Impact of Epistemological Beliefs on Hypertext Learning: A Pilot-Study

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Abstract

This explorative pilot-study investigated the relationship between epistemological beliefs, prior knowledge and self-regulated learning with a hierarchical hypertext. Students who varied in their epistemological beliefs and prior knowledge learned about the topic of genetic fingerprinting. Logfiles and questionnaire data were collected. Results indicate that both epistemological beliefs and prior knowledge are significantly associated with process data such as processing different hypertext parts and calibration to task demands, as well as with the learning outcome.

Keywords: Epistemological Beliefs; Metacognitive Calibration; Hypertext Learning; Prior Knowledge

Theoretical Background

Research on epistemological beliefs, i.e. learners' beliefs about the nature of knowledge and knowing, has expanded considerably in recent years (e.g. Hofer & Pintrich, 2002). One important theoretical assumption in these fields of research is that learners' epistemological beliefs develop from more "naive" views (e.g., knowledge is absolute; knowledge is an accumulation of facts) to more "sophisticated" beliefs (e.g., knowledge is relative and contextual, knowledge is a complex network) during educational processes. An increasing number of empirical studies shows that more sophisticated epistemological beliefs are related to more adequate learning strategies and better learning outcomes in traditional classrooms (e.g., Hofer & Pintrich, 1997; Schommer, 1990). There are some studies concerning computer-based learning environments as well: For example, epistemological beliefs are related to learning with hypertext (e.g., Jacobson & Spiro, 1995), learning processes with computer-simulations (Windschitl & Andre, 1998), information retrieval from the Internet (e.g., Hofer, 2004) and help-seeking in interactive learning environments (e.g., Bartholomé, Stahl, Pieschl, & Bromme, 2006). Thus, on the one hand, there is growing empirical evidence that epistemological beliefs are learner variables that effect learning processes and outcomes, on the other hand the exact functional relationship between epistemological beliefs and learning still remains an open issue, i.e. how they exactly exert their influence.

We assume that hypertexts are well suited to examine this relationship in detail for two reasons. First, methods like log-file analyses or screen capturing allow for detailed analyses of learning processes. Second, information retrieval from the Internet and therefore with hypertexts plays an increasingly important role in today's self-regulated learning, which has advanced into a relevant and desired key competency.

An encouraging theoretical background that helps to specify a functional relationship between epistemological beliefs and learning is given by the COPES-model (e.g. Winne & Hadwin, 1998) According to this model, self-regulated learning occurs in four weakly sequenced and recursive stages: (1) task definition, (2) goal setting and planning, (3) enactment and (4) adaptation. In the task definition stage (1), a student generates her own perception about what the studying task is, and what constraints and resources are in place. Consequently, the student generates idiosyncratic goal(s) and constructs a plan for addressing that study task (2). In the enactment stage (3) the previously created plan of study tactics is carried out. The adaptation stage (4) pertains to fine-tuning of strategies within the actual learning task as well as to long-term adaptations based on the study experience.

All four stages are embedded in the same general cognitive architecture. In the centre of this architecture are processes of metacognitive monitoring and controlling that students' might use to calibrate their learning process to perceived task demands. If and how such metacognitive calibration occurs depends on five constituents whose acronym gave the model its name: conditions (C), operations (O), products (P), evaluations (E) and standards (S). Conditions pertain to external task conditions (e.g. time, resources) as well as to internal cognitive conditions (e.g., motivational factors, domain and task knowledge). Epistemological beliefs and prior knowledge are a part of these internal conditions. Conditions influence the whole learning process, especially the operations and standards. Operations include all cognitive processes (e.g. tactics, strategies) that learners utilize to solve a learning task. In each learning stage, these operations create internal or external products. These include internal mental (e.g. a mental model of how to solve the task) as well as external products (e.g. an observable behavior, such as hypertext navigation). Students' goals are represented as multivariate profiles of standards. Standards can be described as a profile of different criteria that a student sets for the learning task (e.g. targeted level of understanding or targeted time on task). Evaluations occur during the whole learning process when a student metacognitively monitors her learning process. These evaluations are based on comparisons between the intermediate products on the one hand and her standards on the other. When she notices discrepancies she is able to perform metacognitive control by executing fix-up operations (e.g. re-reading a hypertext node).

Based on the COPES-model we hypothesize that learners with more sophisticated beliefs should be better in metacognitively calibrating to task demands during hypertext learning. For example, we believe that learners with naïve epistemological beliefs will set matching naïve internal standards, e.g. "this content is very easy to learn, therefore, I need only superficial understanding and will achieve it by only spending little time and paying little attention". Consequently, they will metacognitively monitor and control their whole learning process according to these standards, e.g. they will employ more superficial learning strategies (control) such as memorizing and probably will not realize (monitor) that superficial learning is not sufficient. Learners with more sophisticated beliefs in more uncertain and complex knowledge on the other hand will set higher standards, e.g. "as this content is very complex, I have to deeply elaborate to really understand it, furthermore, as it is uncertain, I will have to consider different perspectives to evaluate it critically". Consequently, these learners will employ strategies for deep elaboration (control) and will monitor their whole learning process against these high standards. For very easy tasks such as memorizing a factual detail, these different standards will not elicit strong effects. Learners with all kinds of epistemological beliefs will be able to solve such tasks although they might slightly differ in their learning process. But with ascending task complexity, the differences between learners with different epistemological beliefs will become more pronounced. Naïve learners will underestimate content and task complexity which will result in superficial learning and suboptimal results. More sophisticated learners will be better in calibrating their standards to real task complexity. Consequently this will result in a more adequate learning process and outcome. We will investigate this issue in detail with a series of studies within a larger project.

In this article we present the results of a first explorative study within this series. We asked students of biology and humanities to learn with a hypertext about the topic genetic fingerprinting (mtDNA analysis). Thus, we were able to analyse learners with a wide range of prior knowledge. We choose to include different levels of prior knowledge because prior domain knowledge is the one learner characteristic that most consistently influences computer-supported learning (e.g. Michell, Chen & Macredie, 2005).

The main objective of this study was to develop and test material for the main studies of the project. In addition, we also examined two explorative research questions: Our hypertext encompasses three hierarchical level of different complexity (for more details see below). Thus, the COPES-model would predict that learners with different epistemological beliefs would differ in their calibration to this complexity of the learning material, mediated by their different internal standards. Therefore, our first question is: (1) Are learners' epistemological beliefs and prior knowledge related to their calibration processes? In terms of the COPES-model: Do learners' with different epistemological beliefs and different prior knowledge employ different operations and do they set different standards for hypertext parts of different complexity and thus come to different evaluations? We also used a knowledge test to measure learning outcome. Therefore, the second question is: (2) Do epistemological beliefs and prior knowledge influence the learning outcome (in terms of the COPES-model: the product of learning)?

Method

Participants

Fifty-one students participated and received 15 € as reimbursement. The mean age was 23.1 years (SD = 2.5). Twenty-five (13 males and 12 females) studied in the 4.5th (SD = 1.0) semester biology or related majors. Their background knowledge was confirmed by the results of a short microbiology knowledge test (8 points maximum; M = 7.7, SD = 0.7). The other 26 participants (10 males and 16 females) studied in the 6.1th semester psychology or other humanity majors (SD = 3.9). The knowledge test revealed minimal background knowledge (M = 2.8, SD = 1.7). Thus, our students demonstrated a wide range of prior knowledge.

Material

Epistemological Beliefs Questionnaires Epistemological beliefs were measured by one questionnaire of Wood and Kardash (2002) that we labeled WKI (Wood and Kardash Instrument). It measures students' general beliefs about the nature of knowledge and knowing. A second questionnaire, the CAEB (Connotative Aspects of Epistemological Beliefs; Stahl & Bromme, submitted), measured students beliefs referring to the domain of genetics. We decided to calculate factor analyses even with this small sample size and obtained meaningful solutions: The factor solution for the WKI encompassed two factors labeled "simplicity" (9 items, Cronbach's α = .69) and "certainty" (5 items, Cronbach's α = .73) which explained 39 % variance. The factor "simplicity" measures whether students assume that knowledge is an accumulation of facts versus a complex network of interrelated concepts (sample item: "When I learn I prefer to make things as simple as possible."). The students in this study tended to believe in simple knowledge (M = 4.6, SD = 0.8; on a 7-point scale from 1 = knowledge is seen as complex to 7 = knowledge is seen as simple). Students of biology and humanities students did not differ on this factor. The factor "certainty" refers to students' beliefs in absolute and exact versus tentative knowledge. Students believed more in uncertain knowledge (M = 5.9, SD = 0.7; on a 7-point scale from 1 = knowledge is seen as certain to 7 = knowledge is seen as uncertain). Students of biology and humanities students did not differ on this factor. The solution for the CAEB comprised two factors, "texture" (11 items, Cronbach's $\alpha = .81$) and "variability" (9 items, Cronbach's $\alpha = .80$) and explained 41 % variance. The factor "texture" encompasses beliefs about the structure and accuracy of knowledge in a domain and ranges from beliefs that knowledge is exact and structured to beliefs that it is unstructured and vague. A sample item is "structured – unstructured" (The CAEB is conceptualised as a semantical differential. Thus, the students had to judge such pairs of adjectives on a 7-point scale.). Students tended to believe more in structured knowledge in genetics (M = 2.9; SD = 0.7). Humanities students displayed a tendency to belief in more unstructured knowledge ($F (1, 47) = 3.7$, $p = .06$). The factor "variability" encompasses beliefs about the stability and dynamics of domain knowledge and ranges from beliefs that knowledge is dynamic and flexible to beliefs that it is stabile and inflexible. The students of this study believed in relative knowledge (M = 4.8; SD = 0.8; on a 7-point scale from 1 = absolute to 7 = relative). Students of biology and humanities students did not differ on this factor.

Correlational analysis of these factors revealed two significant relations: The WKI factor "simplicity" was significantly related to the CAEB factor "texture" (-.29; $p = .04$). Students who believed in simple knowledge in general also believed in structured knowledge in genetics. Furthermore, the correlation between the two domain-related factors of the CAEB "texture" and "variability" was significant ($r = .43$; $p < .01$). Students who believed in unstructured knowledge in genetics also believed in relative knowledge in genetics.

Hypertext The hypertext was created with MetaLinks (Murray, 2003), an authoring software for hierarchical hypertexts with additional thematic linking. Technically MetaLinks is Filemaker based and uses Netscape Navigator as a browser. It collects logfile data automatically.

The hypertext encompasses an eight-node introduction to genetic fingerprinting that provides general background knowledge necessary to understand the topic (e.g. structure of DNA). The main part of the hypertext (thirty-one nodes) explains the topic of mtDNA analysis. Fourteen of these nodes are arranged in a hierarchical structure with three levels. The first level encompasses five introductory nodes; the two deeper levels give more detailed and specific information (level 2 = 6 nodes; level 3 = 3 nodes). Besides this hierarchical structure, the hypertext contains seventeen nodes (appendices) that are linked thematically with the main text. They belong to the categories of "biological background" (2 nodes), "examples" (7 nodes) and "uncertainties / problems" (8 nodes). Those nodes differ in length as well as difficulty.

Comprehensibility ratings All students had to judge the comprehensibility of each node they processed on a 7-point scale from 1 = "very comprehensible" to 7 = "very incomprehensible".

Knowledge tests Eight multiple-choice questions were developed with the help of a domain expert to test students' prior knowledge. To measure the learning outcome multiple-choice questions each specific to one hypertext node were developed for half of the nodes (15 questions).

Procedure

Students worked in sessions lasting about 2 hours with a maximum of 6 students per session. During the session each student first completed questionnaires on demographics, epistemological beliefs and prior knowledge. Then they were introduced to the structure and navigational options of the hypertext. Afterwards, they were instructed to read the eight-node introduction and subsequently to learn as much as possible about mtDNA analysis. We chose such an unspecific learning task to investigate their spontaneous use and navigation of the hypertext. During this task they had to give comprehensibility ratings for all nodes they read. After one hour of working with the hypertext the students completed the knowledge test, rated their motivation during learning and their interest in the topic.

Results

Because of the explorative character of the study we define ($p < .05$) as significant and ($p < .10$) as a trend.

On average the students rated to be motivated during learning (M = 5.1, SD = 1.2, on a 7-point scale with 7 = very motivated) and to be interested in the topic (M = 5.8, SD = 1.1, on a 7-point scale with 7 = very interesting). We found no relationships between their ratings and any of the other independent variables. Thus interest and motivation were excluded from all subsequent analyses.

Research Question 1

For each hypertext part, i.e. the three hierarchical levels and the three appendices, three variables were computed for each student: (1) Average Processing Duration per Node (APDN = total time spent in a hypertext part divided by number of processed nodes), (2) Percentage of Processed Nodes (PPN = number of processed nodes divided by number of existing nodes) and (3) Average Comprehensibility Rating for each hypertext part (ACR). We calculated a MANCOVA with the three hierarchical levels as repeated-measure factor, prior knowledge and the four epistemological beliefs factors as independent variables and APDN, PPN, and ACR as dependent variables. To further validate our results we also computed correlations and visualized our effects.

The results revealed no main effect of the repeated-measure factor hierarchical levels ($F (6, 32) = 1.9$, $p = .11$. Nonetheless, effects were visible in all separate univariate analyses: Nodes on deeper levels were processed longer ($F (2, 74) = 2.6$, $p = .08$), a lower percentage of nodes was processed on deeper levels ($F (2, 74) = 4.2$, $p = .02$) and nodes on deeper levels were judged to be less comprehensible ($F (2, 74) = 2.5$, $p = .09$).

Epistemological beliefs MANCOVA results reveal a main effect for the epistemological belief factor WKI "simplicity"

(F (3, 35) = 4.1, p = .01) and an interaction effect between WKI "simplicity" and level of hierarchy (F (6, 32) = 2.3, p = .07). The main effect was corroborated univariately on all three dependent variables (APDN: F (1, 37) = 7.6, p = .01; PPN: F (1, 37) = 4.5, p = .04; ACR: F (1, 37) = 5.9, p = .02). Students who believed in simple knowledge processed single nodes longer, processed a smaller percentage of nodes and judged nodes to be more comprehensible than their counterparts who believed in more complex knowledge. These results are supported by the correlation results: The belief in simple knowledge (WKI "simplicity") was positively correlated with more comprehensible node evaluation on level 2 and 3 (see Table 1). The multivariate interaction effect was univariately only replicated on one dependent variable (APDN: F (2, 74) = 6.5, p < .01). Students who believed in simple knowledge not only processed nodes longer (see main effect above) but this difference also became distinctively more pronounced on deeper hierarchical levels (for visualization with a median-split WKI "simplicity" see Figure 1a). Correlation results also reveal a significant association between the belief in simple knowledge (WKI "simplicity") and average processing duration per node (APDN) on level 3 (Table 1).

Table 1: Correlations pertaining to research question 1

	CAEB texture	CAEB variability	WKI simplicity	WKI certainty	Knowledge test score
Level 1 (N = 49)					
APDN	.03	-.19	-.07	-.07	-.30*
PPN	-.13	.09	-.19	-.02	.15
ACR	.21	-.01	-.20	.03	-.40**
Level 2 (N = 47)					
APDN	.09	.06	.09	-.08	-.32*
PPN	-.18	.06	-.24	.19	.33*
ACR	.19	-.09	-.33*	-.14	-.41**
Level 3 (N = 43)					
APDN	.06	.14	.42**	-.01	.00
PPN	-.06	.14	-.13	.26^{+}	.26^{+}
ACR	.29^{+}	.09	-.38*	-.01	-.51**
Biological background (N = 14)					
APDN	-.05	-.15	.19	-.14	-.12
PPN	.18	.28	.42	.28	.17
ACR	.06	-.28	-.41	.08	-.30
Examples (N = 22)					
APDN	.25	.06	.09	-.01	-.24
PPN	-.31	-.32	.00	-.12	.17
ACR	.43*	.04	-.37^{+}	.05	-.26
Problems (N = 17)					
APDN	.39	.56*	.22	.13	.09
PPN	-.57*	-.06	.13	.37	.49*
ACR	.17	-.03	-.29	-.04	-.15

APDN = Average Processing Duration per Node
PPN = Percent of Processed Nodes
ACR = Average Comprehensibility Ratings
** p < .01; * p < .05; $^{+}$ p < .10

MANCOVA results reveal no multivariate effect for the epistemological belief factor WKI "certainty". Still, an interaction between WKI "certainty" and level of hierarchy was detected univariately (F (2, 74) = 3.1, p = .05): Students who believe in uncertain knowledge processed an increasingly higher percentage of nodes (PPN) on deeper levels than their more naïve counterparts (for visualization with a median-split WKI "certainty" see Figure 1b). This effect was corroborated by correlational results: The belief in uncertain knowledge (WKI "certainty") was associated with a higher PPN on level 3 (see Table 1).

MANCOVA results reveal no significant effect for the epistemological belief factors of the CAEB. Nevertheless, the belief in unstructured knowledge in genetics (CAEB "texture") was significantly associated with judging the nodes on level 3 less comprehensible (see Table 1).

Table 1 also displays the correlations within the three appendices. Beliefs in unstructured knowledge in genetics (CAEB "texture") and complex knowledge in general (WKI "simplicity") were associated with judging nodes in the "examples" less comprehensible. Further significant correlations were found concerning the "problem" nodes: Students who believed in unstructured knowledge in genetics (CAEB "texture") processed fewer nodes (PPN). Students who believed in relative knowledge in genetics (CAEB "variability") spent more time on nodes (APDN).

Prior knowledge MANCOVA results reveal a main effect for prior knowledge (F (3, 35) = 4.8, p = .01). This effect was corroborated univariately only on one dependent variable (ACR: (F (1, 37) = 9.6, p < .01): Students with higher prior knowledge judged all nodes to be more comprehensible. This effect was supported by correlational results: Higher prior knowledge was associated with judging nodes more comprehensible on all three levels (see Table 1). We also found an univariate interaction effect between level of hierarchy and prior knowledge for comprehensibility ratings (ACR): Students with higher prior knowledge not only judged the nodes' comprehensibility higher on all levels (see main effect above) but this effect became also more pronounced with deeper levels (F (2, 74) = 5.4, p < .01). For a visualisation of this effect with group affiliation (biology vs. humanities students) as a factor, see Figure 1c. Results of the correlations demonstrated that higher prior knowledge was also associated with a lower processing duration of single nodes (APDN) on level 1 and 2, with higher percentage of processed nodes (PPN) on level 2 and 3, and with higher percentage of processed nodes in the "problem" nodes (see Table 1).

Research Question 2

To examine the learning outcome we calculated the total test score of the mtDNA knowledge test as dependent variable, but also two sub-scores: The percentage of correctly answered questions pertaining to *processed* nodes (PP = Percentage when Processed) will show how much students recalled the information they had read. Furthermore, the percentage of correctly answered questions pertaining to *non-processed* nodes was calculated (PNP = Percentage when Not Processed).

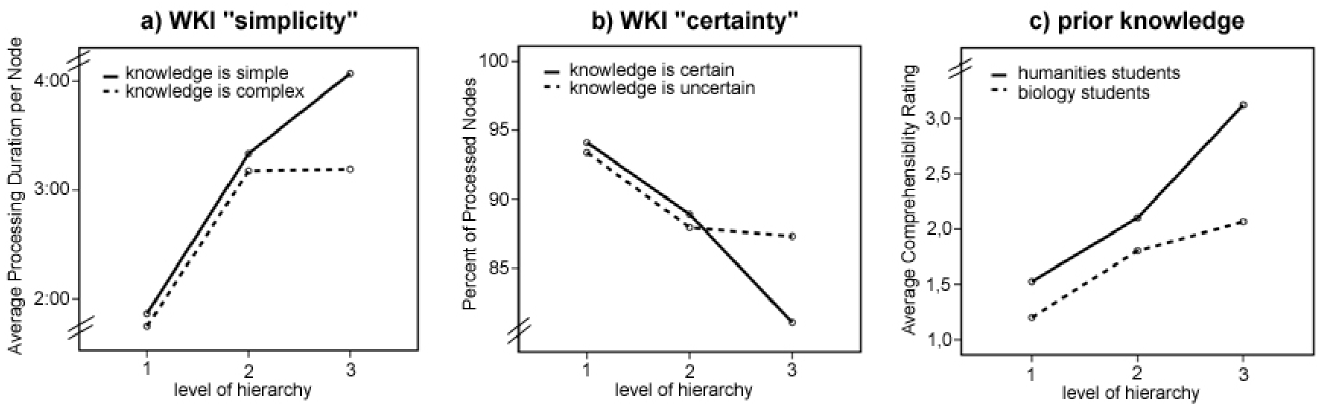

Figure 1: Visualization of significant interaction effects concerning research question 1

We calculated a MANCOVA with prior knowledge and the four epistemological beliefs factors as independent variables, and the total test scores, PP and PNP as dependent variables. We found a main effect for WKI "simplicity": $F (3, 39) = 3.5$. $p = .03$, corroborated univariately only for total test score ($F (1, 41) = 4.7$, $p = .04$). We also found a main effect of prior knowledge ($F (3, 39) = 4.3$, $p = .01$). This effect was corroborated univariately only for total test score ($F (1, 41) = 12.6$, $p < .01$) and the percentage of correctly answered questions for none-processed nodes (PNP: $F (1, 41) = 3.6$, $p = .06$), but not for processed nodes (PP: $F (1, 41) = 2.3$, $p = .14$). Correlations supported this effect (total score: $r = .56$, $p < .01$; PP: $r = .27$, $p = .07$; PNP: $r = .35$, $p = .02$).

Discussion

The central aim of this study was to test material for the main experiments of the project. Thus, students were asked to navigate through one chapter of a large hypertext that we are developing. It is interesting that we found calibration effects even within such a small hypertext (31 nodes) and with a rather unspecific learning task.

Research Question 1

We found clear evidence that students do calibrate their learning to the different levels of the hypertext hierarchy and that this calibration is effected by their epistemological beliefs and prior knowledge.

Concerning the epistemological belief factor WKI "simplicity" we found that students who believed in simple knowledge processed a smaller percentage of nodes across all levels. On the other hand, they process nodes on all levels longer, and this effect becomes more pronounced on deeper levels, especially on level 3. A possible explanation might be that these naïve students who believed in simple, factual knowledge and a structured learning process probably wanted to memorize detailed facts which can be found mainly on deep-level nodes. Because they concentrated on such nodes, these students probably run out of time and were not able to visit more nodes. The more sophisticated students who believed in more complex knowledge on the other hand probably tried to get an overview by processing as many nodes as possible and to understand the most important concepts and their interrelations. Thus they probably ignored very specific details of deep-level nodes. Furthermore, students who believed in simple knowledge judged nodes to be more comprehensible across all levels, probably because they judged comprehensibility in terms of understanding single facts without considering their interrelations. Concerning the epistemological belief factor WKI "certainty" we found that students who believe in uncertain knowledge processed an increasingly higher percentage of nodes on deeper levels, especially on level 3. In accordance with the COPES-model, these students probably tried to get an overview of the whole hypertext by trying to process as many nodes as possible to judge the relevance and validity of the given information. For the domain-related CAEB factors no significant MANCOVA effects were found. Still, correlations demonstrate that the sophisticated belief in unstructured knowledge (CAEB "texture") is associated with judging nodes on deeper levels less comprehensible. As expected more sophisticated students scrutinized the nodes more critically and thus discovered more comprehensibility problems. But, it should be noted that there is also a relation between prior knowledge and CAEB "texture": Humanities students possess less prior knowledge in biology and tended to display more sophisticated beliefs in unstructured knowledge (see above). Concluding, there is an interesting relationship between prior knowledge, CAEB "texture" and comprehensibility. But the exact causal relationship is still unclear and will be investigated in subsequent studies. We also found significant correlations between the CAEB factors and the dependant variables within the appendices (i.e. "biological background", "examples" and "problems"). For example, students who displayed more sophisticated beliefs also processed a higher percent of nodes about problems (CAEB "texture") and processed each of these node longer (CAEB "texture" and "variability"). It is in accordance with the COPES-model that these students with more "sophisticated" beliefs access and scrutinize information about potential problems of mtDNA analysis. Such information assists the evaluation of the validity of the factual information presented in the remainder of the hypertext.

Concerning prior knowledge, the effects were not surprising: Students with higher prior knowledge judged nodes across all levels to be more comprehensible. This effect became more pronounced on deeper hierarchical levels. Because these students were familiar with some of the facts explained in the hypertext, the nodes were easier to comprehend. Further, higher prior knowledge resulted in shorter processing of nodes on level 1 and 2, and processing of more nodes on level 3, probably for the same reason.

Research Question 2

We found significant effects of epistemological beliefs and prior knowledge on learning outcome.

Students believing that knowledge is complex (WKI "simplicity") demonstrated higher learning outcomes than students who believed in simple knowledge. This means that the "naive" students' navigational behavior (i.e. taking more time to read the most complex nodes) did not result in deeper knowledge about the main concepts of the nodes. It is remarkable that we found such an effect within this study: Both, the task ("learn as much as possible") and the test (multiple-choice questions about single facts), concentrate on detailed knowledge of facts. We had assumed that for such an easy task like memorizing facts, students with more "naïve" and "sophisticated" epistemological beliefs would not differ much in the standards they set themselves and consequently they would not differ much in their learning outcome. When considering more complex tasks (e.g. "How valid is mtDNA testing. Write a pro and contra argumentation."), students with more "sophisticated" beliefs would be better in calibrating their standards to such enhanced task complexity whereas more "naïve" students would underestimate task complexity and thus set more superficial standards (e.g. Stahl, Pieschl, & Bromme, accepted). Consequently, differences in their learning outcomes would become higher. Considering these arguments, it is promising all the more that we found such effects even with regard to factual knowledge. We will investigate the impact of different kinds of learner tasks, especially more complex ones, in subsequent experiments.

Prior knowledge effected students learning outcome in a selective way: Students with higher prior knowledge were better able to answer those questions pertaining to nodes they did not read (PNP), but no effect for read nodes (PN) was found. Thus, even students with low prior knowledge were able to comprehend the main concepts of processed nodes equally well.

Conclusion

Summarizing the results, epistemological beliefs and prior knowledge are both significantly associated with the hypertext learning process and the learning outcome. Nevertheless, our results are only explorative in nature. Further research to investigate these research questions more deeply is needed. The COPES-model appeared to be an appropriate framework. It allows for concrete hypotheses about the effects of epistemological beliefs and prior knowledge on metacognitive calibration within different stages of a learning process.

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