# Controversy Awareness on Evidence-led Discussions as Guidance for Students in Wiki-based Learning

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## ABSTRACT

Wikis mainly distribute user-generated content over the article and its corresponding talk page. While educational research provides article-related suggestions for learner's support, research has rarely analysed the potentials of supporting learning-related processes at the talk page level. With the presented experiment, we address this issue by investigating effects of visual controversy awareness information on content-related discussion threads. Such information can induce socio-cognitive conflicts which research assumes to be beneficial for learning, particularly when contradictory evidence leads wiki discussions. We investigated how controversy awareness highlighting as implicit guidance directs students' ($N$ = 81) navigation and learning processes as wells as their internalized knowledge representations. Results indicate that the implementation of controversy awareness representations helped students to focus on selecting meaningful discussion threads. Our findings suggest that wiki talk page users can benefit from additional structuring aids and increase their learning outcome when being aware of occurring controversies.

## 1 INTRODUCTION

Wikis such as Wikipedia or Wikiversity provide a common and widespread opportunity to share user generated content that emerges from collaborative writing processes. These contents are either available publicly over the Internet or within closed networks such as universities providing Wikis for coursework or learning groups. In this paper, we will argue that researchers and instructors should consider several individual prerequisites before writers are enabled to effectively collaborate with others in a collaborative knowledge construction environment. Prevailing theories of writing and knowledge construction of socially shared artifacts helps us to identify, understand and effectively use these prerequisites. In particular, we will focus on the potential benefits of making individual wiki readers and editors aware of controversial perspectives within discussed topics that have differing statuses of resolution. Therefore, we present an experimental study with university students that investigates potential guidance effects of visual controversy awareness support on discussion threads and analyses underlying learning mechanisms from an individual learner's perspective.

### 1.1 Cognitive processes of constructing socially shared artifacts

Text production and furthermore the revision of a socially shared artefact can be a challenging task, especially when building and constructing new knowledge in a collaborative setting. Beyond individual strategies and skills for effectively organising one's own writing, operating environments for collaborative writing should provide basic requirements. These include the optional set up of individual roles (e.g. author, editor or proof-reader) and activity spaces to enable monitoring processes on a group level (Posner and Baecker, 1992). Research in this area has shown that coordination processes in collaborative writing settings especially are crucial for

the quality of the resulting shared knowledge arte-facts (Erkens et al., 2005). To facilitate cognitive processes of writing, most wikis provide substantial functionalities for monitoring the writing processes, such as revision support for text segments.

A very basic, but essential revision technique for monitoring, has been implemented in most popular wiki software (e.g. MediaWiki) even until today. This technique provides direct side-by-side comparisons of two text versions in a revision history. Reviewing text segments is one of the key monitoring processes in a collaborative writing environment. This includes the revision of one's own text segments as well as reviewing the externalisations of others' contributions to the system. For collaborative writing tasks, Scardamalia and Bereiter (1983, 1985) suggested a self-regulated revision model. Authors' main activities are to compare, diagnose and operate (CDO). They apply these activities to a written text on a sentence by sentence basis in a recursive cycle. The application of CDO proposes to compare two text representations: the already written version with a planned revision. This comparison is like the implementations of side-by-side comparisons in revision histories that can be found in most wikis.

There have been several experimental evaluations of the application of this CDO procedure that have generated mixed results. Several studies showed that the usage of CDO resulted in more revisions than intended and that higher quality text passages have been produced (De La Paz et al., 1998; Graham, 1997) (Scardamalia and Bereiter, 1983, 1986). The overall quality of the whole revised texts for CDO users was only higher in a few studies (De La Paz et al., 1998). A number of studies did not find measurable differences in any direction in the resulting overall text quality while using CDO (Alamargot and Chanquoy, 2001). Accordingly, CDO itself is not necessarily a distinct theory, but rather as a scripted procedure for text revision performed by an individual in a collaborative setting. An individual's writing expertise is closely related to the challenges one might face in a collaborative writing scenario.

In general, the composition of a text is not necessarily a straightforward structured task. The required processes differ depending on the goals, the settings, and the individual writer as learner and thus, do not follow an invariant order of production stages. In reference to the Cognitive Process Theory of Writing (Flower and Hayes, 1981), writing is defined as a distinctive set of thinking processes. These are organised hierarchically and can be embedded within any other process. As an example, a writing task's goal-setting can be redefined during phases of reading, generating, or editing texts and is not bound to any specific activity. To successfully achieve one's individual writing goals, the writer should activate monitoring processes such as planning what to write, translating one's thoughts into written text and reviewing text segments. Situational and personal conditions influence these three sub-processes of monitoring, such as the writing task itself, the physical writing environment, individual skills, and existing prior knowledge related to the writing task.

Particularly because of the mixed evidence that research gathered for writing outcomes in collaborative tasks, we wanted to explore supportive measures for individual contributors in a collaborative environment that can serve as additional support to explicit procedures such as CDO. Since wikis already provide the essential functionalities for text revision, we are aiming to support writers as learners with a preceding step that enables them to focus on the most relevant aspects of their writing task. Cues to what contents are most relevant could allow writers to perform fewer, more efficient and effective comparisons, more purposeful diagnoses by emphasising the specific kind of problem and thus, finally resulting in a better operation manifested in higher quality texts. Wikis seem to be an ideal platform for research in this area, because they were specifically designed for knowledge construction supported by an unlimited number of individuals.

## 1.2 Knowledge building and co-evolution of knowledge

In its origin, knowledge building was defined as the creation of knowledge as a social product (Scar-

damalia and Bereiter, 1994). A significant amount of research has been done on how individual learning and knowledge construction processes can be backed by computer-supported collaborative environments like online discussion forums, blogs or wikis (Ioannou et al., 2015; Lai and Ng, 2011; Mayordomo and Onrubia, 2015). Scardamalia and Bereiter (2003) distinguished knowledge construction from individual learning. They originally defined learning as an internal and unobservable individual process. In contrast to that, knowledge construction encompasses the creation or modification of public knowledge such as it is observable in wikis, but without the aspects of collaborative interactions. Cress and Kimmerle (2008) extended the original concept of knowledge construction with a social component, grounded in a combination of Piaget's theory of equilibration (Piaget, 1977b,a) and the systemic approach by Luhmann (1984, 1997). The resulting theory of co-evolution describes and explains the interacting processes of an individual's cognitive system (e.g. author or editor) with a socio-technical system (e.g. wikis), both interacting with each other by processes of internalisation and externalisation of knowledge into one or the other system through processes of accommodation and assimilation.

Between an individual and a wiki as a socio-technical system for knowledge construction it is possible to measure patterns of mutual influences. Research conducted on confirming the theorised co-evolution processes has produced promising results by analysing learning outcomes on individual and collaborative levels in wiki-based environments. Positive effects on processes of co-evolution of knowledge and individual learning have been reported with regard to incongruities between information sources (Kimmerle et al., 2011; Moskaliuk et al., 2009), positive effects between internal and external accommodation and assimilation processes (Kump et al., 2013; Moskaliuk et al., 2009) and on the polarity of information and redundancy of prior knowledge (Moskaliuk et al., 2012). These studies provided evident support for the co-evolution in wiki-based learning, but specifically addressed the construction of knowledge artefacts on the article level of wikis.

In these previous settings the emergence of socio-cognitive conflicts between the individual's internal prior knowledge and the externalised knowledge in the wiki played an important key role, but research so far has not systematically provided support for individuals when they experience these conflicts. So far, research has neglected processes of individual information-seeking and selection behaviour on the layer of wiki discussion pages. These pages can serve as meaningful sources of additional knowledge that no author or editor has integrated or referenced in an article. With our research, we specifically are interested in providing additional support for processes of externalisation and internalisation of conflicting knowledge. We believe that enhancing an individual writer's focus on most relevant artefacts of a conflict before they revise an existing text can foster the externalisation of more relevant information from the social into the individual cognitive system and subsequently result in individual learning gains through optimised internalisation.
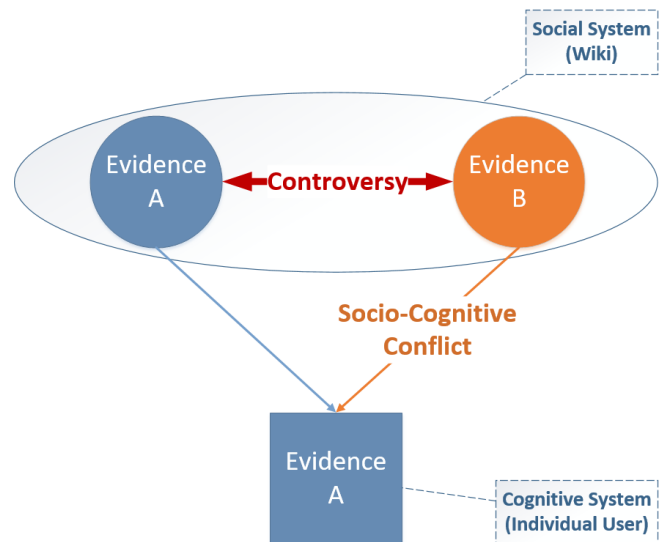
## 1.3 Socio-cognitive conflicts

Conflicts between social and cognitive systems do not need to have a negative impact on a learner. Quite the contrary, the confrontation of opposing information and further elaboration can lead to desirable learning processes and outcomes. Socio-cognitive conflicts are of special significance because collaboratively working in a group can lead to higher cognitive achievements compared to an individual working alone (Doise et al., 1975). Such conflicts emerge when a person's cognitive schemes contradict either another perspective or knowledge base and as a consequence lead to reorganisation and restructuring of cognitive processes, if consensus building is requested or required (Bell et al., 1985). These conflicting knowledge bases can act as a motivational driving force for equilibration processes in wiki-based or similar collaborative writing settings.

Socio-cognitive conflicts should arise from content-related discussions that are mainly led by evidence and based on contradictory information

or controversial positions to be most meaningful and beneficial for learners. Learning benefits on the individual and group level can eventuate by encouraging learners to constructively discuss controversies (Lowry and Johnson, 1981). Furthermore, controversial opinions and points of view have the potential to direct the focus of attention and foster interests (Johnson et al., 2000) and can lead to longer-term learning successes by forming and presenting newly acquired lines of argumentation (Doise et al., 1975; Mugny and Doise, 1978). Even if the learner is provided with incorrect information that causes a socio-cognitive conflict, restructuring and reassessing processes can still be triggered and thus lead to the attainment of higher cognitive levels (Bell et al., 1985).

Promoting the opportunities of taking another perspective to discussants while contributing to meaningful discussions can foster elaboration processes and trigger situational epistemic curiosity. Content-related controversies that have the potential to be beneficial for learners can trigger individual socio-cognitive conflicts that previous research considered as meaningful. Beyond content-related controversies that are our main interest, predominantly structural or socio-emotional controversies can also be identified in social systems like on-line discussion forums or blogs (Janssen and Bodemer, 2013). It is important to note that socio-cognitive in terms of the co-evolution of knowledge does not inevitably require that individuals must be involved in constant interaction with each other (Cress and Kimmerle, 2008). Even simple interactions of an individual's cognitive system with pre-existing contents in a social system that others have generated in a socially shared manner are socio-cognitive in this model (Figure 1). This is especially evident in asynchronous systems such as wikis where no contributor has a guarantee to receive direct or indirect feedback by others within a narrow time frame or even at all.

Existing wiki talk pages contain a bandwidth of these different conflict types ranging from socio-emotionally driven disputes to significant evidence-led discussions which comprise hidden potential for knowledge construction processes. Highlighting



**Figure 1.** Schematic representation of the occurrence of a socio-cognitive conflict, in line with the co-evolution model. An individual with prior knowledge about *Evidence A* perceives a controversy between discussants in the social system with arguments for *Evidence A* and *Evidence B*. The reception of *Evidence B* in the social system conflicts with the individual's prior knowledge about *Evidence A*.

the latter kind of controversies in wiki's underlying discussion threads might guide interested individuals towards essential learning processes based on socio-cognitive conflicts.

## 1.4 Guiding and supporting learners

Using asynchronous collaborative socio-technical environments for learning can be a challenging task. Providing learners with media and letting them freely collaborate does not automatically promote systematic learning processes and is dependent on an interplay of numerous variables such as the task itself, characteristics of the group and its individual members or the underlying collaboration media (Stahl, 2006). It has been shown that missing objectives and a lack of structure is problematic for productive interactions and outcomes in a collaborative setting (Bromme et al., 2005). Thus guiding structured learning and communication processes is essential for the effectiveness of

computer-supported collaborative learning settings (Fischer et al., 2013).

Regarding missing objectives during wiki-based learning, several supportive interventions have been designed and evaluated with a primary focus on the writer's task environment, such as setting a deadline or defining specific goals of an individual's writing task, which led to a set of extensions and design principles to facilitate group writing and constructivist learning processes for students in higher education (Kasemvilas and Olfman, 2009; Zheng et al., 2015). Regarding missing structure, socio-cognitive conflicts are suited for triggering individual elaboration and collaborative discourse, explicitly by suggesting different roles and collaboration processes (Kollar et al., 2006; Heimbuch et al., 2014) or implicitly by providing representational and informational guidance. The latter class of support measures are particularly suited to be embedded within informal information and learning environments as they do not interfere with self-regulated learning processes (Beers et al., 2005; Bodemer, 2011; Dillenbourg, 2002).

Representational guidance (Suthers, 2001, 2003) impacts processes and performances during tasks in a collaborative environment by providing salient cues. It was shown that providing representational guidance can nudge the discussion of controversial evidence (Suthers, 2001) and can lead to learning outcomes of higher quality (Janssen et al., 2010). Recently, cognitive group awareness tools were proven to be beneficial for learning processes and learning outcomes in various CSCL and related scenarios (Bodemer and Dehler, 2011; Janssen and Bodemer, 2013). They guide collaboration behaviours by providing individuals information on other learners' knowledge or opinions. Research on cognitive group awareness tools in controversial online discussions showed that they can highlight high quality arguments and different points of view leading to improved perception of minority opinions, a higher frequency of conceptual change and better learning outcomes (Buder and Bodemer, 2008; Buder et al., 2015).

Visualising controversies on different points of view or contradictory evidence can induce socio-cognitive conflicts leading to restructuring processes of one's own cognitive system as well as within the socio-technical system used for knowledge construction. However, to gain deeper insights of the underlying processes in an individual contributor, we also should consider individual cognitive variables that relate to the processing of information and dealing with conflicts.

## 1.5 Cognitive influences on learning processes

Because of the versatility of an individual's learning preferences, we also expect that specific key cognitive variables influence how learners handle controversies in discussions grounded on opposing evidences. Two interesting constructs in this regard are the individual's need for cognitive closure and their epistemic curiosity. Both constructs are closely related to the processing of new knowledge artifacts and ambiguity. Thus, we should examine these as determinants to identify the degree of support on individual needs, which visualizations of conflict awareness information can provide.

### 1.5.1 Need for cognitive closure

While socio-cognitive conflicts prompt equilibration processes in accordance with the co-evolution model, there is little to no indication of a direction or the intensity of knowledge construction or other cognitive advancements. In terms of the theory of lay epistemology, knowledge emerges by generating hypotheses that are tested deductively (Kruglanski and Freund, 1983). Under specific circumstances people tend to freeze (i.e. epistemic freezing) their hypotheses and do not participate in further testing if they cannot generate plausible alternative hypotheses or if they do not find any evidence to the contrary.

The motivation to generate new alternative hypotheses depends on the need for structure, fear of invalidity and need for specific conclusions (Kruglanski and Freund, 1983; Kruglanski and Mayseless, 1987). These motivational determinants have been summarised under the overarching construct need for cognitive closure (NCC) that can either be measured as a personality variable or in-

duced in a specific situation (Kruglanski and Webster, 1996; Webster and Kruglanski, 1994). The individual's need for cognitive closure is best described as an epistemic motivation with regard to processing and judging information or as a striving for definite and quick answers to a problem and the avoidance of ambiguity (Kruglanski and Webster, 1996). Persons with a high need for cognitive closure experience ambiguity as unpleasant and tend to be more reluctant in accepting new information that is inconsistent to their current state of knowledge. These persons are generally more susceptible to cognitive biases such as primacy effects, stereotypes and anchoring heuristics (Dijksterhuis et al., 1996; Ford and Kruglanski, 1995; Kruglanski and Webster, 1996), generate fewer hypotheses in terms of the lay epistemology and come to final judgements on the basis of easily accessible information and pre-existing knowledge constructs (Ford and Kruglanski, 1995; Webster et al., 1996).

The situational need for cognitive closure rises under circumstances when predictability or immediate action play an important role and when deeper processing and elaboration of information is required and thus associated with an increase in cognitive load (Kruglanski and Webster, 1996; Webster and Kruglanski, 1994). The latter can be the case if a person experiences a task as monotonous and fatiguing. Such mental fatigue (Webster et al., 1996) favours a higher need for cognitive closure induced by the situation. These effects get weaker if a person must justify the results and therefore has a higher fear of invalidity.

### 1.5.2 Epistemic curiosity

Whereas the individual need for cognitive closure helps us to obtain a deeper understanding of how socio-cognitive conflicts in ambiguous situations are handled, the manifestation of epistemic curiosity (EC) may predict information search patterns to support evaluation processes of such conflicts (Berlyne, 1954b). Epistemic curiosity by itself is not coercively a trait but more likely an actual state. It essentially comprises the two dimensions of diversive exploration and specific curiosity. According to Berlyne (1954a,b) curiosity is a motivational

state and is always specific to finding answers to emerging questions.

In contrast, diversive exploration arises if an individual experiences a lack of stimulation or boredom and thus starts seeking any kind of new stimulus material (Litman and Spielberger, 2003). This exploratory curiosity arises out of an information deprivation state and was later termed as D-type curiosity by (Litman, 2008).

Specific epistemic curiosity is directed towards a defined task or problem solution that is triggered by a question and can be satisfied by seeking new information or knowledge artefacts that provide a meaningful answer. In collaborative situations comprising controversies that may induce individual socio-cognitive conflicts, the level of specific epistemic curiosity could predict what kind of information a learner would seek to find the best possible solution to a concrete problem. Persons with a high situational level of epistemic curiosity tend to place more importance on the perceived ease of use and enjoyment of a socio-technical system while searching for new knowledge to solve a problem (Koo and Choi, 2010). As a result, epistemic curiosity correlates highly positive with a smaller number of perceived knowledge gaps in individual learners (Litman et al., 2005).

Epistemic curiosity as a construct can be seen as a complement to the need for cognitive closure where a person with a high need has the desire for an unspecific answer in order to reduce confusion and ambiguity (Kruglanski, 1990). Both personality variables are intentional states that trigger cognitive processes and actions that can be relevant for learning in general and specifically when collaboratively participating in knowledge construction with wikis, where controversies and cognitive conflicts are prevalent due to its specific structures.

## 1.6 Research questions and hypotheses

Our main research interest of this study was to investigate the potentials of additional visual controversy awareness information to influence and guide individual processes and outcomes in Wiki-based learning. Specifically, this study aims at factors that can facilitate knowledge construction in social

systems by inducing socio-cognitive conflicts between prior knowledge in an individual's cognitive system and the perceived controversial exchange of opposing evidence in the Wiki as social system.

### 1.6.1 Controversies and wiki activities

Research on cognitive group awareness tools has shown potentials in different contexts to foster learning processes and enable deeper elaboration (Bodemer, 2011; Buder and Bodemer, 2008; Engelmann et al., 2009; Janssen and Bodemer, 2013). Visualisations of information with regard to conflicting knowledge constellations or opinions of particular groups in online discussions can guide learners towards new points of view or to focus on yet unknown facts (Buder and Bodemer, 2008; Buder et al., 2015). Although previous research on cognitive group awareness has discussed making use of controversies in general, this research did not investigate any visualisations on the occurrence of controversies and the status of resolution yet.

Thus, we were specifically interested in answering the question: To what extent does visual controversy awareness information influence individually relevant learning-related processes in wiki-based environments?

**H1a.** We expect that by providing visual awareness information, learners will make a more focused selection of potentially important topics.

**H1b.** We also expect that by providing visual awareness information, learners will read potentially most relevant topics more intensively.

**H1c.** Furthermore, we expect that by providing visual awareness information about the most relevant topics, learners will make more extensive contributions to the Wiki.

### 1.6.2 Controversies and learning

When controversies are grounded on evidence rather than opinions socio-cognitive conflicts about contradictory opinions can be induced (Johnson et al., 2000; Lowry and Johnson, 1981). The occurrence of such conflicts and its confrontation can trigger equilibration processes that can be beneficial for learners (Bell et al., 1985; Mugny and

Doise, 1978). First qualitative content analyses of the present data showed promising direct effects on the quality of individual replies as well as indirect effects on the quality of individually performed article edits (Heimbuch and Bodemer, 2016).

Therefore, we investigated to what extent learners use visual controversy awareness information on evidence-led discussion threads to foster quantifiable learning outcomes.

**H2.** We expect that providing visual controversy awareness information on the presence of meaningful controversies will lead to a preferred selection of relevant topics and consequently result in a higher learning outcome.

### 1.6.3 Individual cognitive influences

Socio-cognitive conflicts are possible to occur in wiki-based knowledge construction, both in the individual cognitive system and in the socio-technical system through processes of externalisation and internalisation (Cress and Kimmerle, 2008). General processes of accommodation and assimilation that are triggered by conflicting knowledge have been identified in both systems (Kimmerle et al., 2011; Kump et al., 2013; Moskaliuk et al., 2009, 2012). In wiki-related research to date, individual differences regarding the processing of ambiguous information and new perspectives in controversial discussions have not been reported.

With this study, we also wanted to analyse to what extent do one's personal need for cognitive closure and epistemic curiosity affect knowledge construction processes.

**H3a.** We expect individuals who are high in need for cognitive closure and are provided with controversy awareness information and the status of the controversy's resolution will show a preference for resolved conflicts and show avoidance behaviour for ongoing, unresolved controversies.

**H3b.** We also expect individuals with high epistemic curiosity and who are provided with controversy awareness information will seek more information in peripheral topics to find new stimuli.

## 2 METHOD

### 2.1 Design and participants

We used a multivariate between-subjects design for the experiment to investigate the potential benefits of increased controversy awareness on individual learning. The single factor representing differing levels of cognitive group awareness support on controversial discussion topics, was subdivided into three levels (no additional information vs. controversy information vs. controversy + status information). The underlying Wikipedia-like structure of the talk page and discussion thread contents was identical for all three experimental groups. Participating students completed the study's tasks individually at all stages in their own wiki instance (Figure 2).

As dependent variables, we measured individual learning outcome, contribution metrics regarding article edits and discussion replies, and log data recorded by the wiki learning environment. We used an experimentally controlled setting with individuals to isolate potential effects of the deployed experimental variations of our wiki instances. Social interactions that normally occur in such a setting would potentially have led to noise due to social interactions and diversion from the intended guidance effects of controversy awareness indication. Thus, a controlled experiment enabled us to gather evidence about the possible cause-and-effect relationship if changes in the independent variable caused changes in the dependent variables.

A total number of $N = 81$ students took part in this experiment, mainly recruited from the Applied Cognitive and Media Science program (67.90%) at the University of Duisburg-Essen (Germany). The students' age range was between 18 and 30 years ($M = 21,70$; $SD = 2.76$; 58 women; 23 men). We randomly assigned all participants to one of three experimental groups, resulting in an equal distribution of 27 participants per group. Due to one-time

Artikel:"Das Aussterben der Dinosaurier" - Bearbeiten

Ein Eintrag extraterrestrischen Materials durch einen Meteoriteneinschlag auf die Erdoberfläche zum erdgeschichtlichen Zeitpunkt der Kreide-Tertiär-Grenze (vor etwa 66 Millionen Jahren) können durch Forschungsergebnisse belegt werden. Die Frage, ob dieses Ereignis tatsächlich für das massenhafte Aussterben (Extinktion) der Dinosaurier verantwortlich ist, ist noch nicht restlos geklärt.

Als möglicher Ort des Einschlags wird der Chicxulub-Krater im Golf von Mexiko nahe der Halbinsel Yucatán genannt. Kontrovers diskutierte Untersuchungen an Bohrkernen aus dem Kratergebiet durch G. Keller (2004) und M. Harting (2004) deuten allerdings darauf hin, dass der Chicxulub-Krater etwa 300.000 Jahre älter sein könnte. Dieser Einschlag könnte in diesem Fall nicht das Massenaussterben verursacht haben, das im Falle eines global verheerenden Einschlags in einem wesentlich kürzeren Zeitraum als den obigen 300.000 Jahren abgelaufen sein muss.

Ein wesentliches Indiz für die Hypothese eines Einschlags ist der ungewöhnlich hohe Iridium-Gehalt vieler Gesteine nahe der Kreide-Tertiär-Grenze. Da der Erdmantel im Vergleich zu Steinmeteoriten arm an Iridium ist, vermutet man, dass sich in diesen Schichten der beim Einschlag aufgewirbelte Staub wiederfindet. Starke Unterstützung erhält die Hypothese eines Meteoriteneinschlags durch eine Anomalie der Chrom-Isotopenverteilung in derselben Schicht, die auch die Iridium-Anomalie enthält.

Weitere mineralogische Spuren des Einschlages bestehen aus Ergebnissen der Druckwelle und der hohen Temperaturen, wie veränderte Quartzstrukturen, Zirkon, Diamantkristallen und Glaskugeln. Diese Strukturen kommen weltweit vor und nehmen quantitativ proportional mit der Entfernung vom Krater ab.

Inhaltsverzeichnis der Diskussionen

Einschlagsbild(er)
Verwendung des Begriffs KT-Impakt
Zeitpunkt des ersten Auftreten der Dinosaurier ist zu früh
Klassifikation
Alternative Theorien
Größter gefiederter Dinosaurier
"Playing God"
"Neuere" Theorien über den Meteoriteneinschlag
Theorie und Praxis
Alvarez-Hypothese
Bindestrich oder Gedankenstrich?
Ausgeglichenheit des Artikels
Gut gemacht!
Iridium im Erdreich ist ein starker Beleg für einen Meteoriten
Das hauptsächliche Impakt-Bild
Das "Datum" der KT-Extinktion ist falsch
WikiProjekt Wissenschafts-Richtlinien
Ceratopia oder Ceratopsia?
Letztendlich sind die Dinosaurier durch Staub ausgestorben
Literaturhinweise
Unverständlicher Inhalt
Verschieben auf Kreide-Paläogen-Grenze
Defekte Weblinks
Massenaussterben der Dinosaurier oder Pseudoextinktion?

**Figure 2.** Excerpt of the study's generated talk page, depicting a discussion thread comprising a resolved evidence-led controversy between two discussants in one of the experimental groups.

technical issues, resulting in missing data points, we had to perform some statistical analyses with a total number of participants of $N = 79$.

At the beginning of the experiment, we asked participants to assess their interest in the experiment's topic, prior knowledge, and confidence about related hypotheses on 6-point scales ranging from "0 = low" to "5 = high" before the experiment began. The participants' overall topic-specific interest was on a medium level ($M = 2.86$, $SD = 1.20$) and their self-assessed prior knowledge about the topic was low ($M = 1.36$, $SD = 1.15$). Differences between groups in topic-specific interest were small to non-existent, $\chi^2(2, N = 81) = 0.83$, $p = .662$, $\eta_H^2 = .01$, 90% CI [.00, .04]. Likewise, there was no meaningful difference between groups in prior knowledge, $\chi^2(2, N = 81) = 0.36$, $p = .836$, $\eta_H^2 < .01$, 90% CI [.00, .03]. Moreover, we also asked students to assess their confidence about the validity of the topic's related hypotheses, resulting in low to moderate confidence ratings (meteorite hypothesis: $M = 2.51$, $SD = 1.47$; volcano hypothesis: $M = 1.85$, $SD = 1.22$; other hypotheses: $M = 1.63$, $SD = 1.32$).

## 2.2 Material

The subject area that participants worked with for the entire study covered the contemporary theories of dinosaur mass extinction during the Cretaceous-Paleogene (K-Pg) boundary at around 66 million years ago. To provide a common ground for all participants in the three experimental groups, we gave them an initial base article on the topic prior to reading any of the talk page discussion threads. We derived this article from original sections of Wikipedia and adapted for the study's purpose. It had a total length of 220 words and was first presented immediately before the discussion's table of contents. It was accessible for a second time when participants had the task to edit the article with help of previously read contents on the article's corresponding discussions threads.

From original talk page discussions on the corresponding Wikipedia articles, we generated a total number of twenty-four discussion threads with the aim of reproducing a genuine wiki talk page environment. We made up all threads of at least two

discussants and included these on a wiki talk page to represent existing discussions that directly relate to the main article. Six of the integrated discussions comprised content-related controversies with opposing points of view supported by scientific evidence on certain aspects of the presented mass extinction theory. Peripheral topics were of structural or socio-emotional nature (e.g. flames) that are also prevalent in most online discussion forums and were completely task-irrelevant distractors.

## 2.3 Wiki environment
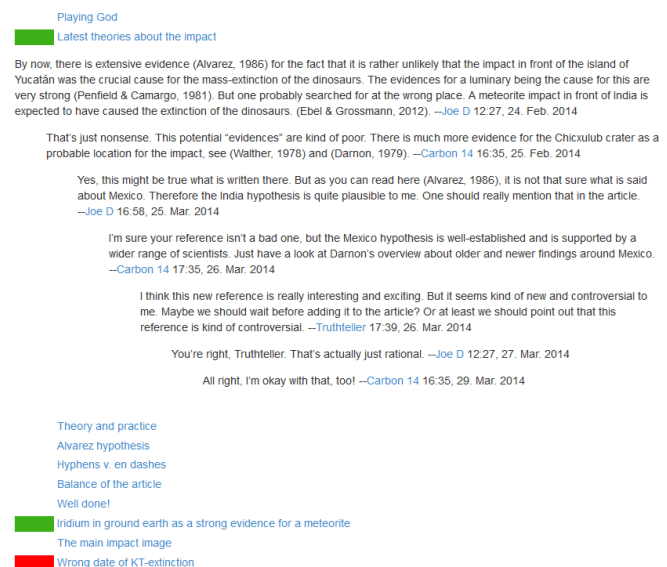


**Figure 3.** Excerpt of the study's generated talk page, depicting a discussion thread comprising a resolved evidence-led controversy between two discussants in one of the experimental groups.

For the experiment, we created a structured Wikipedia-like learning environment. All pages in this study were simplified versions of Wikipedia article and talk page views, with possibly distracting items like navigation panes or logos removed. Additionally, we altered the talk page from the original wiki design to enable recordings of several log data on how participants navigate through the talk page and to examine the effectiveness of our controversy awareness visualisation. For that reason, we integrated the discussion threads into the page's table of contents and made them expandable and collapsible by clicking a desired thread title (Figure 3).

**No highlighting (Control).** The representation for the non-supported group was inspired by a standard wiki talk page and did not provide any further information on the contents of a discussion thread on first sight other than its title.

**Controversy highlighting.** For the first experimental group we added a supplementary external representation. A single-coloured indicator highlighted discussion threads on the talk page that comprised meaningful and relevant conflicting points of view that were primarily led by scientific evidence.

**Controversy + status highlighting.** In the second experimental group we subdivided the external representation into two classes of conflict. Two indicator colours informed participants whether a discussion thread contained unresolved conflicting points of view (red) or an already resolved conflict or consensus (green).



**Figure 4.** Illustration of a talk page excerpt for all groups: no highlighting (top) vs. controversy highlighting (middle) vs. controversy + status highlighting (bottom).

Two of the three experiment's groups were provided with additional visual information on controversial discussion topics. Figure 4 provides an illustration of the differences between the three groups, which we briefly describe in the following. Both experimental groups received equal explanations about the meaning of the coloured indicators in a mandatory tutorial.

## 2.4 Measurements

**Measuring learning success.** In order to measure individual learning success on the study's topic of dinosaur extinction events, we developed a post-experimental multiple-choice knowledge test, as such tests are still widely used to quantify learning results in collaborative and individual settings (Kent et al., 2016). In total the test comprised fifteen questions on the subject matter. Three of those questions were answerable with only the information provided in the original base article and therefore were solvable without having read any of the discussion threads. We constructed the remaining twelve questions in a way that each of the existing six controversial discussion topics were covered by exactly two different questions. Every question had four answering options comprised of three distractors and one attractor (Table 1). We used the test's overall sum as a general indication for individual learning success on the topic. For further detailed analyses, we generated scores for article and discussion-related questions. We also subdivided the discussion-related questions into scores for questions matching unresolved or resolved controversial discussions.

**Measuring selection behaviour.** Our modified wiki environment enabled us to record a participant's topic selection behaviour by measuring individual clicks on a discussion's thread title. Clicking on a title was necessary to select and expand a thread and thus unveil its contents. By design only one topic could be open for reading at a time and had to be collapsed by clicking again before proceeding to the next topic of interest. For further processing click counts that triggered only the expanding/opening events were recorded in the log.

**Measuring reading times.** Discussion reading times were measured by calculating the differences between opening and closing times. If a topic was opened and closed more than once, we also recorded cumulative reading times for each discussion thread.

**Measuring sequential patterns.** We recorded for each opened topic the title and index number of the previously selected topic to perform sequential pattern analyses. If no topic was preceding, we marked this as the initial topic that a participant se-

**Table 1.** Example questions/statements and answers of the 15-item multiple-choice test.

| Sample question or statement | Answer options | Relates to |
|---|---|---|
| The fact that birds descended from dinosaurs is an indication that... | (a) ...a mass-extinction event could not have happened.<br>(b) ...birds cannot directly be descendants of dinosaurs.<br>**(c) ...the scientific evidence is inconclusive with regard to the origins.**<br>(d) ...only pterosaurs could have survived any event of mass-extinction. | unresolved controversy |
| A meteorite impact that triggered a nuclear winter would have most likely caused... | (a) ...that immediately afterwards plant eating dinosaurs (herbivores) were extinct.<br>(b) ...that immediately afterwards meat eating dinosaurs (carnivores) were extinct.<br>(c) ...that immediately afterwards all plants were extinct.<br>**(d) ...secondary effects that could have been responsible for the final extinction.** | resolved controversy |
| The following mineralogical trace is NOT an indicator for an impact: | (a) iridium<br>(b) glass<br>**(c) platinum**<br>(d) diamonds | original article |

*Note*. Answer options in bold print represents the question's attractors.

lected first and marked it as the start of a sequence. For each experimental group sequence databases were created to perform analyses for discovering all frequent closed sequential patterns using the CM-ClaSP algorithm (Fournier-Viger et al., 2014).

**Learning-related cognitive variables.** Need for cognitive closure was measured with the 16-NCCS (Schlink and Walther, 2007). This validated questionnaire comprises 16 statements (e.g. "I prefer tasks that precisely define what needs to be done and how it has to be done.") that participants had to rate on a 6-point scale ranging from fully disagree to fully agree. Epistemic curiosity was measured with the Epistemic Curiosity Scale (Renner, 2006). This validated questionnaire measures with a total of 10 items diversive and specific epistemic curiosity. Each subscale consists of 5 statements (e.g. "When I learn something new, I like to learn even more about it.") and were rated on a 4-point scale ranging from fully disagree to fully agree.
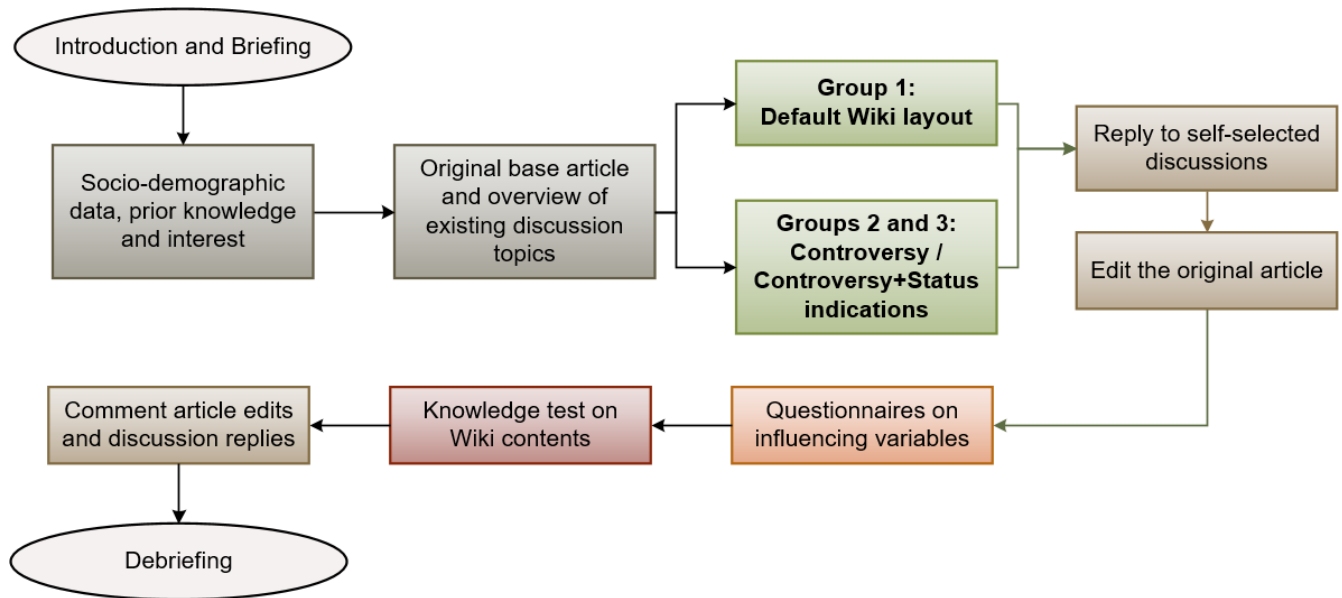
## 2.5 Procedure

We conducted the experiment in an individual setup with up to four participants at the same time, separated by divider panels. Prior to their wiki tasks students completed a mandatory tutorial about the environment's usage and were informed about the study's goals, i.e. to learn more about the subject matter and help to (re-)construct existing knowledge artefacts by contributing to one's personal instance of a wiki article and discussion page snapshot. The tutorial introduced to them the special structure of the wiki-like environment with its distinct layers and had an exploration phase to familiarise themselves with the environment, especially with the structure of the modified talk page. In addition to that, both experimental groups received information about the meaning of the coloured indicators corresponding to their group condition, without further explicit instructions of if or how they should use these indicators. Before the experimental phase started all groups received the same instructions about the following pages and associated tasks.

The control group and both experimental groups had the same task of editing an initial Wikipedia-like base article about the mass extinction of dinosaurs and participating in up to three of the existing discussions. Since they did not receive any additional material regarding the topic, participants received the instructions that the contents of the discussions contain sufficient material to enrich the original article. So, participants could find the information basis to fulfil the editing task on the corresponding article talk page with its twenty-four discussion threads that we generated as the additional knowledge base. At all experimental stages participants had mandatory time limits. They had maximum of five minutes for an initial read of the wiki article and a maximum of ten minutes for selecting and reading threads on the corresponding discussion page.

After reading the article and discussions participants had to contribute to the wiki by first replying to three discussion threads of choice. We did not further instruct participants on what kind of reply they should made for enabling them to solve or start a controversy or any other kind of possible off-task reaction that typically can be found in online discussions. Subsequently, participants were asked to work on the original article supported by the contents of the previously read discussions. In the contribution phase, they had more loose time limits for editing the article and contributing to the discussions compared to the initial reading stage. We suggested and visualised the same time limits as in the reading phase before, but instead of forcing them to the next the wiki environment automatically prompted them when time was up and kindly asked to finish the task as soon as possible.

Followed by the contribution and revision stage, the questionnaires to determine the individual levels of need for cognitive closure (16-NCCS) and epistemic curiosity (ECS) were presented. After filling out these questionnaires participants had to answer a multiple-choice test about the study's contents. Finally, as an additional manipulation check, we asked participants to shortly sum up in open text fields why they have selected certain discussions to comment on and what led to the final decisions for the resulting article edits (cf. Figure 5).

**Figure 5.** Workflow diagram visualising the study procedure with its central stages.

## 3 RESULTS

**Wiki activities.** In the following subsections, we present our findings of the participants' activities at different stages of the experimental wiki by analysing the recorded log data for reading and editing on the article and discussion levels. Effects as proportions of variance ($\eta^2$, $R^2$) are reported with 90% confidence intervals, for effect sizes based on standardised means ($d$, $r$) 95% confidence intervals are used (Steiger, 2004). If the data violated the assumption of homogeneity of variance, we report statistics of the Brown-Forsythe test of variances.

**Discussion topic selections.** We analysed the participants' selection of discussion threads based on recorded click events. Each participating student selected on average $M = 11.86$ ($SD = 5.27$) discussion threads. Analysis of variance using planned comparisons with an orthogonal Helmert contrast revealed that in the experiment's unsupported control group, students selected more discussion threads on the article's talk page compared to both supported conditions, $F(2, 78) = 3.80$, $p = .027$, $\eta^2 = .09$, 90% CI [.01, .18]. The first comparison between the unsupported group and both supported groups showed a difference (Contrast Estimate = 2.76, $SE = 1.20$, $p = .024$), whereas the

contrast estimate for the comparison between the two supported groups differed less (Contrast Estimate = 2.11, $SE = 1.39$, $p = .132$). To further analyse our inferential findings on selection behaviour in the different experimental groups, we performed sequential pattern mining with SPMF using the CM-ClaSP algorithm (Fournier-Viger et al., 2014). The main results of the analysis are shown in Table 2.

**Table 2.** Most frequent closed sequential patterns discovered by the CM-ClaSP algorithm.

| Highlight (Goup) | Thread sequence | Pattern frequency |
|---|---|---|
| No | 1, 2, 3, **5**, 7 | 14 |
| Controversy | **5, 8, 14, 16, 19** | 14 |
| + Status | **5, 8, 14** | 16 |
| | **8, 14, 19** | 15 |
| | **5, 8, 19** | 13 |

*Note.* Content-related thread numbers are highlighted in bold print.

Participants who did not receive additional awareness information on the discussion type showed a tendency to follow a top-down reading strategy, beginning by reading the very first discussion thread

on the experimental wiki talk page. In contrast, members of both supported awareness visualisation groups primarily focused on selecting the most relevant topics first. Both quantitative and qualitative analyses support hypothesis H1a on a more selective behaviour in either visually supported group.

**Wiki reading times.** Overall, each wiki participant spent on average $M = 229.01$ s ($SD = 42.52$) on reading the original article and $M = 488.37$ s ($SD = 73.13$) on reading the corresponding talk page. Regarding the time spent on the entire discussion page a small to medium effect could be found among the three groups, $F(2, 70.72) = 1.13$, $p = .330$, $\eta^2 = .03$, 90% CI [.00, .09]. More detailed analyses of categorised reading times relative to the entire discussion page reception revealed several differences. As a main interest for the study, analysing reading times with a focus on resolved and unresolved controversies using Helmert contrasts, we found a difference between groups with a large effect, $F(2, 71.43) = 21.08$, $p < .001$, $\eta^2 = .35$, 90% CI [.20, .46]. The first comparison between the unsupported group and both supported groups showed a difference (Contrast Estimate = -0.29, $SE = 0.05$, $p < .001$), whereas the contrast estimate for the comparison between the two supported groups did not differ substantially (Contrast Estimate = -0.05, $SE = 0.05$, $p = .374$). Results of detailed analyses for all three discussion categories and descriptive statistics are in Table 3.

Analyses of pooled absolute reading times on the study's topics of relevance showed differences in individual thread reading and selection behaviour dependent on the discussion category and whether the participant received additional awareness information or not. Participants spent less time on reading topics comprising any kind of temporary consensus when no additional awareness visualisation was provided ($M = 103.74$, $SD = 60.21$) compared to the controversy highlighting groups ($M = 196.26$, $SD = 84.96$), $t(69.66) = -5.65$, $p < .001$, $d = -1.33$, 95% CI [- 1.84, - 0.82]. Accordingly, we found a difference in reading times of unresolved controversial discussions between participants of the control group ($M = 102.48$, $SD = 38.32$) and members of

the controversy highlighting groups ($M = 161.06$, $SD = 75.10$), $t(78.94) = -4.65$, $p < .001$, $d = -1.10$, 95% [- 1.58, - 0.60]. Conversely, we found that members in the control group ($M = 292.37$, $SD = 107.83$) read peripheral discussions for longer than participants in the controversy highlighting groups ($M = 125.94$, $SD = 113.90$), $t(79) = 6.31$, $p < .001$, $d = 1.49$, 95% CI [0.97, 2.00]. These findings, visually represented in Figure 6, support hypothesis H1b on more intensive reading of relevant topics through increased awareness.
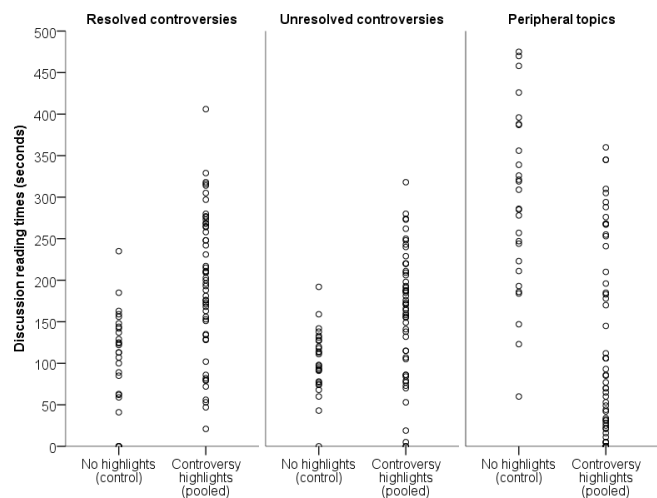


**Figure 6.** Distributions of absolute reading times in seconds of differing discussion thread categories. ** $p < .01$, *** $p < .001$.

**Wiki contributions.** Participants' tasks in this study were to comment on discussion threads on the talk page and to revise the original article after reading selected discussion threads. The final article revision lengths ranged from 218 to 434 words (original article: 220 words), with an average length of $M = 279.89$ ($SD = 37.13$). Control group members wrote the shortest article with an average of $M = 274.88$ ($SD = 27.39$) words. On a descriptive level, the more detailed awareness highlighting participants received, the more additions to the final article were made, with an average of $M = 279.33$ ($SD = 30.30$) words in the group with controversy highlighting and respectively an average article length of $M = 285.46$ ($SD = 50.37$) in the group receiving additional controversy status information. A

one-way ANOVA did not reveal substantial differences between the three groups, $F(2, 56.36) = 0.52$, $p = .596$, $\eta^2 < .01$, 90% CI [.00, .06]. Hypothesis 1c on differences in article length between the experimental groups cannot be supported by these results. Analysing the amount of time participants took to write comments on up to three self-chosen discussions using planned comparisons with an orthogonal Helmert contrast, we found a moderate effect, $F(2, 78) = 2.38$, $p = .099$, $\eta^2 = .06$, 90% CI [.00, .14]. The first comparison between the unsupported group and both supported groups showed a difference (Contrast Estimate = -61.41, $SE$ = 29.54, $p = .041$), whereas the contrast estimate for the comparison between the two supported groups did not differ substantially (Contrast Estimate = 22.67, $SE$ = 34.12, $p = .508$). Multivariate Helmert contrasts indicate a large main effect for the groups, $\lambda = 0.68$, $F(6, 148) = 5.21$, $p < .001$, $\eta_p^2 = .17$, 90% CI [.06, .24]. Detailed contrast comparisons are shown in

Table 4. Participants without visual controversy awareness information replied more frequently to peripheral discussions instead of relevant controversial discussions, $F(2, 76) = 16.73$, $p < .001$, $\eta_p^2 = .31$, 90% CI [.16, .41].

**Learning outcome.** We analysed if providing any kind of controversy awareness support led to a generally positive learning outcome that should have manifested in a higher knowledge test score. On a descriptive level, all three groups showed only fractional differences with $M_1 = 9.85$ ($SD_1 = 1.90$), $M_2 = 9.78$ ($SD_2 = 2.17$) and $M_3 = 9.93$ ($SD_3 = 2.32$). Multivariate analysis of variance could find a small to moderate effect between the three investigated groups on a global level, $\lambda = 0.93$, $F(6, 152) = 0.97$, $p = .447$, $\eta^2 = .04$, 90% CI [.00, .07]. More details on the learning outcomes about the different categories of the questions on the multiple-choice test are presented in Table 5. Separate independent

**Table 3.** In-depth analyses on the relative reading times of the different topic categories.

| Group | Controversial discussion | $M$ ($SD$) | $F(2, 78)$ | $p$ | $\eta^2$ | 90% CI |
|---|---|---|---|---|---|---|
| No highlight | Resolved | .19 (.12) | 14.88 | $< .001$ | .28 | [.13, .39] |
| | Unresolved | .19 (.07) | | | | |
| | Peripheral | .53 (.17) | | | | |
| Controversy highlight | Resolved | .33 (.15) | 8.69 | $< .001$ | .18 | [.06, .29] |
| | Unresolved | .32 (.12) | | | | |
| | Peripheral | .25 (.22) | | | | |
| + status highlight | Resolved | .41 (.18) | 21.06 | $< .001$ | .35 | [.20, .46] |
| | Unresolved | .29 (.15) | | | | |
| | Peripheral | .21 (.19) | | | | |

**Table 4.** Multivariate Helmert contrast comparisons on replies.

| Contrasted groups | Replying to | Contrast Estimate ($SE$) | $p$ |
|---|---|---|---|
| No highlight vs. Controversy highlight | Resolved | -0.74 (0.20) | $< .001$ |
| | Unresolved | -0.34 (0.20) | .084 |
| | Peripheral | 1.19 (0.21) | $< .001$ |
| Controversy vs. + Status highlight | Resolved | 0.08 (0.23) | .722 |
| | Unresolved | 0.14 (0.22) | .543 |
| | Peripheral | -0.24 (0.24) | .315 |

ANOVAs did not indicate substantial differences for any question type reference and no more than small effects.

In further analyses with respect to the experiment's categories of controversial discussion types (resolved vs. unresolved vs. peripheral), we investigated the test scores among the three conditions considering the categorised discussion reading times as mediators in a parallel multiple single-step mediation analysis using the PROCESS macro for SPSS (Hayes, 2013). Although the total effect model encompassed just a small overall effect, $F(1, 79) = 0.46$, $p = .501$, $R^2 = .01$, 90% CI [.00, .08], the analysis revealed an increase in learning outcome for participants receiving controversy awareness information ($a_2 = 24.20$, $p < .001$) mediated by spending more time on reading unresolved controversies ($b_2 = 0.01$, $p < .001$) (Figure 7).

A bias-corrected bootstrap confidence interval (95% CI) for the indirect effect ($a_2b_2 = 0.21$) based on 1000 bootstrap samples was entirely above zero (0.04 to 0.46). There was no evidence that the visual representation of controversy awareness information influenced the learning outcome independent of its effect on reading intensity of unresolved controversies ($c' = -0.10$, $p = .733$). These results in conjunction with the reported analysis of variance partly support hypothesis H2 of increasing individual learning outcome by providing controversy awareness indicators.
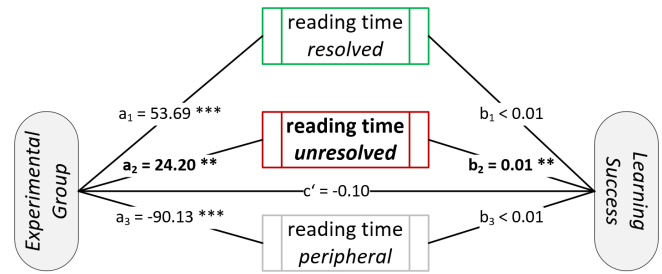


**Figure 7.** Multiple single-step mediation model on the multiple-choice test results as an outcome variable. Unstandardised $a$ and $c'$ weights are measured in seconds. Unstandardised $b$ weights are measured in number of correct answers. ** $p < .01$, *** $p < .001$.

**Individual cognitive influences.** We further investigated potential influences of the cognitive variables of interest, i.e. epistemic curiosity and need for cognitive closure, on topic selection, reading and discussion reply frequency on unresolved or resolved controversies. For analysing the effect of need for cognitive closure in interaction with the provision of visual controversy awareness support on reading times of relevant discussion threads, we conducted a 3 x 2 MANCOVA on replying behaviour to the study's discussion types as dependent variables and the need for cognitive closure as covariate. The multivariate effect of the need for cognitive closure on replying behaviour was moderate, $\lambda = 0.93$, $F(3, 74) = 1.89$, $p = .138$, $\eta_p^2 = .07$, 90% CI [.00, .16] (cf. Figure 8).

**Table 5.** In-depth analyses on the number of correct answers in the knowledge test.

| Group | Reference | $M$ ($SD$) | $F(2, 78)$ | $p$ | $\eta^2$ | 90% CI |
|---|---|---|---|---|---|---|
| No highlight | Original article | 2.52 (0.70) | 1.40 | .252 | .03 | [.00, .11] |
| | Resolved | 2.19 (0.83) | | | | |
| | Unresolved | 2.26 (0.76) | | | | |
| Controversy highlight | Original article | 3.85 (0.95) | 0.41 | .662 | .01 | [.00, .05] |
| | Resolved | 3.70 (1.07) | | | | |
| | Unresolved | 3.96 (1.13) | | | | |
| + Status highlight | Original article | 3.48 (1.28) | 0.66 | .520 | .02 | [.00, .07] |
| | Resolved | 3.89 (1.25) | | | | |
| | Unresolved | 3.70 (1.38) | | | | |

The univariate effect of the need for cognitive closure on replying to unresolved controversies was moderate, $F(2, 76) = 4.42$, $p = .015$, $\eta_p^2 = .05$, 90% CI [.01, .20], indicating that the replies to these topics depend on the individual need for cognitive closure and the type of provided controversy awareness information. Univariate effects of the need for cognitive closure on replying to resolved and peripheral topics were small and trivial with $F(2, 76) = 1.73$, $p = .184$, $\eta_p^2 = .02$, 90% CI [.00, .12], respectively $F(2, 76) = 0.04$, $p = .961$, $\eta_p^2 < .01$.

For epistemic curiosity, we could identify several effects for individual levels of epistemic curiosity and topic selection behaviour as well as for correlations with reading times of different discussion categories. In total, we found a small to moderate effect that the more epistemically curious a participant was, the more effort was invested in seeking additional information. First, further discussion topics were selected, $r(79) = .26$, $p = .010$, 95% CI [.04, .45]. Second, more time on reading additional threads was spent, $r(79) = .21$, $p = .030$, 95% CI [-.01, .41]. More detailed correlations, subdivided into the study's groups of controversy awareness visualisations and discussion categories are presented in Table 6 for topic selection behaviour and Table 7 for relative discussion reading times. The results of our analyses on the influencing variables support both hypotheses H3a (need for cognitive closure) and H3b (epistemic curiosity).
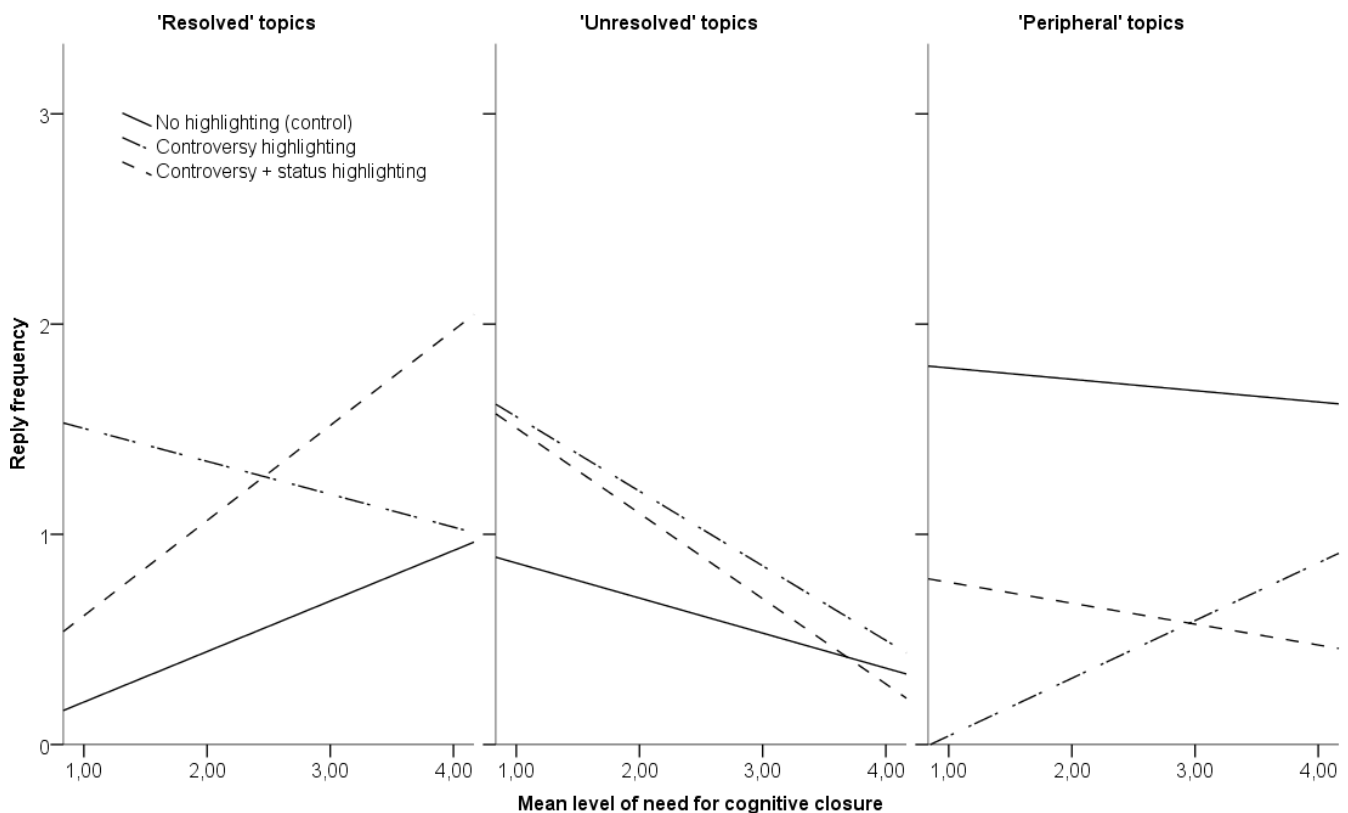


**Figure 8.** Multivariate interaction graphs between groups and the individual need for cognitive closure on replies within the study's different discussion types (resolved vs. unresolved vs. peripheral).

**Table 6.** Correlations between epistemic curiosity and topic selections.

| Group | Discussion type | $r(79)$ | $p$ | 95% CI |
|---|---|---|---|---|
| No highlight | Overall | -.41 | .017 | [-.58, -.21] |
| | Controversies | .16 | .212 | [-.06, .37] |
| | Peripheral | -.44 | .012 | [-.60, -.25] |
| Controversy highlight | Overall | .52 | .003 | [.34, .66] |
| | Controversies | -.03 | .434 | [-.25, .19] |
| | Peripheral | .49 | .005 | [.30, .64] |
| + Status highlight | Overall | .59 | .001 | [.43, .72] |
| | Controversies | .09 | .327 | [-.13, .30] |
| | Peripheral | .53 | .002 | [.35, .67] |

**Table 7.** Correlations between epistemic curiosity and topic reading times.

| Group | Discussion type | $r(79)$ | $p$ | 95% CI |
|---|---|---|---|---|
| No highlight | Resolved | -.01 | .491 | [-.25, .21] |
| | Unresolved | -.11 | .302 | [-.32, .11] |
| | Peripheral | .05 | .395 | [-.17, .27] |
| Controversy highlight | Resolved | -.45 | .009 | [.26, .61] |
| | Unresolved | -.23 | .121 | [-.43, -.01] |
| | Peripheral | .46 | .008 | [.27, .62] |
| + Status highlight | Resolved | -.45 | .009 | [-.60, -.26] |
| | Unresolved | .01 | .481 | [-.21, .23] |
| | Peripheral | .31 | .057 | [.10, .49] |

# 4 DISCUSSION

Knowledge construction and learning within wiki environments presents users as learners with major challenges. Talk page discussions can become exceedingly long and due to their special structure as a normal wiki page, instead of classical threaded discussions in online forums, potentially interested readers or new discussants can be overwhelmed and feel lost in the amount of potentially relevant or irrelevant information. Consequently, significant knowledge artefacts could remain completely undiscovered and unknown to an interested learner, such as deeply elaborated discussions on controversial aspects of a topic that entirely disappear in the depths of a talk page. We have argued that providing cognitive awareness information as implicit representational guidance in the form of supportive visual indications of controversial discussion contents could lead an interested reader to a more focused selection of important knowledge artefacts. Furthermore, we expected a positive learning outcome for learners by benefiting from the reception of socio-cognitive conflicts that are positively associated within collaborative knowledge construction settings. The underlying processes that affect the effectiveness of the investigated guidance mechanisms were expected to be influenced by different inter-individual cognitive variables, that is an individual's capabilities to deal with ambiguous information and personal preferences in information-seeking behaviour regarding epistemic knowledge gains.

To answer our first research question on the potential for guidance of controversy awareness information on the discussion thread level, we investigated the influences on the working processes in wiki-based knowledge construction. Therefore, we investigated whether individual participants who received any kind of additional visual structuring aids in a private wiki instance focused more effectively on relevant discussions about meaningful contents and specifically led by evidence. Analyses of variance of the selection and reading behaviour of the experiment's topics suggested that learners were following a desired selection pattern towards the most

meaningful discussions. Due to a lack of structuring aids, participants of the control group were less focused and selected more talk threads that did not contain any meaningful discussions. Thus, participants of the control group had less remaining time to seek and identify discussions that were relevant for revising the article. Therefore, they were not able to read the content-related meaningful controversies as extensively as participants of both supported groups. Indications of a more unstructured information search behaviour in the control group were additionally supported by analysing patterns of discussion topic selection.

Sequential pattern mining showed that in both supported groups a focused selection of the most relevant topics occurred in contrast to a sequential reading strategy used by the control group, who had no further indications of what contents were hidden inside a topic's discussion thread. That means when wiki learners received additional awareness information about controversies, it was used by participants and worked as intended, as a structuring aid. Regarding article revision, we expected members in both supported groups to identify more relevant evidence to enrich the original article with new knowledge artefacts and thus produce more text, in accordance to the results found by Wichmann and Rummel (2013). While quantitative text production does not generally indicate a higher text quality, in our setting it indicates that learners identified more important evidence that could extend the article meaningfully. However, we only found a minimal tendency on a descriptive level to produce more text depending on support, but this result did not reach statistical significance.

With our second research question, we investigated whether visual awareness information on the occurrence of resolved and unresolved controversies that can be found inside wiki talk pages lead to measurable differences in the learning outcome about the subject matter. We compared two varying degrees of controversy awareness representations with a control group that had no further information on the discussions' contents. Regarding learning outcomes, analyses on a general level did not reveal a difference among the three groups. Consider-

ing the different types of implemented discussions within the experimental talk page, i.e. resolved vs. unresolved controversies and peripheral topics, a parallel multiple mediation analysis identified a meaningful effect. Students benefited more in terms of learning success from an increased degree of guidance towards conflicts arisen from content-related controversies, assuming they spent more time on reading unresolved controversial discussions more extensively.

However, a longer reading times of resolved controversial topics did not lead to measured knowledge gains, even though both types of controversies had an equal number of test questions. One possible explanation for not reaching conventional levels of statistical significance on the resolved controversies path in the mediation model could be that a relative imbalance in the distribution of the need for cognitive closure in the current student sample, who predominantly favoured controversial opinions. Another reason for not finding an effect of the resolved controversy reception could be that presenting information associated with negativity and conflicts triggers increased cognitive activity (van Marle et al., 2009) and elicit more arousal leading to better memorisation (Bradley and Lang, 2007) that can be explained by enhanced visual attention processes (Calvo and Lang, 2004; Nummenmaa et al., 2006). Nevertheless, first qualitative investigations of the individual wiki contributions showed some positive and promising trends in favour of both experimental groups (Heimbuch and Bodemer, 2016). Students who received visual guidance on controversial discussions produced more extensive and more comprehensive discussion replies of higher quality compared to the control group. Beyond such direct effects of controversy awareness implementation on the talk page, we could also see some positive indirect carry-over effects to the article edits. Students in both experimental groups performed more extensive and meaningful edits by including references, adding, or restructuring knowledge artefacts and keeping a neutral point of view by equally addressing opposing evidence on the subject matter.

To answer our third research question whether cognitive variables that have been identified as rele-

vant for learning in contexts where socio-cognitive conflicts can occur, we investigated potential influences of these variables on topic selection and replying behaviour. Therefore, we specifically analysed the influential effects of need for cognitive closure, which is closely related to one's personal preference for or against ambiguity, and the extent of epistemic curiosity, which is closely related to exploratory information seeking behaviour. Students with a high need for cognitive closure favoured replying to controversies that were resolved during the discussions when provided with controversy awareness visualisations. This is in total accordance with previous research that these individuals prefer to avoid ambiguous situations and information (Schlink, 2009) as well as being more impatient to come to more complex conclusions that require extensive information processing capabilities and the analysis of multiple interpretations of facts (Kruglanski and Mayseless, 1987; Kruglanski and Webster, 1996). As expected, the largest effect for the need for cognitive closure impact on replying behaviour could be seen for the experimental group that was provided with visual information on the occurrence of a controversy and its status. Students with low need for cognitive closure scores replied equally to resolved and unresolved controversies. When wiki learners did not receive controversy awareness support, participants replied primarily to peripheral discussions, regardless of the personal need for cognitive closure.

Regarding the effects of epistemic curiosity, we found small to moderate effects for selecting more additional topics as well as small to moderate effects for spending more time on reading peripheral discussions. In general, when visual controversy awareness support was provided, the higher a student scored on the epistemic curiosity scale, the more time they spent in reading additional discussion threads that were not necessarily important to perform best in the study's revision task. Due to an increased focus on what is relevant for the writing tasks, students who received awareness information had more time and resources to engage in further explorations of the wiki contents. Participants with high levels of epistemic curiosity who were in the

control group without controversy awareness were inhibited in their interest to search for new stimuli in other discussions.

In this current study, we showed that modifying wiki talk pages with visual controversy awareness information implicitly guides readers towards meaningful controversial discussions. These can be fruitful sources of information for knowledge construction processes regarding fostering beneficial socio-cognitive conflicts within learners. The study was explicitly designed for addressing learners in higher educational settings such as universities, where wikis can be deployed as course-specific closed mandatory group writing assignments. Therefore, our findings should be treated with caution if they should be transferred to different educational contexts or even trying to implement the presented functionalities of this study into open collaborative platform such as Wikipedia or Wikiversity. To allow more generalised conclusions for these environments, quasi-experimental or even field studies with samples of the corresponding wiki audience would be valuable.

Furthermore, we conducted this study as a laboratory experiment with the advantages of randomisation and control of variables, but with the disadvantages of lacking ecological validity, but not necessarily external validity in terms of population validity. Much of our student sample is typical for numerous student populations. Thus, we believe that the fundamental effects of implicit guidance should be replicable in samples from other student populations because they do not require specific prerequisites tied to certain selection or sampling criteria. Additional guidance measures as presented can be helpful to reduce individual cognitive costs of information-seeking and coordination processes, especially for small learning groups with limited time frames to fulfil a task. Depending on the degree of time constraints for working on a specific wiki task assignment, students might not have the minimal required time to develop a shared mental model that would render coordination as unnecessary (Kittur and Kraut, 2008). Because of such implicit guidance implementations, individual students could potentially have more free cognitive resources that they can beneficially use for collaboration. Regarding the cognitive variables that we have measured, our findings confirmed that individual variations impact the learners' seeking and selection behaviour and correspondingly have an influence on the final learning outcome. Especially our analyses on the students' need for cognitive closure suggest that this variable should be considered for further research that is focused on the provision of supporting guidance in collaborative writing environments where controversies and conflicts occur.

# 5 OUTLOOK

Although we were able to find some promising results with regard to learning in this experimental study and also to higher quality contributions (Heimbuch and Bodemer, 2016), to date we can only cautiously infer from the current quantitative data analyses that the provision of controversy awareness information leads to qualitatively better contributions to the wiki article and talk page threads. Therefore, more detailed content analyses of the produced knowledge artefacts are required in order to investigate if the additional support regarding the reception of this study's controversy types led to substantial differences in text production quality and elaborations of discussion replies. Furthermore, such analyses should be conducted in conjunction with the individuals' personal need for cognitive closure, which was identified as a meaningful determinant to guide one's information-seeking behaviour when dealing with ambiguous contents. The presented approach might be enriched by developing and implementing methods of automating the generation of visualisations representing controversy status information on wiki talk page discussions with the help of natural language processing (Bär et al., 2011; Daxenberger et al., 2014). Collaborations in this area between computational and psychological researchers could be fruitful to draft and test cognitive group awareness tools focused on evidence-led controversies for real-world deployment opportunities, such as on Wikipedia or Wikiversity talk pages. Beyond usage scenarios in wikis, we would be interested in investigating the potential of con-

troversy awareness information in other contexts where learning materials can be socially shared and discussed.

## REFERENCES

Alamargot, D. and Chanquoy, L. (2001). *Through the models of writing*, volume 9 of *Studies in Writing*. Springer Netherlands, Dordrecht.

Beers, P. J., Boshuizen, H. P. A. E., Kirschner, P. A., and Gijselaers, W. H. (2005). Computer support for knowledge construction in collaborative learning environments. *Computers in Human Behavior*, 21(4):623–643.

Bell, N., Grossen, M., and Perret-Clermont, A.-N. (1985). Sociocognitive conflict and intellectual growth. *New Directions for Child and Adolescent Development*, 1985(29):41–54.

Berlyne, D. E. (1954a). An Experimental Study of Human Curiosity. *British Journal of Psychology. General Section*, 45(4):256–265.

Berlyne, D. E. (1954b). A theory of human curiosity. *British Journal of Psychology. General Section*, 45(3):180–191.

Bodemer, D. (2011). Tacit guidance for collaborative multimedia learning. *Computers in Human Behavior*, 27(3):1079–1086.

Bodemer, D. and Dehler, J. (2011). Group awareness in CSCL environments. *Computers in Human Behavior*, 27(3):1043–1045.

Bradley, M. M. and Lang, P. J. (2007). The International Affective Picture System (IAPS) in the study of emotion and attention. In *Handbook of Emotion Elicitation and Assessment*, pages 29–46. Oxford University Press, Oxford, UK.

Bromme, R., Hesse, F. W., and Spada, H., editors (2005). *Barriers and biases in computer-mediated knowledge communication - and how they may be overcome*, volume 5 of *Computer-Supported Collaborative Learning Series*. Springer, New York, NY.

Buder, J. and Bodemer, D. (2008). Supporting controversial CSCL discussions with augmented group awareness tools. *International Journal of Computer-Supported Collaborative Learning*, 3(2):123–139.

Buder, J., Schwind, C., Rudat, A., and Bodemer, D. (2015). Selective reading of large online forum discussions: The impact of rating visualizations on navigation and learning. *Computers in Human Behavior*, 44:191–201.

Bär, D., Erbs, N., Zesch, T., and Gurevych, I. (2011). pages 74–79, Stroudsburg, PA, USA. Association for Computational Linguistics.

Calvo, M. G. and Lang, P. J. (2004). Gaze Patterns When Looking at Emotional Pictures: Motivationally Biased Attention. *Motivation and Emotion*, 28(3):221–243.

Cress, U. and Kimmerle, J. (2008). A systemic and cognitive view on collaborative knowledge building with wikis. *International Journal of Computer-Supported Collaborative Learning*, 3(2):105–122.

Daxenberger, J., Ferschke, O., Gurevych, I., and Zesch, T. (2014). DKPro TC: A Java-based Framework for Supervised Learning Experiments on Textual Data. *Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics. System Demonstrations*.

De La Paz, S., Swanson, P. N., and Graham, S. (1998). The contribution of executive control to the revising by students with writing and learning difficulties. *Journal of Educational Psychology*, 90(3):448–460.

Dijksterhuis, A., van Knippenberg, A., Kruglanski, A. W., and Schaper, C. (1996). Motivated Social Cognition: Need for Closure Effects on Memory and Judgment. *Journal of Experimental Social Psychology*, 32(3):254–270.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. *Three worlds of CSCL. Can we support CSCL?*, pages 61–91.

Doise, W., Mugny, G., and Perret-Clermont, A.-N. (1975). Social interaction and the development of cognitive operations. *European Journal of Social Psychology*, 5(3):367–383.

Engelmann, T., Dehler, J., Bodemer, D., and Buder, J. (2009). Knowledge awareness in CSCL: A psychological perspective. *Computers in Human Behavior*, 25(4):949–960.

Erkens, G., Jaspers, J., Prangsma, M., and Kanselaar, G. (2005). Coordination processes in computer supported collaborative writing. *Computers in Human Behavior*, 21(3):463–486.

Fischer, F., Kollar, I., Stegmann, K., and Wecker, C. (2013). Toward a Script Theory of Guidance in Computer-Supported Collaborative Learning. *Educational Psychologist*, 48(1):56–66.

Flower, L. and Hayes, J. R. (1981). A cognitive process theory of writing. *College Composition and Communication*, 32(4):365–387.

Ford, T. E. and Kruglanski, A. W. (1995). Effects of Epistemic Motivations on the Use of Accessible Constructs in Social Judgment. *Personality and Social Psychology Bulletin*, 21(9):950–962.

Fournier-Viger, P., Gomariz, A., Campos, M., and Thomas, R. (2014). Fast Vertical Mining of Sequential Patterns Using Co-occurrence Information. In Tseng, V. S., Ho, T. B., Zhou, Z.-H., Chen, A. L. P., and Kao, H.-Y., editors, *Advances in Knowledge Discovery and Data Mining*, pages 40–52. Springer International Publishing.

Graham, S. (1997). Executive control in the revising of students with learning and writing difficulties. *Journal of Educational Psychology*, 89(2):223–234.

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford Press.

Heimbuch, S. and Bodemer, D. (2016). Effects of Implicit Guidance on Contribution Quality in a Wiki-based learning environment. In *12th International Conference of the Learning Sciences (ICLS 2016)*, volume 2, pages 906–909. International Society of the Learning Sciences.

Heimbuch, S., Uhde, K., and Bodemer, D. (2014). "A new Wiki way?" - An experimental study of collaborative knowledge building scripts. In Liu, C.-C. et al., editor, *Proceedings of the 22nd International Conference on Computers in Education*, volume WIPP, pages 10–12, Nara, Japan. Asia-Pacific Society for Computers in Education.

Ioannou, A., Brown, S. W., and Artino, A. R. (2015). Wikis and forums for collaborative problem-based activity: A systematic comparison of learners' interactions. *The Internet and Higher Education*, 24:35–45.

Janssen, J. and Bodemer, D. (2013). Coordinated computer-supported collaborative learning: Awareness and awareness tools. *Educational Psychologist*, 48(1):40–55.

Janssen, J., Erkens, G., Kirschner, P. A., and Kanselaar, G. (2010). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science*, 38(1):59–88.

Johnson, D. W., Johnson, R. T., and Tjosvold, D. (2000). Constructive controversy: The value of intellectual opposition. In M. Deutsch P. T. Coleman, editor, *The handbook of conflict resolution: Theory and practice*, pages 65–85. Jossey-Bass, San Francisco, CA.

Kasemvilas, S. and Olfman, L. (2009). Design alternatives for a MediaWiki to support collaborative writing. *Journal of Information, Information Technology, and Organizations*, 4:87–106.

Kent, C., Laslo, E., and Rafaeli, S. (2016). Interactivity in online discussions and learning outcomes. *Computers & Education*, 97:116–128.

Kimmerle, J., Moskaliuk, J., and Cress, U. (2011). Using wikis for learning and knowledge building: Results of an experimental study. *Educational Technology & Society*, 14(4):138–148.

Kittur, A. and Kraut, R. E. (2008). Harnessing the Wisdom of Crowds in Wikipedia: Quality Through Coordination. In *Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work*, pages 37–46, New York, NY, USA. ACM.

Kollar, I., Fischer, F., and Hesse, F. W. (2006). Collaboration scripts – A conceptual analysis. *Educational Psychology Review*, 18(2):159–185.

Koo, D.-M. and Choi, Y.-Y. (2010). Knowledge search and people with high epistemic curiosity. *Computers in Human Behavior*, 26(1):12–22.

Kruglanski, A. W. (1990). Motivations for judging and knowing: Implications for causal attribution. In Higgins, E. T. and Sorrentino, R. M., editors, *Handbook of Motivation and Cognition: Foundations of Social Behavior*, volume 2, pages 333–368. Guilford Press, New York, NY, USA.

Kruglanski, A. W. and Freund, T. (1983). The freezing and unfreezing of lay-inferences: Effects on

impressional primacy, ethnic stereotyping, and numerical anchoring. *Journal of Experimental Social Psychology*, 19(5):448–468.

Kruglanski, A. W. and Mayseless, O. (1987). Motivational effects in the social comparison of opinions. *Journal of Personality and Social Psychology*, 53(5):834–842.

Kruglanski, A. W. and Webster, D. M. (1996). Motivated closing of the mind: "Seizing" and "freezing.". *Psychological Review*, 103(2):263–283.

Kump, B., Moskaliuk, J., Dennerlein, S., and Ley, T. (2013). Tracing knowledge co-evolution in a realistic course setting: A wiki-based field experiment. *Computers & Education*, 69:60–70.

Lai, Y. C. and Ng, E. M. (2011). Using wikis to develop student teachers' learning, teaching, and assessment capabilities. *The Internet and Higher Education*, 14(1):15–26.

Litman, J. A. (2008). Interest and deprivation factors of epistemic curiosity. *Personality and Individual Differences*, 44(7):1585–1595.

Litman, J. A., Hutchins, T., and Russon, R. (2005). Epistemic curiosity, feeling-of-knowing, and exploratory behaviour. *Cognition & Emotion*, 19(4):559–582.

Litman, J. A. and Spielberger, C. D. (2003). Measuring epistemic curiosity and its diversive and specific components. *Journal of Personality Assessment*, 80(1):75–86.

Lowry, N. and Johnson, D. W. (1981). Effects of Controversy on Epistemic Curiosity, Achievement, and Attitudes. *The Journal of Social Psychology*, 115(1):31–43.

Luhmann, N. (1984). *Soziale Systeme: Grundriss einer allgemeinen Theorie*. Suhrkamp.

Luhmann, N. (1997). *Die Gesellschaft der Gesellschaft*. Suhrkamp.

Mayordomo, R. M. and Onrubia, J. (2015). Work coordination and collaborative knowledge construction in a small group collaborative virtual task. *The Internet and Higher Education*, 25:96–104.

Moskaliuk, J., Kimmerle, J., and Cress, U. (2009). Wiki-supported learning and knowledge building: Effects of incongruity between knowledge and information. *Journal of Computer Assisted Learning*, 25(6):549–561.

Moskaliuk, J., Kimmerle, J., and Cress, U. (2012). Collaborative knowledge building with wikis: The impact of redundancy and polarity. *Computers & Education*, 58(4):1049–1057.

Mugny, G. and Doise, W. (1978). Socio-cognitive conflict and structure of individual and collective performances. *European Journal of Social Psychology*, 8(2):181–192.

Nummenmaa, L., Hyönä, J., and Calvo, M. G. (2006). Eye movement assessment of selective attentional capture by emotional pictures. *Emotion*, 6(2):257–268.

Piaget, J. (1977a). *The development of thought: equilibration of cognitive structures*. Viking Press.

Piaget, J. (1977b). Problems of equilibration. In Appel, M. H. and Goldberg, L. S., editors, *Topics in Cognitive Development*, pages 3–13. Springer US.

Posner, I. R. and Baecker, R. M. (1992). How people write together. In *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences, 1992*, volume IV, pages 127–138.

Renner, B. (2006). Curiosity about people: The development of a social curiosity measure in adults. *Journal of Personality Assessment*, 87(3):305–316.

Scardamalia, M. and Bereiter, C. (1983). The development of evaluative, diagnostic and remedial capabilities in children's composing. pages 67–95. Wiley and Sons.

Scardamalia, M. and Bereiter, C. (1985). Development of Dialectical processes in composition. pages 307–329. Cambridge University Press.

Scardamalia, M. and Bereiter, C. (1986). Research on written Composition. In Wittrock, M., editor, *Handbook of research on teaching*, pages 778–803. Macmillan, New York, NY, USA.

Scardamalia, M. and Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences*, 3(3):265–283.

Scardamalia, M. and Bereiter, C. (2003). Beyond Brainstorming: Sustained Creative Work with Ideas. *Education Canada*, 43(4):4.

Schlink, S. (2009). *Persönlichkeit entscheidet: Der Einfluss des Bedürfnisses nach kognitiver Geschlossenheit auf Entscheidungen unter Unsicherheit*. PhD thesis, Universität Trier.

Schlink, S. and Walther, E. (2007). Kurz und gut: Eine deutsche Kurzskala zur Erfassung des Bedürfnisses nach kognitiver Geschlossenheit. *Zeitschrift für Sozialpsychologie*, 38(3):153–161.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Acting with Technology. The MIT Press, Cambridge MA.

Steiger, J. H. (2004). Beyond the F Test: Effect Size Confidence Intervals and Tests of Close Fit in the Analysis of Variance and Contrast Analysis. *Psychological Methods*, 9(2):164–182.

Suthers, D. D. (2001). Towards a systematic study of representational guidance for collaborative learning discourse. *Journal of Universal Computer Science*, 7(3):254–277.

Suthers, D. D. (2003). Representational guidance for collaborative inquiry. In Andriessen, J., Baker, M., and Suthers, D., editors, *Arguing to learn*, pages 27–46. Springer, Dordrecht, Netherlands.

van Marle, H. J. F., Hermans, E. J., Qin, S., and Fernández, G. (2009). From Specificity to Sensitivity: How Acute Stress Affects Amygdala Processing of Biologically Salient Stimuli. *Biological Psychiatry*, 66(7):649–655.

Webster, D. M. and Kruglanski, A. W. (1994). Individual differences in need for cognitive closure. *Journal of Personality and Social Psychology*, 67(6):1049–1062.

Webster, D. M., Richter, L., and Kruglanski, A. W. (1996). On Leaping to Conclusions When Feeling Tired: Mental Fatigue Effects on Impressional Primacy. *Journal of Experimental Social Psychology*, 32(2):181–195.

Wichmann, A. and Rummel, N. (2013). Improving revision in wiki-based writing: Coordination pays off. *Computers & Education*, 62:262–270.

Zheng, B., Niiya, M., and Warschauer, M. (2015). Wikis and collaborative learning in higher education. *Technology, Pedagogy and Education*, 24(3):357–374.