Psychological Topics 23 (2014), 1, 31-52

Original scientific paper – UDC – 159.953.5.072-057.87

High School Students' Adaptation of Task Definitions, Goals and Plans to Task Complexity – The Impact of Epistemic Beliefs

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Abstract

Accurate task perception is an important prerequisite for self-regulated learning. The present study explores if 12th-grade high school students (*N*=131) adapt their task definitions, goals and plans to task complexity when confronted with six differently complex tasks and if this process is related to their epistemic beliefs. Results indicate that students successfully discriminate between tasks and mostly adapt accordingly. For example, students plan to use the strategy of processing critically more frequently for progressively more complex tasks. These adaptations are also related to students' epistemic beliefs. For example, students who believe in variable knowledge plan more shallow approaches to learning for simple tasks and deeper approaches for complex tasks than their counterparts believing in stable knowledge.

Keywords: task complexity, epistemic beliefs, adaptation, hypermedia

Introduction

Learners are continuously confronted with a vast variety of learning tasks, they have to recall facts, answer multiple-choice questions, explain complex issues, apply procedures to new contexts, critically evaluate arguments, or write original essays on diverse topics. These kinds of tasks vary substantially in their demands and constraints. Models of self-regulated learning (Winne & Hadwin, 1998, 2008) predict that if learners fail to recognize and adapt to these external conditions, their learning processes and their performance cannot be optimal. This study investigates if and under which conditions learners adapt successfully to task complexity, one of the most important external conditions (Anderson et al., 2001). Furthermore, it

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This research was supported by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG). Data was collected as part of the second author's thesis requirements.

scrutinizes how this adaptation is related to learners' epistemic beliefs, namely their beliefs about the nature of knowledge and knowing (Pieschl, Stahl, & Bromme, 2013).

For this purpose we chose a very specific setting: First, we intentionally focus exclusively on the preparatory stages of self-regulated learning. We acknowledge that there is a substantial gap between what learners plan to do and what they actually do (Jamieson-Noel & Winne, 2003). However, if learners fail to notice differences in task complexity and fail to adequately incorporate this into their plans, then the subsequent stages of self-regulated learning must be flawed (Winne & Hadwin, 1998, 2008). Second, we intentionally use a hypermedia learning environment. Hypermedia are open databases that organize learning material in pages of hyperlinked information. This open structure necessarily requires successful self-regulated learning in order to search for and select relevant information. Nowadays, the use of such learning technologies becomes more pervasive in educational settings. Therefore, this context is an ideal and ecologically valid test-bed for self-regulated learning.

Epistemic[1] Beliefs

Epistemic beliefs are beliefs about the origin, definition and justification of human knowledge (Hofer, 2002). Most theoretical accounts differentiate so-called "naïve" beliefs (knowledge is certain and objective) from "sophisticated" beliefs (knowledge is evolving and socially constructed). Two broad clusters of theoretical conceptualizations have been proposed (for extensive reviews see, for example: Buehl & Alexander, 2001; Hofer, 2001; Hofer & Pintrich, 1997; Pintrich, 2002): Models within the developmental tradition focus on the stage-like development of epistemic beliefs from absolutistic views that knowledge is either right or wrong, via relativistic views that knowledge is a matter of opinion, to evaluativistic views that some knowledge claims are corroborated by more evidence and it is possible to evaluate knowledge claims. Models within the educational tradition focus on different dimensions of epistemic beliefs. This study is based on this tradition; we assume that our target population of secondary school students possesses differentiated personal epistemologies that are adequately captured by multiple dimensions.

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[1] In this paper we use the term "epistemic beliefs" synonymously to the more traditional term "epistemological beliefs". However, it should be noted that this terminology – as well as all other currently discussed terminologies in this field – is not universally accepted and that the questionnaires employed in this study were conceived as questionnaires about "epistemological beliefs" (Hofer, 2000; Stahl & Bromme, 2007). However, detailing this controversial discussion about terminology is beyond the scope of this paper.

The most widely used framework in educational psychology (Hofer & Pintrich, 1997) proposes four interrelated dimensions of beliefs. The first two dimensions represent the nature of knowledge and concern the perceived *certainty* of knowledge as well as the perceived *simplicity* of knowledge. The second two dimensions represent the nature of knowing and concern the evaluation of knowledge claims (*justification*) as well as accepted *sources* of knowledge. More "sophisticated" beliefs on these dimensions have been linked to, for example, success on different comprehension tasks, the acquisition and integration of new information, and students' cumulative grade-point average (Bråten & Strømsø, 2006; Hofer, 2000; Kardash & Scholes, 1996; Schommer, 1993). However, the exact number and kind of these dimensions is discussed controversially, among others because these dimensions could rarely be replicated empirically (DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008). One potential explanation for these psychometric problems is that not all learners have *explicit-denotative* knowledge about the nature of knowledge and knowing. When confronted with items such as "All experts in this field understand the field in the same way." (Hofer, 2000) learners often have to think about such issues for the first time and may come up with inconsistent ad hoc answers.

Stahl and Bromme (2007) suggested that learners may possess additional *associative-connotative* assumptions about knowledge and knowing. To measure these assumptions, they derived antonymous adjective pairs from existing questionnaires of epistemic beliefs and devised a semantic differential. They found two reliable dimensions. *Texture* encompasses beliefs about the structure and accuracy of knowledge and is closely related to the dimension of simplicity; *variability* encompasses beliefs about the stability and dynamics of knowledge and is congruent with the dimension of certainty (Hofer & Pintrich, 1997). "Sophisticated" associative-connotative beliefs in unstructured and variable knowledge have been linked to, for example, better metacognitive calibration within a hypermedia learning environment (Pieschl, Stahl, & Bromme, 2008; Stahl, Pieschl, & Bromme, 2006) and more adequate use of help functions in an interactive learning environment (Bartholomé, Stahl, Pieschl, & Bromme, 2006).

To sum up, epistemic beliefs are a complex construct that has been consistently linked to processes and products of learning. Therefore, we consider this variable highly relevant for self-regulated learning. In order to capture explicit-denotative and associative-connotative facets of epistemic beliefs in this study, we use multiple instruments.

The COPES Model of Studying

A theoretical framework which allows for modeling the functional relationship between learners' epistemic beliefs and different phases of self-regulated learning is Winne and Hadwin's (1998, 2008) COPES model of studying. The model postulates four recursive stages of self-regulated learning – (1) task definition, (2) goal setting and planning, (3) enactment and (4) adaptations – and five common dimensions that characterize instances of studying – Conditions (C), Operations (O), Products (P), Evaluations (E) and Standards (S). These COPES facets are assumed to be relevant for all stages of learning, but the content of these categories changes. All learner characteristics constitute internal cognitive conditions, for example epistemic beliefs. All external constraints and resources like task complexity constitute external task conditions. Operations are cognitive tactics and strategies which are intended to construct, retain and use knowledge. They lead to products, both internal and external. Studying is assumed to be goal-directed and goals are represented as multivariate profiles of standards. Standards consist of qualitative or quantitative criteria against which products can be evaluated. They are set by the learner and repeatedly adapted at each stage of the learning process. Evaluations are based on a comparison between learners' standards and their products.

Adaptation to Task Complexity

The COPES model (Winne & Hadwin, 1998, 2008) also allows us to specify how students may *adapt* their learning process to an external condition like *task complexity*. In the initial task definition stage skillful students should generate an accurate "perception of what the task is, and what constraints and resources are in place" (Winne & Hadwin, 1998, p.12). They should discriminate between tasks of differing complexity and they should systematically adapt their task definitions accordingly. As a product they should set different profiles of standards for different tasks. However, not every given task is thoroughly defined regarding all COPES facets, for example teachers might not prescribe specific "operations" for solution. Therefore, standards may be idiosyncratic because learners have to fill-in these blanks of indeterminate COPES facets. In the second goal setting and planning stage learners may re-frame their goals if personal standards differ from the perceived "given" task definitions. As a product of this stage, learners generate idiosyncratic task-specific goals that are assumed to translate into internal standards for metacognitive monitoring. Based on these goals learners also plan adequate tactics and strategies for addressing the task at hand, the second product of this stage.

Research by Gibbs (1990) suggests that there are students who are "cue-seekers" in the sense that they are looking out for central task characteristics in these stages, which enable them to flexibly generate suitable goals and choose appropriate study strategies. "Cue-blind" students tend to use the same approaches and strategies for all tasks. However, flexible strategy adaptation is necessary to succeed academically (Simpson & Nist, 2000).

To sum up, one of the hallmarks of self-regulated learning is adaptation. Thus, we assume that skillful learners adapt their task definitions, goals and plans to task complexity. More specifically, we predict task-discrimination (learners derive *different* task definitions, goals, and plans for differently complex tasks) and task-calibration (learners task definitions, goals, and plans *systematically co-vary* with task complexity) (Pieschl, 2009). In this study, we capture students' task definitions, goals and plans regarding tasks of different complexity.

Adaptation and Epistemic Beliefs

The COPES model (Winne & Hadwin, 1998, 2008) also allows us to specify how this process of adaptation may be influenced by internal conditions such as *epistemic beliefs*. Starting in the task definition stage epistemic beliefs can be seen as apprehension structure through which learning tasks and materials are perceived (Bromme, Pieschl, & Stahl, 2010) and therefore influence students' internal standards (Greene, Muis, & Pieschl, 2010; Muis, 2007). For example, if a student assumes that knowledge is either true or false, she might derive simplified task definitions and goals focusing on the reproduction of discrete facts which might lead to a preference for rehearsal strategies. Such learners may derive too superficial task definitions, goals, and plans for complex tasks. On the other hand, the belief that knowledge is a web of complex, interrelated, and tentative facts might lead to a perception of task demands in favor of critically evaluating all knowledge claims and seeking connections. Such learners may derive (more adequate) deep task definitions, goals and plans for complex tasks.

To sum up, we predict main effects of epistemic beliefs in terms of a general preference for superficial versus deep task definitions, goals and plans. In addition, we also predict interactions between epistemic beliefs and task complexity. Differences between epistemically "naïve" and "sophisticated" learners might be minimal regarding simple tasks. However, when tasks demands become more complex or ambiguous the influence of epistemic beliefs should become more pronounced.

Hypotheses

We start from the assumption that task definition, goal setting and planning is critical for strategic self-regulated learning (Winne & Hadwin, 1998, 2008). This assumption should be especially valid in open settings such as hypermedia learning environments where learners have only few constraints. In this study we presented six tasks of different complexity to secondary school students. All tasks were about genetic fingerprinting. In order to build an adequate representation of these tasks students had the chance to navigate through a hypermedia learning environment about genetic fingerprinting before answering questionnaires about their task definitions, goals and plans. Previous research with university students shows that these learners can adapt their self-regulated learning significantly to task complexity in all stages of self-regulated learning (Bromme et al., 2010; Pieschl, Stahl, Murray, & Bromme, 2012; Stahl et al., 2006) and that these learners' epistemic beliefs are systematically related to these adaptations (Bromme et al., 2010; Stahl et al., 2006). However, it is an open question if similar effects can be found in an ecologically valid secondary school context.

Therefore, we investigate the following two hypotheses: (1) Secondary school students significantly adapt their task definitions, goals and plans to task complexity (task-discrimination and task-calibration). More specifically, we assume that they select *shallow* task definitions, goals and plans for simple tasks and progressively *deeper* task definitions, goals and plans for progressively more complex tasks. Another part of this hypothesis is exploratory. We make no predictions regarding the specific COPES facets of self-regulated learning regarding which learners demonstrate adaptation.

Such significant task-calibration is a prerequisite for our second hypothesis: (2) Students' epistemic beliefs are significantly related to their adaptation to task complexity. We predict *main* effects indicating that "naïve" epistemic beliefs, for example in simple/certain or stable knowledge, will be associated with shallow task definitions, goals, and plans whereas "sophisticated" beliefs, for example in complex/uncertain or variable knowledge, will be associated with deep task definitions, goals and plans. Additionally, we predict *interactions* indicating that the same "naïve" beliefs will be associated with low adaptation to task complexity while the same "sophisticated" beliefs will be associated with more pronounced adaptation.

Method

Participants

Data were collected from 12^{th}-grade high school students (N=131) of eight German Gymnasien (grammar schools) and Gesamtschulen (comprehensive schools). As compensation for participation in the study, students chose between a 15 € reimbursement (n=76) and participation in a gratuitous training on "Successful Presentation in Oral Exams" (n=55). Students attended either to a biology class or a chemistry class in the current school year and were recruited directly in class. They constitute an ecologically valid sample because molecular genetics and more specifically the topic of genetic fingerprinting (DNA analysis) is regularly taught in such classes. Their mean age was 18 years (*SD*=0.71) and about half of them had chosen biology as a major for their final high school exam.

Materials[2]

Epistemic beliefs questionnaires. Explicit-denotative epistemic beliefs were measured with the Domain–specific aspects of Epistemological Beliefs Questionnaire (DEBQ; Hofer, 2000) that had to be answered referring to the domain of molecular genetics. All original 18 items were answered on 7-point scales ranging from 1 = *"strongly agree"* to 7 = *"strongly disagree"*. After dropping four items according to the Alphamax procedure (Thompson, 1990) the reliability of the sub-scales was between minimally acceptable and respectable (DeVellis, 1991) for DEBQ Certainty/Simplicity (5 of 8 original items, Cronbach's α=.79; sample item: "All experts in this field understand the field in the same way."), DEBQ Source: Authority (all 4 original items, Cronbach's α=.69; sample item: "Sometimes you have to accept answers from the experts in this field even if you do not understand them.") and DEBQ Attainability of Truth (all 2 original items, Cronbach's α=.65; sample item: "Experts in this field can ultimately get to the truth."). The sub-scale DEBQ Justification: Personal exhibited unacceptably low internal consistency (3 of 4 original items, Cronbach's α=.54), therefore we did not include this scale in further analyses.

The Connotative Aspects of Epistemological Beliefs instrument (CAEB, Stahl & Bromme, 2007) is a semantic differential that assesses associative-connotative beliefs and had to be answered referring to the domain of molecular genetics. It consists of 17 pairs of antonymous adjectives where the degree of association could be rated on 7-point scales. After dropping four items according to the Alphamax procedure (Thompson, 1990) the reliability of both sub-scales was between undesirable – but still acceptable – and very good (DeVellis, 1991) for CAEB Texture which refers to beliefs about the accuracy and structure of knowledge (7 of 10 original items, Cronbach's α=.81; sample item: "unambiguous - ambiguous") and CAEB Variability which refers to beliefs about the stability of knowledge (6 of 7 original items, Cronbach's α=.61; sample item: "accepted - contested"). Therefore, we retained these original factors.

[2] The materials we administered were more extensive than reported here. We excluded instruments from this paper if the constructs were not significantly related to our measure of self-regulated learning (cf. COPES Questionnaire). This was the case for a multiple-choice measure of domain knowledge and for domain-general and domain-specific measures of academic self concept. Furthermore, we excluded one domain-general measure of epistemic beliefs because we could neither replicate the original factor structure nor find a meaningful factor solution via exploratory factor analysis.

All scales were (re-)coded in a way that high values represent "naïve" beliefs that knowledge is certain and simple (DEBQ Certainty/Simplicity), that experts are a valid source of authority (DEBQ Source: Authority), that truth is attainable (DEBQ Attainability of Truth), that knowledge is structured (CAEB Texture) and stable (CAEB Certainty).

Learning tasks. We used six learning tasks of differing complexity according to Bloom's revised taxonomy (Anderson et al., 2001). This taxonomy distinguishes learning tasks on the basis of the complexity of cognitive operations required to solve them. This is not necessarily related to task difficulty. For example, tasks which simply require retrieval of information from memory (easy example: "Who is the president of the United States of America?"; answer: "Barack Obama") by this definition are considered simple, independent of their difficulty (difficult example: "Who is the president of Iceland?"; answer: "Ósafur Ragnar Grímsson"). This taxonomy includes six ascending categories of task complexity: (1) remember, (2) understand, (3) apply, (4) analyze, (5) evaluate and (6) create. A previous study on this topic used six tasks per category (Stahl et al., 2006). For the current study, one task was selected from each category; each of these tasks had to be solvable with the help of the hypermedia learning environment about genetic fingerprinting. For example, a multiple-choice task with five options was given as remember task. The question was "What happens during a gel electrophoresis?" and the correct answer was "DNA fragments are sorted according to length by applying an electrical field to the gel." And for example, the evaluate task required to evaluate different methods of DNA analysis with regard to potential problems due to DNA degradation. We will refer to this within-subject independent variable as "Bloom Categories".

Hypermedia learning environment. In order to enable students to better judge task demands and predict task solution processes, students had the opportunity to access a hypermedia environment about genetic fingerprinting (Pieschl et al., 2013). This hypermedium includes an introduction presenting basic knowledge about molecular genetics. Its main part is a hierarchically organized section which includes three methods of DNA analysis (mtDNA analysis, STR analysis, and YSTR analysis). A third part covers additional information on the biological background of genetic fingerprinting, giving examples, and presenting potential problems.

The COPES questionnaire. Students judged each of the six tasks with a questionnaire developed on the basis of the COPES model of self-regulated learning (Winne & Hadwin, 1998, 2008) that aims at assessing task definition, goal setting, and planning. It consists of 46 items directly deducted from the COPES model and from additional articles and questionnaires about self-regulated learning and learning strategies (for more details see Stahl et al., 2006). According to the cognitive constituents of the COPES model the items cover students' assessments on Conditions ("How important are the following conditions for the solution of the present task?", students rate 10 external/internal conditions like interest, motivation, or prior knowledge), Operations ("How important are the following learning strategies for the solution of the present task?", students rate 12 strategies like elaborating, planning, or memorizing), Evaluations ("Rate your agreement to the following items.", students rate 6 statements like "This task is easy to solve.") and Standards ("How important are the following kinds of information/information-sources for the solution of the present task?", students rate 18 sources/kinds of information like newspapers, textbooks, or facts and details). We did not include a section about Products because "products" are redundant with conditions, operations, evaluations, and standards in these stages. Forty-three of the COPES items have to be answered on 7-point Likert scales, two items require short open answers ("Estimated Time" for task solution and "Estimated Nodes" within the hypermedia environment needed for task solution), and one item ("Bloom Classification") had a forced-choice format with six alternative answers that represent the six categories of Bloom's revised taxonomy. All COPES items constitute the repeated-measure dependent variables in this study.

Procedure

Data were collected in group sessions of 6-24 students at the respective schools which lasted about 2.5 hours. Sessions consisted of three parts: In the first part, participants were seated apart and each completed questionnaires, for example about their epistemic beliefs. In the second part, the structure of the hypermedia environment and the navigation commands was introduced using a standardized Power Point Presentation. Because of the limited number of computers in the schools' computer labs, students were then paired in dyads for the hypermedia research phase. The dyads where presented with the six learning tasks in randomized order. Students were instructed to make themselves familiar with the demands of all the learning tasks, trying to find out which would be the best strategy to deal with each task by searching for task-related information in the hypermedium. Because the focus of this study is exclusively on the first two stages of self-regulated learning, namely task definition, goal setting and planning, students were not required to solve the presented tasks. When students signaled they had finished their research about the tasks, they were seated separately again and completed the COPES questionnaire for each of the six tasks and a questionnaire on demographics in the last phase of this study.

Results

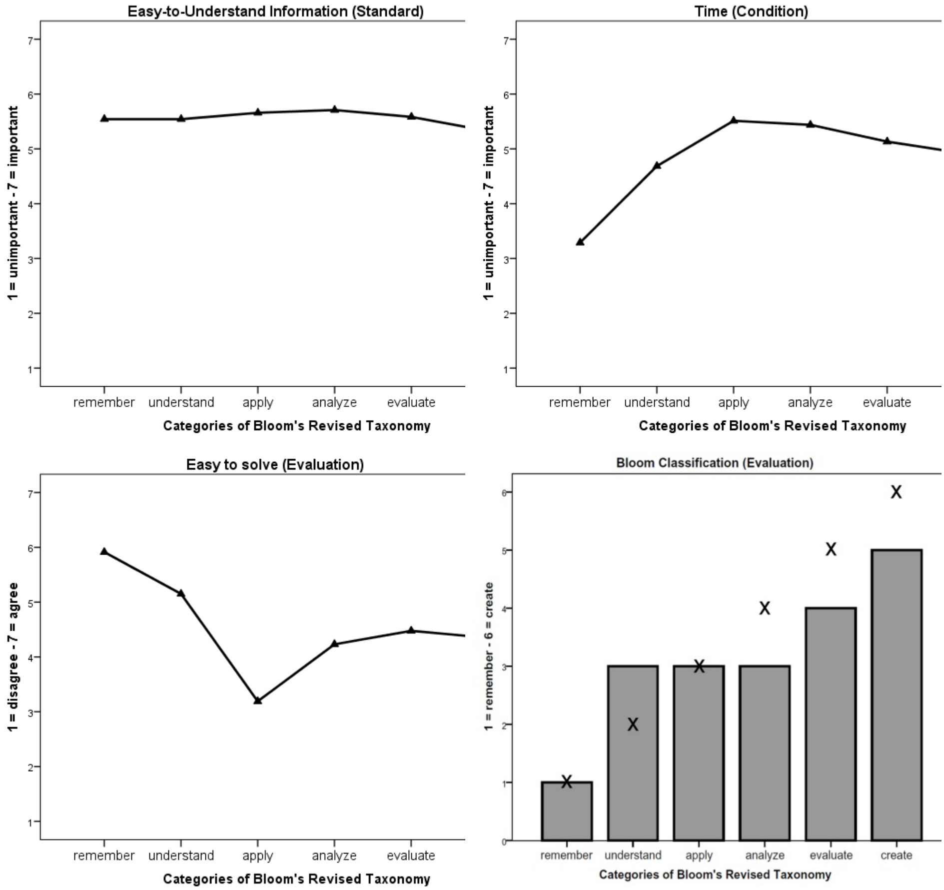
Secondary School Students Significantly Adapt Their Task Definitions, Goals and Plans to Task Complexity (Hypothesis 1)

We checked if working in dyads in the hypermedia research phase resulted in dependent answers in the COPES questionnaire. More specifically, we computed one-way random-effect single measure intra class correlations (ICC(1,1)) for each of the forty-six COPES items regarding each of the six tasks (Alferes & Kenny, 2009). After alpha adjustment none of these tests indicated significant dependency. Therefore, we used students as unit of analyses.

To answer this research question, we employed three methods. First, we computed analyses with the six tasks of different Bloom Categories as repeated-measure factor to determine *task-discrimination*. More specifically, we computed repeated-measure MANOVAs for each of the four parts of the COPES questionnaire (*Conditions, Operations, Standards*, and *Evaluations*) for all items with the same interval scale answer format. For the items with different task formats (Estimated Time, Estimated Nodes, and Bloom Classification) we computed corresponding non-parametric repeated-measure Friedman tests. Second, we computed (between-subject) Kendall's tau (τ) correlations between the six Bloom Categories and learners' judgments for each of the COPES items as indicators of *task-calibration*, namely to determine if task-discriminations were systematically related to task complexity (Bloom Categories). We computed this rank correlation because Bloom's revised taxonomy only orders tasks according to complexity without assuming equidistance between tasks. We consider τ>.20 the minimum effect size for meaningful task-calibration. Third, we compare students' Bloom Classifications directly to the correct Bloom Categories as a measure of absolute accuracy.

The repeated-measure analyses (task-discrimination) show multivariate and univariate significant effects of the repeated-measure factor task complexity (Bloom Categories) for all but one COPES item. Students consider "easy-to-understand information" equally important for tasks of all complexities and do not discriminate between tasks regarding this item (see Figure 1, top left). The remaining effects range from small to moderate in effect size (η_p^2=.02-.29) and the task-discrimination takes different shapes regarding different items. Most *Conditions* are judged unimportant for *remember* and *understand* tasks, most important for *apply* and *analyze* tasks, and the importance is judged slightly less for *evaluate* and *create* tasks (i.e., interest, motivation, prior knowledge, deep understanding, strategic knowledge, task knowledge, help from others, and time; see Figure 1, top right). Often specific *Operations* are judged very important for *understand* and *analyze* tasks (i.e., structuring, integrating, selecting content, or planning) or for *apply* tasks (i.e., relating to prior domain knowledge or practicing). Similarly, specific *Standards* are judged very important for *understand* and *analyze* tasks (i.e., consult scientific journals, science books, or encyclopedias, use most important points or hard-to-understand information) or for *apply* tasks (i.e., use rules and heuristics or not use summaries). The COPES items referring to *Evaluations* all point to the fact that students consider the *apply* task the hardest (i.e., least easy to solve, most complex, most cognitive effort required, less sure that they would be able to solve this task, and acquiring the necessary scientific knowledge most difficult; see Figure 1, bottom left), except for the item Bloom Classification (see Figure 1, bottom right) where students classified more complex task consistently as more complex.

Figure 1. Examples of Students' Answers on the COPES Questionnaire Across the Six Tasks of Different Complexity (Bloom Categories; X-axis)



Note: Means connected by lines are reported for interval scale item (easy-to-understand, time, and easy to solve); medians are reported in column format for the item Bloom Classification with a forced-choice format (bottom right). We found significant discrimination between tasks of different complexity for all depicted items (time, easy to solve, and Bloom Classification) except for easy-to-understand (top left). We found significant calibration to task complexity for Bloom Classification (bottom right); diagonal marks indicate hypothetical correct classifications.

The correlations (task-calibration) between task complexity (Bloom Categories) and students' answers on the COPES items indicate mixed results. For *Conditions* correlations were partly non-significant (i.e., interest, prior domain knowledge, deep understanding, strategic knowledge, task knowledge), partly significant (i.e., motivation, information sources, help from others, and time; see Figure 1, top right), but only one correlation showed a meaningful effect size, namely for the item "ability to draw independent conclusions" (τ=.22, p<.001). For *Operations* correlations were also partly non-significant (i.e., relating to prior knowledge, elaborating by information search, and practicing), partly significant (i.e., structuring, integrating, memorizing, analyzing, selecting content, planning, elaborating deeply, elaborating by discussion), but only one correlation showed a meaningful effect size, namely for the item "processing critically" (τ=.22, p<.001). For *Standards* correlations were also partly non-significant (i.e., consult science books or the internet, use facts and details, the most important points and ideas, easy-to-understand information, hard-to-understand information, confirmatory information, and summaries; see Figure 1, top left), partly significant (i.e., consult newspapers, scientific journals, text books, encyclopedias; use definitions, rules and heuristics, contradictory information, Estimated Time, and Estimated Nodes), but only one correlation showed a meaningful effect size, namely for the item "use multiple perspectives" (τ=.23, p<.001). For *Evaluations* correlations were all significant (i.e., easy to solve, complex, I can solve this task, and acquiring the necessary scientific knowledge is easy; see Figure 1, bottom left), and correlations showed meaningful effect sizes for two items, for "cognitive effort required" (τ=.23, p<.001) and Bloom Classification (τ=.36, p<.001, see Figure 1, bottom right). Thus, across forty-six COPES items, we found significant task-discrimination *and* meaningful task-calibration only for five items.

The direct comparison between students' Bloom Classifications and the correct Bloom Categories shows that on average students classified 36.16% of the six tasks correctly (number of correct Bloom Classifications: M=2.17, SD=1.32). The corresponding graph (Figure 1, bottom right; also see Table 2) indicates that the majority of students correctly classified the *remember* and *apply* tasks, that students overestimate the complexity of the *understand* task, and that they underestimate the complexity of the more complex tasks (*analyze, evaluate,* and *create*).

Students' Epistemic Beliefs are Significantly Related to their Adaptation to Task Complexity (Hypothesis 2)

Students strongly believe in structured knowledge (CAEB Texture) and in experts and books as valid sources of knowledge (DEBQ Source: Authority). They express more neutral views – near the scale midpoint – regarding CAEB Variability, DEBQ Certainty/Simplicity and DEBQ Attainability of truth. These dimensions of epistemic beliefs are consistently and positively interrelated (see Table 1).

Table 1. *Descriptives of and Intercorrelations Between Epistemic Beliefs Scales*

Epistemic Beliefs Scale	*M*	*SD*	1	2	3	4	5
1 CAEB Texture	5.11	0.99	-	$.33^{***}$	$.38^{***}$	$.18^{*}$	.12
2 CAEB Variability	3.61	0.95		-	$.50^{***}$	$.38^{***}$	$.20^{*}$
3 DEBQ Certainty/Simplicity	4.17	1.18			-	$.47^{***}$	$.42^{***}$
4 DEBQ Source: Authority	5.03	1.02				-	$.35^{***}$
5 DEBQ Attainability of Truth	4.62	1.41					-

Note. All epistemic beliefs scales range from 1 to 7 with high values representing "naïve" beliefs in structured, stable, and certain/simple knowledge that could be attained from authorities, and beliefs that truth is attainable. The numbers heading the columns 1 through 5 refer to the epistemic beliefs scales given in the rows.

$^{*}p$<.05, $^{***}p$<.001.

Significant *task-calibration* is a necessary precondition for investigating this hypothesis. Therefore, we only consider those COPES items in these analyses that show meaningful adaptation in this sample (task-calibration; see Hypothesis 1). We conducted an exploratory factor analysis (principal component analysis with oblique rotation) with the four items with the same answer format (i.e., "ability to draw independent conclusions", "processing critically", "use multiple perspectives", and "cognitive effort required"; see above). Results indicate the existence of one underlying factor that explains 49% of variance and has minimally acceptable reliability for exploratory purpose (Cronbach's α=.64). We label this factor *COPES Deep Approach* and use this factor as well as the remaining single item with meaningful task-calibration (Bloom Classification) as dependent variables for investigating Hypothesis 2. For descriptives and evidence of task-discrimination and task-calibration of these variables see Figure 1 (bottom right) and Table 2.

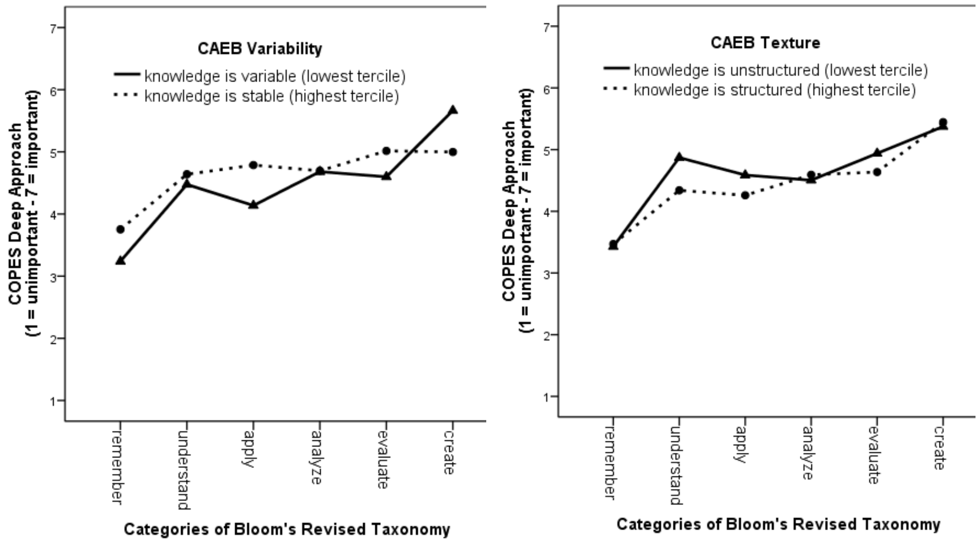
Table 2. *Descriptives and Adaptation of the Dependent Variables for Hypothesis 2*

Bloom Categories	COPES Deep Approach		Bloom Classification
	M	*SD*	% correct
Remember	3.35	1.39	52%
Understand	4.58	0.95	30%
Apply	4.40	1.16	55%
Analyze	5.58	1.14	30%
Evaluate	4.71	0.87	21%
Create	5.36	1.01	29%
Task-discrimination[a]	$F(5,126)=41.07$, $p<.001$, $\eta_p^2=.62$		$X^2(5)=183.95$, $p<.001$
Task-calibration[b]	$.41\ (.35)^{***}$		$.43\ (.38)^{***}$

Note. [a] In this row the results of a repeated-measure ANOVA for *COPES Deep Approach* and a Friedman test for Bloom Classification are reported. [b] In this row the mean and standard deviation (in brackets) are reported for the within-subject Goodman-Kruskal gamma correlations between students' judgments and Bloom Categories; these calibration indices differ significantly from zero with $^{***}p$<.001.

To analyze if *task-discrimination* was related to epistemic beliefs, we included all epistemic beliefs scales (CAEB Texture, CAEB Variability, DEBQ Certainty/Simplicity, DEBQ Attainability of Truth, and DEBQ Source: Authority) as covariates in a repeated-measures ANCOVA across the six Bloom Categories for the dependent variable *COPES Deep Approach*. Because the second dependent variable, Bloom Classification, only contains rank order information, we were not able to apply a similar analysis to this variable. To analyze whether epistemic beliefs were related to students' *task-calibration*, we computed within-subject Goodman Kruskal gamma correlations (γ) between the Bloom Categories (*n*=6 for six tasks) and students' judgments for each of the dependent variables (*COPES Deep Approach* and Bloom Classification) as individual calibration indices (Pieschl, 2009; see Table 2) and subsequently correlated these indicators of adaptation with the epistemic beliefs scales.

Figure 2. Visualization of the Effects of Epistemic Beliefs on Adaptation to Task Complexity



Note. We found a significant interaction between CAEB variability (left; lowest vs. highest tercile) and task complexity (Bloom Categories; X-axis) and a significant main effect of CAEB texture (right; lowest vs. highest tercile).

The repeated-measure ANCOVA for *COPES Deep Approach* elicited the following significant effects of the epistemic beliefs scales: A significant interaction between task complexity (Bloom Categories) and the covariate CAEB Variability ($F(5,120)=2.40$, $p=.04$, $\eta_p^2=.09$) and a significant main effect of the covariate CAEB Texture ($F(1,124)=5.82$, $p=.02$, $\eta_p^2=.05$). We found no significant main or interaction effects of the DEBQ scales. We visualize the significant effects for better interpretation by splitting the scales CAEB Variability and CAEB Texture into terciles and plotting the lowest and highest terciles across tasks. Figure 2 (left, interaction effect of CAEB Variability) indicates that across all tasks students who believe that knowledge is variable are more flexible with their judgments regarding *COPES Deep Approach*. They consider a deep approach less important for *remember, apply,* and *evaluate* tasks and more important for *create* tasks than their counterparts who believe in stable knowledge. Figure 2 (right, main effect of CAEB Texture) also indicates that across all tasks students who believe that knowledge is unstructured consider *COPES Deep Approach* more important than their counterparts who believe that knowledge is structured.

We found no significant correlations between the indices of students' task-calibration and their epistemic beliefs for any of the dependent variables.

Discussion

Secondary School Students Significantly Adapt Their Task Definitions, Goals and Plans to Task Complexity (Hypothesis 1)

This hypothesis could be confirmed, but only for few items of the COPES questionnaire. We found significant differences between tasks of different Bloom Categories (*task-discrimination*) for all COPES items but one. But only for five items these discriminations were systematically related to task complexity (Bloom Categories) with a meaningful effect size (*task-calibration*). These five items are clearly related to the shallowness versus depth of students' task definitions, goals, and plans and represent all COPES facets. For each of the six tasks they refer to how important the internal *Condition* of "drawing independent conclusions" is, how important the *Operation* of "processing critically" is, how important it is to set the *Standard* of using "multiple perspectives", how students *Evaluate* the "cognitive effort required" and how students classify tasks according to complexity (Bloom Classification). For these items, the results are in line with our prediction that students possess shallow task definitions, goals, and plans for simple tasks and progressively deeper task definitions, goals, and plans for progressively more complex tasks. These results are also in line with results with university students even though university students show significant adaptation regarding more items (n=18) and adaptations of larger effect sizes (see Bromme et al., 2010; Stahl et al., 2006).

The relatively small number of significant effects as well as the only small to moderate size of these effects might have a number of different explanations. Secondary school students might not be as skillful as university students in their self-regulated learning. They constitute a more academically diverse sample with potentially more inter-individual differences regarding abilities and competencies.

For example, they might posses less knowledge about learning with hypermedia, less domain-specific knowledge about the learning content, or less metacognitive knowledge about task demands than university students. Therefore, high school students might have different representations of task complexity than theoretically assumed by Bloom's revised taxonomy. The descriptive data as well as the figures indicate that these students did not always order tasks in the assumed sequence (*remember* < *understand* < *apply* < *analyze* < *evaluate* < *create*). For many COPES items they ranked the *understand* task much higher and the most complex tasks much lower than Bloom's revised taxonomy indicates. This general pattern was also detected in university students (see Bromme et al., 2010; Stahl et al., 2006), but these biases were larger in this secondary school student sample. Additionally, secondary school students might also possess less metacognitive knowledge about learning strategies than university students. University students might have an appropriate representation about what constitutes a deep approach to learning with many associated strategies and they might also have appropriate conditional knowledge about when to apply such strategies. Secondary school students on the other hand might possess less practiced metacognitive strategic knowledge.

In sum these results show that task complexity is indeed a relevant external condition for self-regulated learning with hypermedia and that it is important even in the first preparatory stages of learning. However, secondary school students do only adapt those task definitions, goals, and plans to task complexity that are most indicative of a deep approach to learning. They show significantly less task-calibration than university students.

Students' Epistemic Beliefs are Significantly Related to Their Adaptation to Task Complexity (Hypothesis 2)

This hypothesis could be confirmed, but only in one set of analyses and only for the scales of the CAEB, a measure of the associative-connotative aspects of epistemic beliefs. In a repeated-measure ANCOVA for the dependent variable *COPES Deep Approach* we found two significant effects: First, beliefs in unstructured knowledge (CAEB Texture) were related to judging *COPES Deep Approach* more important across all tasks (main effect). We assume that students who believe in unstructured knowledge need to plan more strategies of deep elaboration in order to deal with this anticipated complex nature of knowledge. Second, beliefs in variable knowledge (CAEB Variability) were related to more pronounced adaptation of *COPES Deep Approach* to task complexity (interaction with Bloom Categories). More specifically, students who believe in variable knowledge judge *COPES Deep Approach* more important for the complex *create* task and less important for simple *remember* and moderately complex *apply* and *evaluate* tasks. Bloom's revised taxonomy does not provide norms as to the specific task definitions, goals, and plans suitable for the respective Bloom Categories.

Therefore, we did not specifically predict this pattern of adaptation. However, we assume that students who believe in variable knowledge need to plan more strategies of deep elaboration in order to deal with this anticipated tentative nature of knowledge, especially for more complex tasks such as *create*. This more flexible adaptation could be recognized by a steeper gradient across tasks (see Figure 2, left). Therefore, the overall pattern of both of these effects is in line with our hypothesis and with previous research findings with university students (see Bromme et al., 2010; Stahl et al., 2006).

However, we found no significant main or interaction effects for any of the three scales of the DEBQ and no significant correlations between the epistemic beliefs scales and task-calibration scores for any dependent variable. This pattern of results is not in line with our predictions and might have different explanations. It is conceivable that the selected sample is responsible for this small number of effects. Secondary school students constitute an academically diverse sample. Therefore, their understanding of the epistemic beliefs instruments might have varied more than in university student samples. This should constitute more of an issue for instruments of *explicit-denotative* nature like the DEBQ (Hofer, 2000) than for instruments of *associative-connotative* nature such as the CAEB (Stahl & Bromme, 2007). Another potential explanation concerns the theoretical differentiation between beliefs about the nature of *knowledge* and beliefs about the nature of *knowing*. Hofer (2004) mapped beliefs about the nature of knowledge to metacognitive knowledge and she mapped beliefs about the nature of knowing to metacognitive judgments and monitoring. Therefore, beliefs about the nature of knowledge might be relevant for all stages of self-regulated learning while beliefs about the nature of knowing might only become relevant in the enactment stages. If this was true, we would expect effects of CAEB Variability, CAEB Texture, and DEBQ Certainty/Simplicity. However, CAEB Variability and DEBQ Certainty/Simplicity are significantly related (see Table 1), which might be an explanation for the fact that only one of these scales emerged as a significant predictor of task definition, goal setting and planning across tasks. Regarding the lack of significant correlations between the calibration indices and epistemic beliefs we can only speculate. One potential explanation also concerns the diverse secondary school sample. The mean calibration indices of both dependent variables were only of moderate effect size and secondary school students displayed much inter-individual variance regarding their degree of task-calibration (see Table 2). Therefore, any existent relation with epistemic beliefs might have been lost in this "noise".

In sum these results show that epistemic beliefs are a relevant internal condition for self-regulated learning with hypermedia and that these beliefs are important even in the first preparatory stages of learning. Beliefs about unstructured and variable knowledge are associated with more pronounced and more flexible judgments concerning the importance of deep approaches for learning. These beliefs seem to be productive for this sample and for these tasks. However, we found only a fraction of the predicted effects, namely only effects of the associative-connotative scales of the CAEB (Stahl & Bromme, 2007).

Limitations

To adequately consider the theoretical and practical implication of these results we have to discuss potential limitations of this study. First, the sample is ecologically valid for investigating these hypotheses, especially because it does not consist of psychology students. We purposely selected such a sample to analyze if the – potentially idealized – assumptions of self-regulated learning models hold in a more natural learning context. However, doing research in the field also has some shortcomings. We could only recruit students from schools that voluntarily agreed to be part of the study and our sample size did not allow for analyzing effects of schools or classrooms. Furthermore, because of a lack of computer equipment we were unable to provide each student with their own computer for exploring the hypermedium and students worked in dyads during this phase. Nonetheless, we considered individual students as unit of analysis in this study because dyadic interdependence was non-significant.

Second, we tried to capture students' epistemic beliefs in the most valid and reliable way possible. We administered instruments for different aspects of epistemic beliefs and tested their psychometric qualities. Given the general measurement problems in research on epistemic beliefs (DeBacker et al., 2008) we consider our results excellent. We could replicate the overall factor structure of the DEBQ (Hofer, 2000) and the CAEB (Stahl & Bromme, 2007) with acceptable reliability. However, we concede that the psychometric problems associated with the measurement of epistemic beliefs could be problematic for the interpretation of our results. Additionally, we had to drop our measure of domain-general epistemic beliefs because we did not find a meaningful factor solution (cf. footnote 2) and we could not interpret one scale of the DEBQ due to low reliability.

Third, initially we included additional measures of internal conditions in this study, namely measures of general and domain-specific academic self-concept and a measure of prior knowledge. None of these elicited any significant effects; therefore we dropped these variables (cf. footnote 2). We can only speculate that these learner variables might be more relevant for later stages of learning but irrelevant for task definition, goal setting, and planning.

Fourth, we operationalized task complexity according to Bloom's revised taxonomy (Anderson et al., 2001). We consider this classification adequate, especially because it distinguishes between moderately complex to complex tasks on a fine-grained level. However, the task categories of this taxonomy are not distinct but overlapping and they are not exclusively associated with specific task definitions, goals, and plans. Therefore, there is no "given" optimal solution for each task; we can only diagnose relative task-calibration via correlations.

Last but not least, the COPES questionnaire intentionally only addresses learners' task definitions, goals, and plans. We acknowledge that these might not necessarily predict students' behavior in subsequent stages of self-regulated learning (Jamieson-Noel & Winne, 2003). Additionally, this questionnaire was conceptualized in order to capture the different COPES facets but items did not load on common factors according to these facets but rather depicted common approaches to learning, namely a deep approach. This does not necessarily contradict the COPES model (Winne & Hadwin 1998, 2008). It describes ideal self-regulated learning by skillful learners, for example only SMART operations are outlined in this model. However, the COPES questionnaire also comprises other – probably more realistic – operations such as "memorizing".

Implications

Despite these limitations we can draw some conclusions: Secondary school students show significant task-discrimination and task-calibration, but these effects are fewer and smaller in effect size than for university students. Therefore, secondary school students seem to need additional help in adequately recognizing task demands and constraints and in adequately adapting their goals and plans accordingly. Our findings indicate that secondary school students have special difficulties in recognizing the complexity of very complex tasks and in adequately planning well-suited approaches to these tasks. Therefore, we recommend that educators incorporate more variation in task complexity and especially more complex tasks into their curricula. Furthermore, they could explicitly address task demands, adequate goals and plans in class. Additionally, more metacognitive knowledge about learning tactics and strategies might be helpful, especially conditional knowledge. With respect to research, further effort is required for a better understanding of the context- and age-specific functional relationships between epistemic beliefs, elements of metacognition, and knowledge acquisition. A vast challenge will lie in creating instruments which are both sensitive enough to assess contextual influences and reliable enough to yield reproducible results.

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Received: October 21, 2013