecdotal knowledge and add further information at the same time. The following text section is an illustrating example: *"Stretching is used to foster a quick regeneration after high physical load. The reduced blood flow and the traction on the stressed and micro-traumatized musculature during static stretching provide an explanation for the assumed positive effect of stretching on regeneration."* This inconsistency was adapted by inserting further information about missing scientific evidence. In addition, this student adapted the illegitimate conclusion from the scientific fact by deleting *"the assumed positive effect of stretching on"* and by inserting a correct conclusion. The whole section of the text appeared after the revision in the following way: *"Stretching is used to foster a quick regeneration after high physical load. <u>However, this has not yet been proved, since regeneration processes cannot be associated with stretching</u>. The reduced blood flow and the traction on the stressed and micro-traumatized musculature during a static stretching <u>do not</u> provide an explanation for ~~the assumed positive effect of stretching on~~ regeneration."*

Besides a deep understanding of the specific content, such an elaborate revision requires people's ability to reflect on the current stage of knowledge about the effectiveness of stretching. Students who were able to perform such revisions had to be aware of the uncertainty in medical anecdotal knowledge and also of the lack of scientific evidence in physiotherapy.

Apart from these strategies to resolve inconsistencies as described so far, inconsistencies within the text also stimulated the participants to modify the scientific fact. Thirty-one (16.3%) of the logical inconsistencies were edited in this way.

In the following example the scientific fact was adapted in order to fit to the anecdotal knowledge. This was the original sentence: *"The reduced blood flow and the traction on the stressed and micro-traumatized musculature during a static stretching ..."*. A participant changed this sentence in the following way: *"The ~~reduced~~ <u>enhanced</u> blood flow ..."*.

This is another example of a participant who revised the scientific fact: *"... the stress-strain curve of the muscle is left unchanged after stretching"* was changed into: *"... the stress-strain curve of the muscle is ~~left unchanged~~ <u>changed positively</u> after stretching."* After this student's revision the conclusion that the scientific

fact would be an explanation for the positive effect of stretching became logically correct (even though it was still incorrect with regard to current scientific knowledge).

Students who performed such adaptations had to be aware of the inconsistencies in the text. But in these cases, they identified the scientific knowledge as the source of the inconsistency. It seems they considered scientific knowledge as less certain and trustworthy than established anecdotal knowledge.

Inconsistencies between a Text and a Learner's Attitude

In total, 190 sections of the texts represented a biomedical therapeutic health concept which contradicted the participants' health concept. We found that 102 (53.7%) sections were not modified at all. This indicates that the mere existence of inconsistencies between a text and learner's attitude did not necessarily lead to text modifications. Perhaps students did not realize the inconsistencies or they were not personally affected by them.

In the following, we provide a deeper analysis of the remaining 88 (46.3%) text sections in which the students did modify the text. Nine (4.7%) biomedical statements were revised without changing the therapeutic health concept. In the following example only the extent of the standard ROM of the knee joint was modified: *"A deficit in the mobility which should be treated exists, if a patient does not achieve the standard ROM [i.e., knee: ext/flex ~~(0/0/180)~~ (0-5/0/120-150)]"*

It seems that students who performed such an adaptation were not bothered by the biomedical statement; they even tried to improve the accuracy of the biomedical information. This is remarkable in the face of the fact that all participants preferred biopsychosocial statements. This behavior seems to reflect some open-mindedness toward other attitudes or at least a willingness to tolerate other perspectives.

In contrast to this editing behavior we also found that 21 (11.1%) text sections that represented a biomedical therapeutic health concept were completely deleted. Deleting the whole section of the text was an option which had the effect of neutralizing attitudes represented in the text. Students who deleted the entire section made an effort to diminish the contradicting therapeutic health concept. It seems they were disturbed by the contradicting attitude but they did not invest much effort to transform the section of the text to fit their own perspective.

Another approach of some participants was to transform the contradicting statement to be in sync with their own perspective. Twenty-eight (14.7%) biomedical statements were transformed into biopsychosocial statements, whereas no biopsychosocial statement was transformed into a biomedical statement. The following example demonstrates this strategy. The statement *„Since stretching has various effects, patients benefit most from standardized examination and the use of evidence-based treatments"* was adapted by replacing the biomedical keywords *"standardized"* and *"evidence-based"* with the biopsychosocial keywords *"individualized"* and *"individual"* respectively.

Another approach to eliminating the biomedical perspective was to relativize the biomedical statement with the help of a biopsychosocial statement. For example, keywords like *"standard ROM"* remained unchanged. But at the same time the statement *"A deficit in the mobility which should be treated exists, if a patient does not achieve the standard ROM [i.e., knee: ext/flex (0/0/180)"* was revised by replacing the second part of the statement with the following change: *"... which should be treated exists, if a patient isn't able to handle his daily routine caused by the deficits. However treatment decision should not mainly depend on the standard ROM."*

Students who performed these strategies made an effort to diminish the contradicting therapeutic health concept and to adapt the text to their personal way of thinking. This behavior seems to reflect a very strong opinion and little willingness to accept other attitudes.

So far only strategies of acceptance or rejection have been presented, but there were also 30 (15.8%) statements for which students made an effort to integrate the contradicting attitude with their own attitude. The statement *"A deficit in the mobility which should be treated exists, if a patient does not achieve the standard ROM [i.e., knee: ext/flex (0/0/180)"* was supplemented by *"while the main focus should be on deficits that become apparent in the everyday life of the patient."*

Another student only replaced *"standardized"* with *"individualized"* and left the biomedical keyword *"evidence-based"* unchanged. The transformation of this biomedical statement appeared as follows: *"Since stretching has various effects, patients benefit most from ~~standardized~~ individualized examination and the use of evidence-based treatments."*

Students who exhibited such editing behavior made an effort to reach a balanced presentation of the therapeutic health concepts. They did not devalue the contradicting attitude. This seems to be a very sophisticated way of handling those inconsistencies between the opinion voiced in the text and their own attitude—particularly impressive since all students had a strong biopsychosocial orientation.

Interaction of the Different Types of Inconsistencies

A particularly interesting and key question is how the combinations of the two types of inconsistencies exerted influence on the contributions and the editing behavior of students. Therefore, we examined the students'

reactions to inconsistencies within a text when the text was in line with their personal attitude compared to the situation in which the text contradicted their biopsychosocial health concept. To test differences in the reactions to inconsistencies depending on the health concept of the text, we calculated chi-squared tests.

There were 95 sections that included inconsistencies within the text which were embedded in a health concept contradictory to that of the students. Another 95 sections contained inconsistencies within the text which were in line with the participants' health-related attitude. In the following, we present three types of revision strategies which were applied by the participants: Reasonable resolutions of inconsistencies, deletions, and rearrangements of scientific facts.

Overall, 61 (64.2%) text-immanent inconsistencies were edited in texts that expressed contradictory health concepts, while only 46 (48.4%) inconsistencies were revised in texts that were in line with the participants' personal attitude: $X^2 = 4.81$, $p = .028$.

This difference is not attributable to reasonable resolutions of inconsistencies, however. Twenty (21.1%) inconsistencies within biomedical texts and 24 (25.3%) inconsistencies within biopsychosocial texts were revised in this way: $X^2 = 0.47$, $p = .492$.

The differences regarding deletions were greater, though also not statistically significant. Here, 20 (21.1%) inconsistencies within biomedical texts and twelve (12.6%) inconsistencies within biopsychosocial texts were completely deleted: $X^2 = 2.41$, $p = .121$.

The strategy that contributed to the overall difference very strongly was the rearrangement of scientific facts. Here, the frequency differed significantly between conditions. Twenty-one (22.1%) inconsistencies within biomedical texts but only ten (10.5%) inconsistencies within biopsychosocial texts were revised by using this strategy: $X^2 = 4.66$, $p = .031$.

In sum, it seems that students were more tolerant toward logical inconsistencies within a wiki text when this text was in line with their personal attitude toward health and therapy. Our findings regarding deletions clearly support this interpretation. The attitude represented in the text, however, had no influence on the most sophisticated and challenging revision strategy, that is, to resolve the text-immanent inconsistencies reasonably. Finally, the cases where a biomedical (i.e., contradictory) text caused the participants to revise a scientific fact stand out. They give the impression that a contradictory attitude as expressed in a wiki text was even able to tempt the physiotherapy students to manipulate scientific content according to their personal preferences.

Discussion

When shared digital artifacts, such as wikis, are used as learning settings to foster collaborative knowledge construction, students are confronted with different kinds of inconsistencies. Because of the fluctuating quality of knowledge and its diverse sources, inconsistencies may frequently occur within a shared artifact. In the analysis presented here we examined how students handle different types of inconsistencies.

First, we considered how inconsistencies within a wiki text affected the collaborative production of knowledge. We found that inconsistencies within the text resulted in diverse reactions of the participants. Almost half of the inconsistencies were not modified at all. The remaining inconsistencies were either deleted, reasonably resolved, or resolved in that students changed scientific facts. It was rather surprising that the students tended to modify scientific facts to such an extent. This can possibly be attributed to the nature of their vocational training. As can be seen from the German training and examination regulations of physiotherapy (PhysTh-APrV, 1994), physiotherapy is more a practical than an academic type of training. This might be one reason why anecdotal knowledge was apparently considered to be more trustworthy. Another reason may be that the anecdotal knowledge as presented in our material was closely linked to the practical knowledge of the students. In this situation, practical knowledge seemed to be more robust than theoretical knowledge (see also Hascher, Cocard, & Moser, 2004).

In a second step, we considered how inconsistencies between a text and a learner's personal attitude affected the participants' contributions. We found that students also used various strategies to handle such inconsistencies. Again, about half of the inconsistencies were not modified at all. The remaining inconsistencies were deleted, revised without changing the therapeutic health concept, transformed to fit people's own perspectives, or integrated into their own point of view. That some students tried to transform biomedical statements into biopsychosocial statements strongly indicates that the therapeutic health concept is a very central and stable concept for physiotherapists' professional identity. That some students integrated the contradictory attitude with their own attitude might be caused by the social character of the shared digital artifact. As already reported in previous research (e.g., Kimmerle, Moskaliuk, Bientzle, Thiel, & Cress, 2012) people tend to revise shared artifacts in a rather deliberate and tactical way.

Finally, our qualitative analysis suggests that the co-occurrence of inconsistencies led to specific effects. We found that students questioned logical inconsistencies within the text to a lesser degree if the general text was in line with their personal attitudes. This means that students seemed to take a more critical look at text-immanent inconsistencies when the shared artifact contradicted their own attitude. This might be an

interesting starting point for researchers and practitioners who want to foster critical handling of uncertain information by learners. In addition, we found that a contradictory attitude in particular fostered the revision of scientific facts. Since we operationalized the inconsistencies between the wiki and the participants' attitude only through the biomedical vs. biopsychosocial therapeutic health concept, we cannot certainly conclude that this effect would also occur when other types of inconsistencies exist between a text and a learner's attitude. Whether this result is specifically due to the clash of biomedical and biopsychosocial health concepts or can be generalized to other inconsistencies is an open question for future research.

The selective handling of information has important implications for the collective construction of knowledge, and is highly relevant for the learning sciences. According to our qualitative analysis, it is important to be aware that the pertinent source of an inconsistency may exert an essential influence on how students deal with it. Learning scientists should take into account the complex interplay between individuals (their knowledge, beliefs, attitudes, and abilities) on the one hand and shared digital artifacts on the other. And they should also consider the interplay among different sources of inconsistencies, if they want to implement learning settings that support collective knowledge construction.

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