The dual nature of epistemic beliefs and their relations to self-regulated learning. Two replication studies in the context of teacher education

Samuel Merk

University of Tübingen

Krista R. Muis

McGill University

Augustin Kelava and Thorsten Bohl

University of Tübingen

Author Note

Samuel Merk, Faculty of Economics and Social Sciences, University of Tuebingen; Krista R. Muis, Department of Educational and Counselling Psychology, McGill University; Augustin Kelava, Faculty of Economics and Social Sciences, University of Tuebingen; Thorsten Bohl, Faculty of Economics and Social Sciences, University of Tuebingen.

Correspondence concerning this article should be addressed to Samuel Merk, Faculty of Economics and Social Sciences, University of Tuebingen, Muenzgasse 22, 72070 Tuebingen, Germany.

Abstract

In two studies we addressed actual findings in research on topic- and domain-specific epistemic beliefs and replicated them in the context of teacher education. In Study 1, 232 student teachers (*n* = 122 females) were surveyed about their general and topic-specific epistemic beliefs about topics of general pedagogical knowledge. In Study 2, interactions between domain-specific epistemic beliefs and self-regulated learning of 805 student teachers (*n* = 531 females) were explored. Results of Study 1 showed evidence for the dual nature (topic-generality and topic-specificity) of topic-specific epistemic beliefs as they vary substantially within persons and systematically between persons and can consequently be predicted by general epistemic beliefs. Study 2 replicated the predictive effects of epistemic beliefs on the adaption of learning strategies to task complexity. Common methodological approaches of investigating the dual nature of epistemic beliefs are discussed along with the relevance of epistemic beliefs for teacher education in general.

Introduction

In today's knowledge societies, laypersons and professionals are confronted with vast amounts of information, whose veracity and relevance they have to evaluate in order to make it useful for them. For example, teachers are inundated with high volumes of research results derived from various scientific disciplines adopting certain paradigmatic approaches. How do they evaluate this knowledge? What are their assumptions about the origin of such research, the genesis, and the justification of this knowledge? In other words: what do they think about the epistemic nature of this information? Scholars have invested much effort in investigating such questions under keywords like epistemic beliefs or epistemic cognition. Here, "epistemic beliefs" can be defined as beliefs about the nature of knowledge and knowing (Muis, 2007), while the term "epistemic cognition" emphasizes "knowledge and the processes involved in its definition, acquisition and use" (Greene, Azevedo, & Tourney-Purta, 2008, p. 143) and has several other diverging definitions (Greene, Sandoval, & Bråten, 2016). An area of current research on epistemic beliefs focuses on their dual nature where epistemic beliefs are often considered being both: domain-general as well as domain-specific (Buehl & Alexander, 2001; Hofer, 2006a; Muis, 2004; Muis, Bendixen, & Haerle, 2006). Another prominent line of research within the epistemic beliefs literature explores their relations to metacognitive and self-regulatory processes (Barzilai & Zohar, 2014; Bromme, Pieschl, & Stahl, 2010; Mason & Bromme, 2010; Muis, 2007). For example, research has shown that epistemic beliefs are related to students' learning strategies (Schommer, Crouse, & Rhodes, 1992), their behavior in computer-based learning environments (Greene, Muis, & Pieschl, 2010), and their regulation of cognition while solving (hypothetical) problems with unmotivated students (Muis & Franco, 2010).

In the following research, we aim to contribute to these two research strands with two replication studies. Both replication studies further their original versions by the use of advanced statistical methods, test an actual theoretical model, and are embedded into the context of teacher education: Study 1 is a replication study of findings from Trautwein, Lüdtke and Beyer (2004), focuses on the *Theory of Integrated Domains in Epistemology* (TIDE, Muis et al., 2006), and tests the assumption that epistemic beliefs about different theories of educational research are both domain general and domain specific. Study 2 is a replication study of selected results by Pieschl (2009) and relies on the *calibration hypothesis* (Pieschl, 2009), which assumes a functionality of epistemic beliefs for adapting learning strategies to task complexity. Before describing the two studies in detail, we present an overview of relevant theory, empirical research, and the theoretical models.

The Dual Nature of Epistemic Beliefs: Definitions, Frameworks, Issues

The literature on epistemic beliefs encompasses a wide variety of definitions and frameworks (Hofer, 2001; Hofer & Bendixen, 2012; Hofer & Pintrich, 1997; Pajares, 1992). However, as noted earlier (Bråten, 2010; Hofer & Bendixen, 2012), most of them are defined from a developmental (Belenky, Clinchy, Goldberger, & Tarule, 1986; Kitchener & King, 1981; Krettenauer, 2005; Perry, 1970), multidimensional (Hammer & Elby, 2004; Hofer & Pintrich, 1997; Schommer, 1990; Stahl & Bromme, 2007), or integrated perspective (Bendixen & Rule, 2004; Greene et al., 2008; Muis et al., 2006). We first present an overview of the various prominent theoretical frameworks, and then describe Muis et al.'s (2006) framework, which takes into consideration the dual nature of epistemic beliefs.

Developmental Perspectives

Research on epistemic beliefs was pioneered by Perry (1970), who interviewed college students on an annual basis to investigate their reactions on the pluralisitc and intellectual contexts at the university. He educed a model wherein epistemic beliefs develop from a dualist view, whereby knowledge is seen as absolute and certain, and is followed by relativism (all opinions are equal), and, finally, by commitment within relativism. In this final stage, commitment within relativism, individuals accept that there is no such thing as the absolute truth, but believe instead that it is possible and necessary to evaluate the argumentative strength of competing statements.

Although Perry's method and modeling approaches have been enhanced by many researchers (e.g., King & Kitchener, 1994; Kuhn, 1991), this study does not concern itself with the differences in epistemic beliefs between different academic domains. In fact, all developmental models adopted a domain-general perspective and therefore modeled beliefs from positions of absolutism, through multiplism and, finally, evaluativisim (Kuhn, Cheney, & Weinstock, 2002).

Multidimensional Perspectives

While Perry and his colleagues continued to refine their developmental model, multidimensional models of epistemic beliefs were developed, such as the personal epistemological profiles (PEP) model (Royce & Smith, 1964), which classifies individuals by assessing their most dominant epistemic style (empirical, rational, or metaphorical). This particular model was grounded in philosophy and psychology and focused on how knowledge is acquired and justified. Although research within this framework was very active around the same time as Perry's empirical work, it did not have a large impact on subsequent theoretical frameworks.

Among multidimensional frameworks, Schommer's (1990) is particularly influential. Like Royce (1980), Schommer proposed that epistemic beliefs include multiple dimensions that can be captured through Likert-type items. Accordingly, she developed the Schommer Epistemological Questionnaire (SEQ), which measures beliefs about the simplicity and certainty of knowledge as well as those about innate ability and quick learning (Schommer, 1990). An important issue in the discussion of this framework is the fact that the latter two dimensions are not *epistemic* in nature, as they concern beliefs about *learning* (Hofer & Pintrich, 1997). Following this work, a broad range of theoretical frameworks and related measurement tools were developed under the multidimensional perspective. The most widely used multidimensional framework (Bromme et al., 2010) was proposed by Hofer and Pintrich (1997). It contains two dimensions related to beliefs about *knowledge*, called simplicity and certainty, and two dimensions related to beliefs about *knowing*, called justification and source.

With the rise of multidimensional frameworks, experts debate whether epistemic beliefs are domain-specific or domain-general. With the exception of some recent work (Muis et al., 2015), most studies used Likert-type questionnaires to assess the specificity of beliefs, and most agree today that beliefs are both domain-general and domain-specific (see Muis et al., 2006).

The TIDE Framework

One theoretical framework that takes into consideration the dual nature of epistemic beliefs is Muis et al.'s (2006) Theory of Integrated Domains in Epistemology (TIDE) framework. As Figure 1 shows, epistemic beliefs include multiple levels of specificity, are reciprocally influential, and hierarchically structured. The authors assume that epistemic beliefs are multidimensional and propose four dimensions—certainty, simplicity, justification and source—similar to the framework of Hofer and Pintrich (1997). Specifically, Muis et al. proposed three types of beliefs—general, academic, and domain-specific—whose domains are defined as academic or particular fields of study (Alexander, 1992). Although individuals espouse distinct beliefs about various domains, they are reciprocally influential. Domain-specific epistemic beliefs also interact reciprocally with more general academic beliefs. Academic beliefs refer more generally to beliefs about school knowledge and are more domain-general. These beliefs interact in turn with a subset of general epistemic beliefs, which are defined as epistemic beliefs that are generated in non-academic contexts. All these beliefs are influenced by socio-cultural contexts on the same or a higher level of the general/academic/domain hierarchy. Furthermore, all three types of beliefs develop over time as indicated in Figure 1. The horizontal arrow at the bottom indicates that epistemic beliefs at all levels of specificity show progression which can be described in terms of the developmental perspective (absolutism, multiplism, evaluativisim). In addition, the assumed interaction of life experiences and educational experiences within each dimension of epistemic beliefs indicates that epistemic beliefs change over time.

Some researchers advocate the inclusion of yet another fine-grained level of specificity for epistemic beliefs that are specific to certain topics or theories (Strømsø, Bråten, & Samuelstuen, 2008; Trautwein & Lüdtke, 2004). Given that epistemic beliefs are multidimensional and the general/academic/domain hierarchy can be extended to this theory level (within the domain level), a confirmatory verification of the whole framework would be very challenging. However, the TIDE framework reflects the emerging broad consensus for the need to overcome the duality of the domain-specificity or domain-generality of epistemic beliefs (Buehl & Alexander, 2001; Buehl & Alexander, 2005; Hofer, 2006a; Stahl & Bromme, 2007). In our Study 1 we try to replicate the findings that test some key aspects of this framework within the context of teacher education.

Epistemic Beliefs and Self-Regulated Learning

As mentioned above, a number of studies have been conducted to explore relations between epistemic beliefs and self-regulated learning. Some results have already been incorporated into several theoretical frameworks within the self-regulated learning literature. Winne and Hadwin's (1998) COPES model of self-regulated learning served as a heuristic to deduce the role of epistemic beliefs in self-regulated learning processes (Greene et al., 2010; Muis, 2007; Muis, Kendeou, & Franco, 2011). In the following section, we provide a short description of the COPES model along with two theoretically and empirically elaborated specifications of the functional relationship between epistemic beliefs, self-regulated learning, and metacognition: the consistency hypothesis (Muis, 2007; Muis et al., 2011), and the hypothesis of (extended) calibration (Pieschl, 2009; Pieschl, Stahl, & Bromme, 2008).

The Copes Model

The COPES model consists four weakly sequential phases in the process of self-regulated learning. First, in the task definition phase, individuals create their own definition of a task through their perception of the task, the context of the task given, and the relationship of their self to the task. In phase two, individuals use the resulting definition to set goals and make plans for the realization of the task. Phase three begins when the learner applies cognitive and metacognitive strategies to carry out and complete the defined task. Finally, an optional phase of adaption might follow, when short- and long-term strategies are updated and modified, if necessary. The acronym COPES refers to the postulated topology of the information and operations that underlie all four phases: conditions, operations, products, evaluations, and standards.

The Consistency Hypothesis

According to Bromme et al. (2010), at least two approaches elaborate the functionality of epistemic beliefs within self-regulated learning: the consistency hypothesis and the calibration hypothesis. To derive the consistency hypotheses, Muis (2007) proposed four kinds of interactions between epistemic beliefs and self-regulated learning and located them within the COPES model. The propositions are: "(1) Epistemic beliefs are one component of the cognitive and affective conditions of a task. (2) Epistemic beliefs influence the standards students set when goals are produced. (3) Epistemic beliefs translate into epistemological standards that serve as inputs to metacognition. (4) Self-regulated learning may play a role in the development of epistemic beliefs" (Muis, 2007, pp. 179–184). The consistency hypothesis is built on the third proposition: if epistemic beliefs set epistemic standards for metacognitive activity, these standards should be most successfully achieved if the learner's epistemic standards match the underlying epistemology of the task at hand. To test this hypothesis, Muis and colleagues (Muis, 2008; Muis & Franco, 2010) profiled students as predominantly rational, empirical, or metaphorical (Royce & Mos, 1980). They then assessed self-reported and actual metacognitive strategies and justifications of solutions. Results revealed that students were more engaged in metacognitive regulation when their PEP-profile was consistent with the domain of the given task. In another study, Muis et al. (2011) and Franco et al. (Franco et al., 2012) revisited the level at which the consistency was conceptualized from the domain to the representation: they gave students texts about Newton's laws that differed in the epistemic style with respect to the textual representation (e.g., metaphors versus equations). They found evidence for the consistency hypothesis (e.g., more metacognitive processes, better recall performance) at this level as well.

The Calibration Hypothesis

Pieschl's (2009) extended conceptualization of calibration offers another way to embed the functionality of epistemic beliefs within the COPES model of self-regulated learning. While the term "calibration" conventionally refers to "the degree to which individuals' judgments about their understanding, capability, competence, or preparedness correspond to the understanding, capability, competence, or preparedness they actually manifest" (Alexander, 2013, p. 1), Pieschl takes metacognitive strategies and external criteria into account. Hence, calibration in a task like "How is it possible to generate general characteristics of effective classroom management" or to a task like "What are the characteristics of effective classroom management in Kounin's 'Discipline and Group Management in Classrooms'?" not only refers to the learner's (e.g., student teachers) metacognitive judgments about his or her performance (for each task) but also to external criteria. In the given example, external criteria can be found in the fact that the solution to the first task objectively requires much more complex cognitive operations according to Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Thus, according to this extended conceptualization, an exemplary teacher candidate is well-calibrated if s/he uses deep elaboration in preparation to the first example task and memorization strategies in preparation for the second task.

The consistency hypothesis would predict an interaction between this (extended) calibration and epistemic beliefs. For example, imagine a teacher candidate who believes that knowledge in educational research is definite, confirmable, and has been discovered. When confronted with the first complex task, according to the COPES model, s/he will first define what the task entails. On the basis of her/his epistemic beliefs, s/he perceives this complex task as being easier than it actually is. S/he might mistake the task as an order for recalling the design and methodology of a particular classroom management study rather than interpreting it as an order for synthesizing the methodological strengths and weaknesses of classroom management studies in general. Therefore, her goal setting and planning in stage two of the COPES model leads to the use of less complex strategies, such as searching for a pre-defined answer to this question. Thus, epistemic beliefs function as a lens (Bromme et al., 2010) that transforms objective task characteristics into subjective ones, with the consequence of choosing more or less ambitious metacognitive strategies. In other words, epistemic beliefs interact with the extended calibration process.

In a series of experiments, Bromme and colleagues (Bromme, Pieschl, & Stahl, 2014; Stahl, Pieschl, & Bromme, 2006; Stallmann, 2007) found evidence for the calibration hypothesis in the preparatory stage of learning (e.g., task definition) as well as in the enactment phase of learning (Pieschl, Bromme, Porsch, & Stahl, 2008; Pieschl, Stahl, et al., 2008). Results showed that learners adapt their judgments about subjective task complexity and the strategies necessary to carry out the task to the objective task complexity. Second, university students who believed that knowledge is highly uncertain considered complex metacognitive strategies (e.g., deep elaboration) as being more important for tasks with varying complexity. However, this result could not be replicated with high school students. The authors suggest the context sensitivity of epistemic beliefs as a potential explanation for this inconsistency (Bromme et al., 2010).

Given the substantial theoretical and empirical work on interactions between epistemic beliefs and self-regulated learning described above, we argue that it is promising to apply this framework to the context of teacher education, which is the intention for Study 2.

The Present Studies

With the two studies presented here, we contribute to two strands of research on epistemic beliefs in the context of teacher education. Study 1 aims to test whether epistemic beliefs are dual in nature in accordance with the TIDE framework and if the results of Trautwein et al. (2004) can be replicated in the context of teacher education. This experiment extends existing research on the dual nature of epistemic beliefs in at least three different ways. First, we embed the replicated study in the theoretical TIDE framework, which could not be done by the earlier authors because the TIDE model was proposed later. Second, we add another level of specificity to the TIDE model (the theory level) and test this extension following the approach of the replicated study. The third contribution is the replication itself, as replication studies are necessary (Open Science Collaboration, 2015) but neglected (Schmidt, 2009) steps of gaining evidence in the social sciences.

In particular, we aim to examine between-person differences and within-person variation *simultaneously* as the TIDE framework supposes that students from different academic contexts may develop different epistemic beliefs (between-person differences), and their beliefs may vary between different domains (within-persons differences). Further, we address the issue of the level of specificity and analyze the within-person variance of epistemic beliefs at the more fine-grained theory level. In doing so, we formulated the following three research questions to examine the dual nature of epistemic beliefs:

1.1 How do epistemic beliefs about different theories from general pedagogical knowledge (such as big-fish little-pond effect, constructivist theory of learning) vary within and between student teachers? As the TIDE framework assumes that "as individuals progress through higher levels of education, general epistemic beliefs are less dominant and domain-specific epistemic beliefs become more influential" (Muis et al., 2006, pp. 31), we expect the main proportion of total variance in epistemic beliefs to be located at the theory level and a smaller proportion at the person level. Further, we presume structural invariance of epistemic beliefs at the theory and person level.

1.2 To what extent can theory-specific epistemic beliefs be predicted by global (not specific) epistemic beliefs and theory-specific knowledge? According to the TIDE framework, global academic and domain-specific epistemic beliefs are reciprocally dependent. As we agree with this postulation and extend it to another, more fine grained theory level, we expect a predictive effect of global epistemic beliefs on theory-specific beliefs. In addition, we anticipate to replicate a predictive effect of self-reported theory-specific knowledge on theory-specific epistemic beliefs, as found in Trautwein, Lüdtke and Beyer (2004).

1.3 Is there between-person domain-specificity in global epistemic beliefs and person-specific means of theory-specific epistemic beliefs? In line with current literature reviews we expect small mean differences between student teachers coming from different disciplines.

Study 2 aims to replicate findings concerning the extended calibration hypothesis (Pieschl, 2009) with advanced statistical modelling within the context of teacher education. For this purpose, we had two research questions:

2.1 Do student teachers adapt their learning strategies to the externally defined (objective) complexity of tasks dealing with general pedagogical knowledge?

2.2 Is this adaption to task complexity moderated by their epistemic beliefs? From the extended calibration hypothesis and previous results we expect both: an adaption of learning strategies to task complexity as well as the moderation of these effects through epistemic beliefs.

Methods (Study 1)

Participants

Two hundred and twelve student teachers (n = 122 females, n = 69 studying at least one science, technology, engineering, or mathematics (STEM) subject) volunteered to participate. All the participants were undergraduates, and were invited to participated while they were attending an introductory educational lecture. For ethical reasons, we did not ask for further covariates in the online survey such as age and semester, as contextual information could have allowed re-identification.

Procedure and Materials

Procedure. Participants were presented abstracts of 11 theories from educational research (see Table 1). After having read each abstract, the student teachers were prompted to rate an adapted version of the theory-specific absolutism scale (Trautwein et al., 2004) and their theory-specific knowledge.

Theory abstracts. These abstracts contained 24 to 38 words and were of standard text complexity, as measured by the German adaption of the Flesch Reading Ease index (M = 30, SD = 17.20).

The theory-specific absolutism scale. The theory-specific absolutism scale consisted of six items, to be rated on a 4-point Likert-type scale ranging from 1 (completely disagree) to 4 (completely agree). It contained absolutistic items (e.g., "*This theory reflects reality exactly*") as well as (recoded) relativistic items (e.g., "*It is possible that this theory turns out to be false*"). Internal consistency (Cronbach's alpha coefficient) for each theory is given in Table 1.

Theory-specific knowledge. We assessed the self-reported theory-specific knowledge using one six-point Likert-type item that included the anchors "*I do not know the theory at all*" and "*I know this theory very well*").

Global certainty. The theory-specific (or within-subject or within-person) measurements as described above were supplemented by the measurement of global (domain-general) certainty. This was based on Likert-type items from Hofer (2000) and Schommer (1990), which have been validated in a large-scale longitudinal study with college students (Trautwein & Lüdtke, 2007). This measurement (sample item: *Scientific research shows that for most problems, there is one clear-cut answer*) showed acceptable internal consistency (Cronbach's α = .63).

Lastly, the teaching subjects of the student teachers—and therefore actual *field of study*—was assessed and recoded to a dummy variable, with a value 1 if an STEM subject was at least one of the fields of study.

Statistical Analysis

In Study 1 we aimed to examine the hypothesis of the dual nature of epistemic beliefs about general pedagogical knowledge (GPK). Instead of analyzing between-person or within-person differences in separate studies, we combined these perspectives, using multilevel confirmatory factor analyses (MCFA) and multilevel structural equation modeling (MLSEM) (Mehta & Neale, 2005). Multilevel modeling techniques are typically used in contexts where individuals are clustered in higher units (e.g., in classrooms). With respect to our hypothesis, we conceptualized the 11 theory-specific absolutism ratings as clustered within each person. Hence, we defined level 1 as the "theory-level" and level 2 as the "person-level." Using MCFA for confirming the factor structure at both levels is also advantageous for deriving intraclass correlation coefficients (ICC(1)) for the theory-specific (within-person) items. In principle, the ICC(1) can be interpreted as the proportion of total variance located at the between-level (Hox, 2010). In our case the ICC(1) indicated the *degree of theory-generality/theory-specificity* and, in doing so, served as a metric measurement of the dual nature of epistemic beliefs. To model the predictive effects at both levels (see research questions 1.2 and 1.3), we used MLSEM whose central idea is outlined in the following paragraph.

Multilevel Structural Equation Modeling

The central idea in MCFA/MLSEM is to decompose a measurement y_i (e.g., absolutism according to a certain theory i) in a level 1 specific component y_w (theory-specific component) and a component specific to level 2 y_b (person-specific component), so that $y_i = y_w + y_b$. Thus, the theory-specific values y_w could be interpreted as the difference between the observed value y_i and the mean in y_i for the person y_b. The corresponding population covariance matrices, necessary for MCFA and MLSEM $\sum_i$ could be decomposed in the same way: $\sum_i = \sum_w + \sum_b$ where the estimation of this matrices is more complex than in single level structural equation modeling (see Muthén, 1994).

Using MLSEM allowed us to investigate at level 1 the intra-individual variability as well as the intra-individual associations of constructs (absolutism and self-reported knowledge). At level 2 MLSEM allowed the inspection of inter-individual variability in the student teachers in terms of theory-specific epistemic beliefs and to model relations of these with person-specific measurements. In addition, we used MLSEM to investigate differences in group by means of these level 2 variables (research question 1. 3).

Assessment of Model Fit

To assess the fit of our MCFA and MLSEM models, we followed the guidelines for single-level models (Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004) and used the χ^2 statistic, the Tucker-Lewis Index (TLI), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). For CFI and TLI, values greater than .90 are considered acceptable and those greater than .95 indicate excellent fit; for RMSEA, values greater than .10 indicate unacceptable fit and values smaller than .06 show good model fit; and with SRMR, values smaller than 0.08 indicate good model fit (Hu & Bentler, 1999).

Missing Values

Handling missing data in a naïve way (e.g., list wise deletion) is known to pose problems (Rubin, 1976; Schafer & Graham, 2002). Although the percentage of missing data was not very high (from 0% to 15.5%), we decided to handle missing values model-immanent, using the robust maximum likelihood estimator, which additionally adjusts for non-normality of the indicators. The program package MPlus 7.7 (Muthén & Muthén, 2012) was used for all MCFA and MLSEM parameter estimations for Study 1.

Results (Study 1)

Research Question 1.1: Structural Invariance and Dual Nature

We investigated the dual nature of epistemic beliefs about GPK by confirming the one-factor structure of the theory-specific “absolutism” at the theory- and person-level simultaneously, using MCFA. In the first model (M1, see Figure 2), we specified an unrestricted one-factor structure at each level. The model fit was excellent (χ^2 = 39.349, *df* = 18, CFI = 0.990, TLI = 0.984, RMSEA = 0.022, $SRMR_{within}$ = 0.009, $SRMR_{between}$ = 0.078). We continued by restricting M1 and hypothesized a one-factor structure at each level with level-invariant loadings. Again, the fit indices of the resulting model (M2) indicated very good fit (χ^2 = 122.528, *df* = 24, CFI = 0.955, TLI = 0.944, RMSEA = 0.040, $SRMR_{within}$ = 0.019, $SRMR_{between}$ = 0.151), with the exception of the $SRMR_{between}$ value, indicating that the restriction is a misspecification at level 2. Results from the χ^2-difference test between M1 and M2 suggest that the unrestricted model ($\Delta\chi^2$

= 87.3, $\Delta df = 6$, $p = 0.000$) fits the data better. So we inspected the ICC(1) coefficients of the indicators of M1 to determine their degree of theory-generality/theory-specificity to answer research question 1.1. The ICCs ranged from .11 to .40 ($M = .274$, $SD = .10$), implying that 11-40% of the total variability in theory-specific ratings were located at the person-level. Specifically, 11–40% of the total variance in theory-specific rating stems from the nesting of theory-specific ratings in persons (Lüdtke, Robitzsch, Trautwein, & Kunter, 2009).

Research Question 1.2: Predictive Effects of Global Epistemic Beliefs and Knowledge

We then proceeded with the analysis of the dual nature of epistemic beliefs about GPK by extending M2 with latent and manifest predictors at both levels. To answer research question 1.2, we added the theory-specific knowledge as manifest predictor at level 1 and global certainty as a latent predictor at level 2. The resulting model (M3) showed good fit indices ($\chi^2 = 111.790$, $df = 67$, CFI = 0.987, TLI = 0.983, RMSEA = 0.016, $SRMR_{within} = 0.016$, $SRMR_{between} = 0.075$), and significant predictive effects with positive signs of moderate size (see Figure 3).

Research Question 1.3: Between Person Domain-Specificity

Our final model (M4) was specified by adding predictive effects from a dummy variable I^{STEM}, indicating an STEM subject, to global certainty and the person-specific means of theory-specific absolutism to M3 (see Figure 3). M4 shows a small, non-significant effect from I^{STEM} on global certainty and no effect on the person specific means of theory-specific absolutism. M4 showed excellent fit, too ($\chi^2 = 144.630$, $df = 77$, CFI = 0.981, TLI = 0.976, RMSEA = 0.019, $SRMR_{within} = 0.016$, $SRMR_{between} = 0.078$).

Brief Discussion of Study 1

These results replicate the findings in Trautwein et al. (2004) and provide evidence for the dual nature of epistemic beliefs assessed at the theory level. We found the main proportion of total variance in theory-specific absolutism items within persons as well as substantial variation in the person-specific means of these items. And yet these person-specific means of theory-specific absolutism could be significantly predicted with the global certainty measurement. The latter result emphasizes empirically the reciprocal dependence of global and theory-specific epistemic beliefs and their dual nature, as theoretically proposed by the TIDE framework. These results persisted as we controlled for between-person domain-specificity, which turned out to be small and insignificant. We discuss these results with respect to previous and future research in the last section. The next section describes Study 2 in which we examined the role of epistemic beliefs for self-regulated learning in the context of teacher education.

Methods (Study 2)

Participants (Study 2)

The sample for Study 2 consisted of 805 student teachers (n = 531 females, n = 306 studying at least one STEM subject). All the participating student teachers were enrolled during the introductory education lecture in which they were invited to voluntarily participate. Again, further demographic variables were not sought for ethical reasons as contextual information could have allowed re-identification.

Procedure and Materials (Study 2)

Tasks of different complexity. We designed a within-person experiment in which three curricular valid tasks of different complexity were presented to every teacher student (see Table 2), following Bloom's revised taxonomy (Anderson & Krathwohl, 2001; 1956).

The COPES questionnaire. For each task, the importance different of learning conditions, operations, and standards were assessed using the COPES questionnaire (Stahl et al., 2006). The COPES questionnaire uses Likert-type items ranging from 1 = very unimportant to 7 = very important. The item groups are preceded with the prompt “How important is/are the following conditions/strategies/information/information sources for the solution of the present task.” As Study 2 was conducted as an online assessment, we designed the environment in a way that allowed student teachers to see the task on the left-hand side of their screen and the COPES questionnaire on the right. The COPES questionnaire contains three dimensions: deep processing (sample items: “to elaborate deeply”, “to structure”; number of items = 7), dealing with multiple information sources (sample items: “contradictory information,” “elaborating by discussion”; number of items = 5), and superficial processing (items: “definitions,” “memorizing”; number of items = 2). Internal consistency (Cronbach’s α) was acceptable for the first two dimensions (deep processing $\alpha = .69$, dealing with multiple information sources $\alpha = .78$) and problematic for the superficial processing scale ($\alpha = .53$).

Connotative aspects of epistemic beliefs. Epistemic beliefs were assessed using the connotative aspects of epistemological beliefs (CAEB) instrument (Stahl et al., 2006). The CAEB was developed under the multidimensional perspective of epistemic beliefs, to assess evaluative/associative assumptions of knowledge. Therefore, it consists of 17 opposing adjective pairs like objective–subjective or dynamic–static in a semantic differential with a 7-step scale. The CAEB evaluates two dimensions: texture and variability. As the variability dimension showed low internal consistency in the pilot study, we used only the texture dimension with 10 items, which addresses the source (negotiated–discovered) and simplicity (integrated–separated) of knowledge, which are also reflected in the TIDE framework. To assess domain-specific epistemic beliefs about GPK, we modified the prompt of the CAEB to “The general pedagogical knowledge is …”. Internal consistency for the texture scale was good (Cronbach’s $\alpha = .75$).

Statistical Analysis (Study 2)

Like Study 1, Study 2 included hierarchical data. Because every teacher student was asked the same questions (COPES questionnaire) about three tasks, these answers can be regarded as clustered (or nested) within person. Consequently, person-specific measurements (e.g., domain-specific epistemic beliefs) represent level 2 variables (variables that do not vary within a cluster). Specifically, we investigated individuals' calibration to task complexity and its interaction with epistemic beliefs using hierarchical linear models (HLMs) (Snijders & Bosker, 2012). HLM allowed us to model predictive effects both at the task level and the person level simultaneously, as illustrated below. We predicted calibration of the learning strategy (e.g., superficial processing sup_{ij} of person j and task i) by objective task complexity, using

$$\mathrm{sup_{ij}} = \mathrm{b_{0j}} + \mathrm{b_1} \cdot \mathrm{I_{ij}^{apply}} + \mathrm{b_1} \cdot \mathrm{I_{ij}^{23eate}} + \mathrm{r_{ij}} \quad (1)$$

where I^{apply} and I^{create} represent dummy variables for the task complexity "apply" and "create", r_{ij} represents the level 1 residual, so that b_{0j} can be interpreted as the importance rating of superficial processing of person j for the remember task, whereas b_1/b_2 represents the average difference in importance ratings of superficial processing between the task complexities remember/apply and remember/create. The person-specific importance of superficial processing for the remember task can then be predicted using level 2 variables such as $texture_{j,}$ which represents the texture of person j. Further, cross-level interaction terms like $\mathrm{texture_j} \cdot \mathrm{I_{ij}^{apply}}$ and $\mathrm{texture_j} \cdot \mathrm{I_{ij}^{23eate}}$ result in a level 2 equations such as

$$\mathrm{b_{0j}} = \gamma_{00} + \gamma_{01} \cdot \mathrm{texture} + \mathrm{u_{0j}} \quad 02)$$

and

$$\mathrm{b_{0j}} = \gamma_{00} + \gamma_{01} \cdot \mathrm{texture} + \gamma_{01} \cdot \mathrm{texture} \cdot \mathrm{I_{ij}^{apply}} + \gamma_{03} \cdot \mathrm{texture} \cdot \mathrm{I_{ij}^{23eate}} + \mathrm{u_{0j}} 03),$$

respectively. As we centered the continuous level 2 variables texture, γ_{00} can be interpreted as the average of person-specific importance ratings of superficial processing for the "remember task" and of a "typical teacher student," whose texture values equal the mean of all texture ratings. γ_{01} could be interpreted as the predictive effect of texture on the importance rating of superficial processing for the remember task. Finally γ_{02}/γ_{03} corresponds to the difference between the predictive effect from texture on rating of importance of superficial processing in the case of apply/create tasks, and this is the predictive effect for "remember tasks" (γ_{01}).

Results (Study 2)

In the following we present the results of both research questions concerning the calibration hypothesis (2.1, 2.2) in two separate paragraphs and illustrate the results from the HLMs with calibration plots (Pieschl, 2009).

Research Question 2.1: Calibration to Task Complexity.

Graphical elaboration. In Figure 4, task complexity is plotted against the self-reported importance of different learning strategies. The three subfigures correspond to the three dimensions of the COPES questionnaire. The left subfigure details the self-reported importance of the learning strategy "deep processing" at the ordinate, the subfigure in the center shows the importance of the learning strategy "dealing with multiple information" at the ordinate, and the subfigure on the right shows self-reported importance of "superficial processing." To assess interactions with epistemic beliefs, plots were divided into two subgroups, which yield means in the epistemic belief measurement that are higher/lower than the arithmetic mean of that measurement (see Figure 4). Additionally, we plotted standard deviations and standard errors of the mean per group to provide graphical approximations of effect sizes and significance of mean differences between groups. To answer research question 2.1 on whether student teachers calibrate to task complexity, we examined the means of the learning strategies for different task complexities. While they were monotonous for superficial processing, they mostly increased for dealing with multiple information sources. A steady rise was also observed for deep processing when the task complexity increased. Thus, we expected a confirmation of the global calibration hypotheses using HLM.

Results from HLM. To detect global calibration with HLM, we initially specified models with random intercepts and dummy variables for the higher task complexities (see Table 3). As expected from the graphical elaboration, their regression weights were all significant except for the strategy “dealing with multiple information sources” for the task of the lowest complexity. This means that student teachers’ self-reported importance of learning strategies is significantly adapted to task complexity with the exception mentioned.

Research Question 2.2: Calibration Moderated Through Epistemic Beliefs

Graphical elaboration. The mean differences between the groups, shown in Figure 4, indicate that the group with smaller values in texture calibrated strongly and more consistently to task complexity as the slopes of the dashed lines become stronger in every subpicture and are unexceptionally positive.

Results from HLM. Modeling research question 2.2 with HLM showed significant main effects of texture on every learning strategy, suggesting that student teachers’ epistemic beliefs (texture dimension of the CAEB) affect all learning strategies significantly across different task complexities. Also the regression weights of the moderation terms became significant with signs, which shows that higher texture values accompanies stronger calibration to task complexity for all three learning strategies (see Table 3).

Brief Discussion of Study 2

Results revealed that student teachers recognize the growing importance of complex learning strategies with increasing complexity of the task at hand – and the reverse for simple learning strategies (see results of research question 2.1). The results also provide evidence that learners yielding higher texture measures (e.g., stating that GPK is rather negotiated than discovered, rather unstructured than structured, ...) adapt their learning strategies in the same way but with greater differences between the tasks (research question 2.2). This is consistent with the (extended) calibration hypothesis, but yields different results from the study we replicated (Pieschl, 2009). We discuss this in the following section.

Summative Discussion

Our main purpose was to replicate two studies from two actual research strands concerning epistemic beliefs in the context of teacher education and embed them in actual theoretical frameworks. These research strands are the dual nature of epistemic beliefs, deduced from the theory of integrated domains in epistemology (Study 1, research questions 1.2, 1.2, 1.3) and the calibration hypothesis from Pieschl's extended conceptualization of metacognitive calibration (Study 2, research questions 2.1, 2.2). In the subsequent paragraphs, we discuss the strength and limitations of the two studies as well as future directions of research on the relevance of epistemic beliefs and teacher education in general.

Strength and Weakness of Study 1

Theoretical deduction. Since Trautwein et al. (2004) conducted their study, which we replicated here, the question of domain-specificity/domain-generality of epistemic beliefs has been widely discussed (Buehl & Alexander, 2001). This convergence of these discussions over the years (Limón, 2006) along with the theory of integrated domains in epistemology (Muis et al.,

2006) point to the existence of a deeply elaborated framework, which reflects the domain-specificity/domain-generality issue of epistemic beliefs. In this work, we extend this framework to a more fine-grained level of specificity and argue that this theoretical underpinning of the replicated study strengthens the results described below.

Simultaneously modeling. One of the most important strengths of the study is the simultaneous modeling of within-person variation and between person-differences in theory-specific epistemic beliefs about GPK. The results of ICC(1) estimations highlight the need for such an analysis: ICC(1) ranging from .11 to .40 can be interpreted as evidence for the interaction of specific beliefs, as postulated by the TIDE model. But these ICC(1) coefficients also imply that one would lose between 60–89% of the total variance if the theory-level is be ignored. If we explicitly model the within-person level, this variance is welcome as it can be explained with within-person predictors—here theory-specific knowledge. But what if we had assessed epistemic beliefs only at the higher domain-specific or even domain-general level? It is likely that a good deal of this within-person variance would result in measurement error variance and in low reliability, since prompts like “in the field of GPK ...” or “scientists...” are very ambiguous. While one individual might link the prompt to a researcher conducting a large-scale assessment, another could presume a researcher studying the philosophy of science. On the other hand, we cannot claim that our approach to assessing within-person variance (by choosing 11 specific theories) is free of arbitrariness as we cannot be certain of what would have happened if we had chosen other theories.

Appropriate level of modeling. Beyond the simultaneous modeling of within-person variation and between-person differences, another strength of our approach lies in the choice of the appropriate level (Buehl & Alexander, 2006) for detecting between-person domain-specificity. As the TIDE framework models domain-specific instructional contexts related to domain-specific epistemic beliefs better than those related to global epistemic beliefs, it is reasonable to investigate differences in global epistemic beliefs at the between-person level and the between-person differences in theory-specific epistemic beliefs only for the person-specific means (see Figure 3). The so detected differences in the means of global certainty (research question 1.3) are consistent with the (potential) ambiguity mentioned above: if student teachers with a STEM subject are prompted with questions such as “scientific research shows that for most problems there is one clear-cut answer,” they may associate “scientific research” with predominantly the domains of their subject, which would lead to higher certainty scores because they (implicitly) do not rate global certainty but rather domain-specific certainty beliefs for “their” domain. However, we are aware that the groups of study subjects we generated and GPK itself are epistemologically heterogeneous. For instance, there might be methods in political science that are more similar to a certain method in biology than to a specific method in history. While completely overcoming this problem is a challenge, we believe that we have taken an important step toward minimizing this problem by addressing within- and between-person variations simultaneously.

Apart from resolving the limitations of Study 1 mentioned above, it would be beneficial to use exactly the same constructs and wordings at each level of specificity. An investigation of the within-person variation in domain-specific beliefs (in the way we did for the theory-specific beliefs) within the field of GPK would also offer some insight into the duality of epistemic beliefs.

Strength and Weakness of Study 2

Psychometric properties of the COPES questionnaire. Our confirmation of the calibration hypothesis (research question 2.1, 2.2) should be interpreted with caution because of the weak measurability of the COPES questionnaire, especially the dimension of superficial processing, which consists of only two items showing poor reliability. Our approach of using HLM to model the calibration hypothesis can be seen as one way to address this problem, as the random intercept we predicted by epistemic beliefs (research question 2.2) is free of measurement error (Skrondal & Rabe-Hesketh, 2004). However, we see the need for replicating these results using a measurement with high psychometric quality.

Focus on further learning phases. Beyond the fidelity issues mentioned earlier, improvements in the bandwidth of the learning strategy measurements are also warranted. As we studied the calibration hypothesis only in the preparatory phase of self-regulated learning (Winne, 2001), widening the focus to further stages could provide new insights into the object of study. Previous attempts to do so were often undertaken from the perspective of learning in computer-based environments (for an overview see Greene et al., 2010), using, for example, log file analyses or think-aloud protocols. As computer-based learning environments seem to be rather different from existing learning environments in teacher education, following this approach would not yield high external validity.

Epistemic Beliefs in the Context of Teacher Education: Perspectives for Further Research

When we embarked on our two replication studies, we had intended to generate a sophisticated contribution to the converging debate (Hofer, 2006a) about domain-specificity/domain-generality of epistemic beliefs as well as a replication of the extended calibration hypothesis in the field of teacher education. To describe our vision of further research on the role of epistemic beliefs in teacher education, firstly we want to distinguish the educational perspective on epistemic beliefs about GPK as a learning goal from a more psychological perspective—in the way others did before (Köller, Baumert, & Neubrand, 2000; Merk, 2013; Strømsø & Bråten, 2011; Trautwein et al., 2004). We conducted our Study 2 under the "learner variable perspective," as epistemic beliefs measurements were used to predict the self-reported importance of different learning strategies. It is easy to imagine further research being done under the same perspective and inspired by the current investigations concerning epistemic beliefs in general. Studies of this kind would be potentially beneficial to teacher education because of the "learner variables perspective." In addition, it is easy to transfer research conducted under the "learner variables perspective" to the field of GPK, because GPK matches this research very well in to some aspects. For example, empirical findings related to GPK are often inconsistent or contradictory (Baumert & Kunter, 2006; Bromme, Prenzel, & Jäger, 2014)—exactly depicting a well-known issue in research on epistemic beliefs (Ferguson, Bråten, & Strømsø, 2012; Kienhues, Stadtler, & Bromme, 2011; Mørk, Aanestad, Hanseth, & Grisot, 2008) —and should therefore be easily adapted to the context of teacher education.

In contrast, it seems more tricky to use the learning-goal perspective as a heuristic for generating promising future research directions. Indeed, we can find simplifying and normative statements in the literature (based on results generated under the "learner-variable perspective"), claiming that learners should have "more sophisticated" epistemic beliefs as they are positively related to desirable dependent variables. However, this seems to be problematic as there are inconsistent results and also theoretical doubts over a simple (linear) association between the sophistication of epistemic beliefs and learning performance (Bråten, Strømsø, & Samuelstuen, 2008; Elby & Hammer, 2001; Pieschl, Stahl, Murray, & Bromme, 2012). To overcome these problems in the research on epistemic beliefs and teacher education, we suggest following the concept of "epistemic competence" (Alexander & DRLRL, 2012; Alexander et al., 2011; Grossnickle, Alexander, & List, in press; Maggioni, Fox, Alexander, & Fox, 2010). This concept broadens the naïve-sophisticated continuum with at least the dimension of context as it is defined as "the use of available contextual elements to determine the sources of evidence best suited for a given problem in an effort to provide an answer that is justified true belief" (Grossnickle et al., in press). Given that teacher education tries to promote successful (classroom) behavior by presenting academic (e.g., general pedagogical) knowledge, an adaption of, for example, justification standards seems inevitable. Imagine a teacher student who reflects about different research findings of classroom management in an academic or applied context. An inspection of theoretical depth, research designs, sample sizes, statistical procedures etc. might be an adequate justification of the object in the academic context; nevertheless, it could be completely different in the one applied. The concept of epistemic competence reflects this, whereas the naïve-sophisticated continuum only provides one score of epistemic beliefs for both situations.

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Table 1:

Internal consistencies (Cronbach's α values) of the theory-specific assessed variables

Theory	Theory-specific absolutism
Effects of classroom climate on learning outcomes	.70
Organismic integration theory	.80
Programmatical education	.85
Social disparities in attainment	.72
Structural professional approach	.76
Constructivist theory of learning	.77
Big-fish little-pond effect	.80
Pygmalion effect	.84
Corruption of intrinsic motivation	.82
Situated learning	.84
Theory of learning vs. performance goals	.81

Table 2:

Wording and complexity of the tasks provided in Study 2

Task wording	Task complexity
Mark the true answers about optimal classes according to the study of Helmke (1997)	Remember
Group the following words about instructional quality into sense-making subgroups	Apply
The constitution of your federal state holds an educational duty to every teacher. What would happen in schools if this duty was ignored?	Create

Table 3:

Fixed and random effects for random intercept models predicting self-reported importance of different learning strategies (COPES subdimensions)

	Dependent variables											
	Superficial processing				Dealing with multiple information sources				Deep processing			
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
	Fixed effects											
Intercept	4.30***	5.10***	5.10***	5.10***	4.10***	3.60***	3.60***	3.60***	4.60***	3.90***	3.90***	3.90***
	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)
I^{apply}		-0.87***	-0.87***	-0.88***		-0.07	-0.07	-0.06		0.74***	0.74***	0.74***
		(0.07)	(0.07)	(0.07)		(0.05)	(0.05)	(0.05)		(0.05)	(0.05)	(0.05)
I^{create}		-1.60***	-1.60***	-1.60***		1.50***	1.50***	1.50***		1.40***	1.40***	1.40***
		(0.07)	(0.07)	(0.07)		(0.05)	(0.05)	(0.05)		(0.05)	(0.05)	(0.05)
tex			-0.12*	0.16*			-0.18***	-0.40***			-0.18***	-0.34***
			(0.05)	(0.07)			(0.04)	(0.06)			(0.04)	(0.05)
$I^{apply} \times$ tex				-0.36***				0.26***				0.22***
				(0.09)				(0.07)				(0.07)
$I^{create} \times$ tex				-0.49***				0.41***				0.39***
				(0.09)				(0.07)				(0.04)
	Random Parameters											
$\sigma^2(r_{ij})$	2.30	1.70	1.70	1.70	1.90	1.10	1.10	1.10	1.40	0.91	0.91	0.90
$\sigma^2(u_{0j})$	0.21	0.41	0.40	0.41	0.02	0.28	0.26	0.27	0.03	0.21	0.20	0.20
$R^2_{marginal}$	0.00	0.16	0.16	0.17	0.00	0.27	0.28	0.29	0.00	0.24	0.25	0.25
$R^2_{conditional}$	0.08	0.32	0.32	0.34	0.01	0.41	0.42	0.43	0.02	0.38	0.38	0.39

Note: Unstandardized estimates; standard errors are in parentheses; I^{apply} = Dummy variable for task complexity apply; I^{create} = Dummy variable for task complexity create; tex = texture; **p<0.05; **p<0.01;* ***p<0.001. *R^2-coefficients were calculated according to Nakagawa and Schielzeth (2013).*

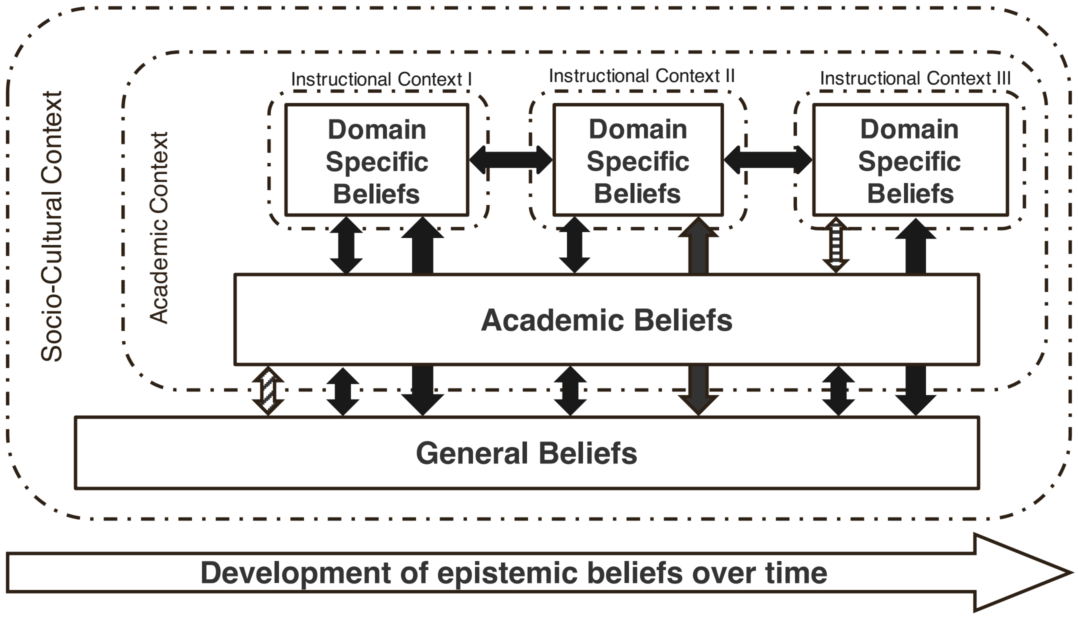

Fig. 1: The theory of integrated domains in epistemic beliefs. (Source: Muis et al., 2006)

Figure 2. Standardized results of the final MCFA model (M1). Estimations of intercepts and residual variances are not shown. *Note:* ta = theory-specific absolutism.

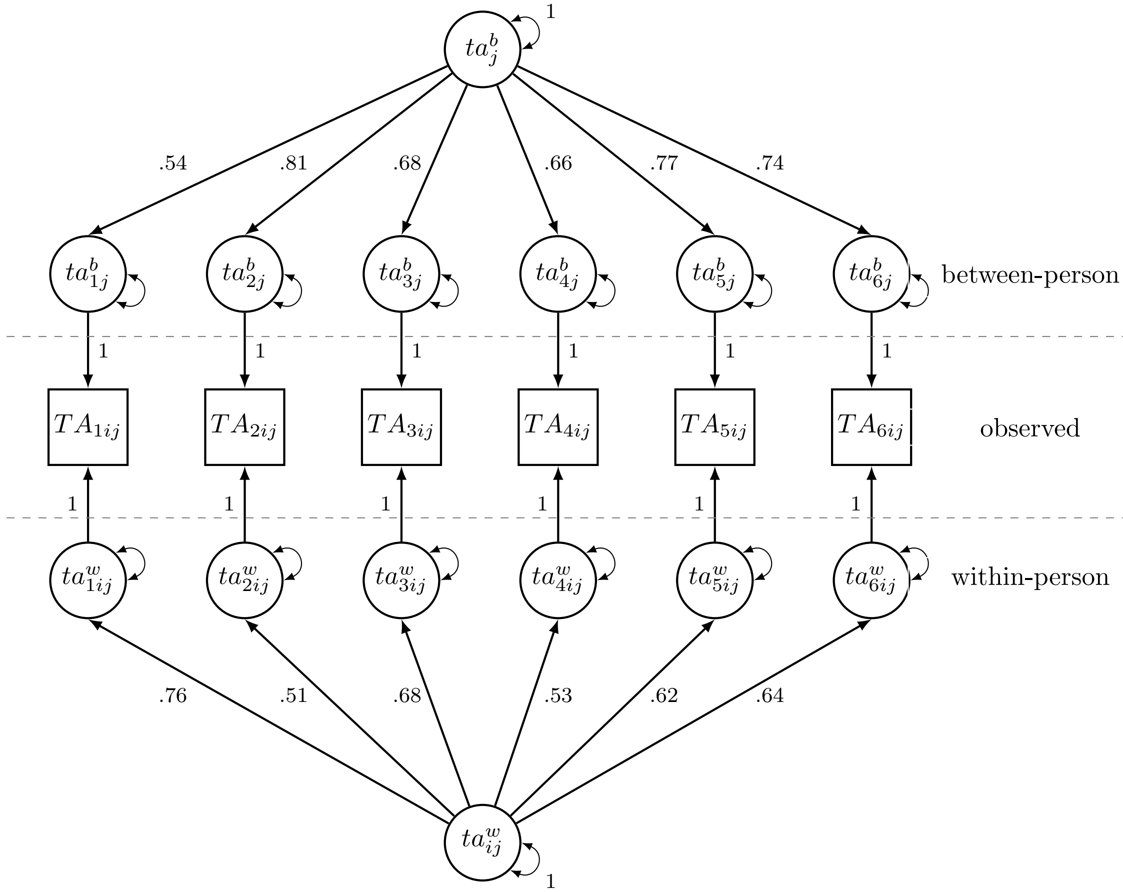

Figure 3. Standardized results of the final MLSEM model (M4). Estimations of intercepts, loadings, and residual variances are not shown. *Note:* ta = theory-specific absolutism; tk = knowledge; gc = global certainty; I^{STEM} = dummy variable for STEM study subject (= 1 if student teachers study at least one STEM subject). ***p < .001.

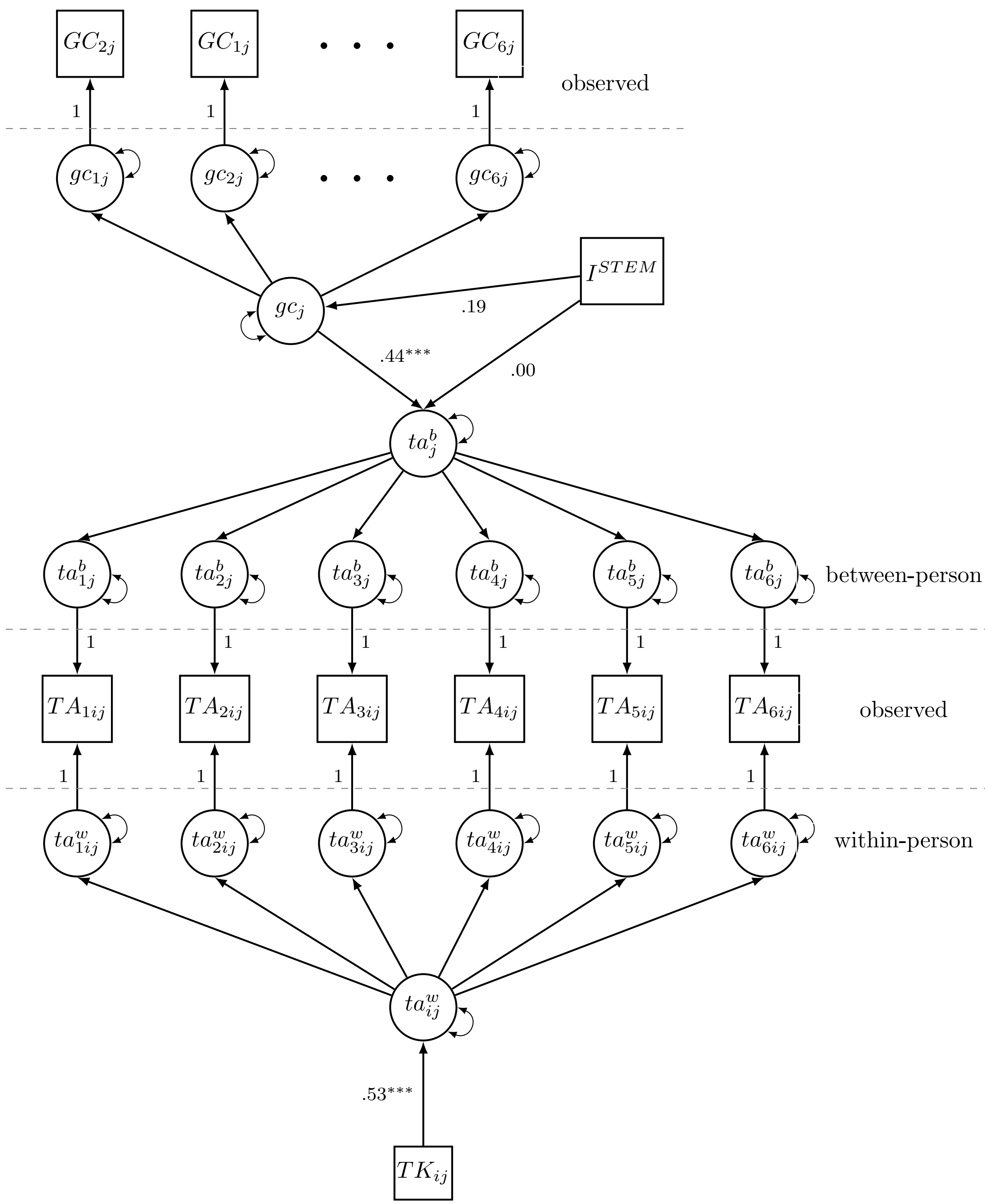

Figure 4. Calibration plots depicting interactions of calibration to task complexity with epistemic beliefs. Thin bars represent standard deviations; thick bars standard errors. Points are offset horizontally so that the bars are visible. *M* = arithmetic mean.