Available online at www.sciencedirect.com
ScienceDirect
Contemporary Educational Psychology 32 (2007) 348–366
Contemporary Educational Psychology
www.elsevier.com/locate/cedpsych

Epistemological beliefs, school achievement, and college major: A large-scale longitudinal study on the impact of certainty beliefs ☆

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Available online 23 January 2006

Abstract

Epistemological beliefs are subjective theories on the structure and acquisition of knowledge. Using data collected in the final year of high school (Time 1) and early in the college career (Time 2) as part of a large-scale longitudinal study, we examined the relationship of beliefs in the certainty of knowledge with school achievement and choice of college majors in Germany. In line with our hypothesis, students high on certainty beliefs showed lower school achievement at Time 1, even when controlling for indicators of intelligence and family background. Certainty beliefs also predicted the choice of future fields of study at college (self-selection hypothesis) and were shaped by enrolment in specific fields of study at college (socialization hypothesis).

Keywords: Epistemological beliefs; Achievement; Academic choices; Self-selection; Socialization

☆ The data presented come from the large-scale project on the Transformation of the Secondary School System and Academic Careers (TOSCA), jointly conducted by the Center for Educational Research at the Max Planck Institute for Human Development, Berlin, Germany, and the Institute for Quality Enhancement in Education at the Humboldt University, Berlin, Germany. The TOSCA study is supported by a grant from the German Research Foundation (Ko 1513/6-1). Authors thank Olaf Köller, Jürgen Baumert, Gabriel Nagy, Barbara Hofer, and Marlene Schommer-Aikens for helpful comments on an earlier version of the manuscript.
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doi:10.1016/j.cedpsych.2005.11.003

1. Introduction

Epistemological beliefs are subjective theories about the structure and boundaries of knowledge and about the nature of knowledge acquisition (Hofer & Pintrich, 1997). Sophisticated epistemological beliefs are seen as both an important goal of instruction and a key predictor of achievement (Hofer, 2001; Hofer & Pintrich, 1997; Schoenfeld, 1992). For these reasons, the last two decades have seen lively psychological discussion on the epistemological beliefs of students (for an overview, see Hofer & Pintrich, 2002) and, more recently, of teachers (e.g. Alexander, Murphy, Guan, & Murphy, 1998; Sinatra & Kardash, 2004; Staub & Stern, 2002).

Despite this intense interest, and several important theoretical and empirical contributions to research on epistemological beliefs and their effects on thinking and learning (see Hofer & Pintrich, 1997, 2002), no consensus has yet been reached on many of the central questions in this field of research (Pintrich, 2002). Ongoing debates address, for instance, the relationship of epistemological beliefs to academic achievement (e.g. Wood & Kardash, 2002) and fields of study (e.g. Jehng, Johnson, & Anderson, 1993). Progress in these areas is subject to the implementation of rigorous methodological standards in terms of research designs, samples, and statistical analyses (e.g. Wood & Kardash, 2002).

This article aims at elucidating the relationship between beliefs in the certainty of knowledge, on the one hand, and students' scholastic achievement and college majors, on the other. In the following section, we give a brief overview of some of the main strands of research on epistemological beliefs that are most closely related to our approach, focusing primarily on work with a background in educational psychology. In the empirical section, we report results from a large-scale, longitudinal student assessment that examines the relationship between epistemological beliefs and achievement, as well as the association between epistemological beliefs and the choice of college major.

2. The certainty dimension

The starting point of modern empirical studies on epistemological beliefs can be traced to the work of Perry (1970). Perry studied the way university students deal with knowledge and knowledge acquisition, and how they come to grips with the uncertainties of knowledge. Based on his interviews with students, Perry developed a scheme describing the development of epistemological beliefs. His model encompasses four broad developmental steps (see Hofer & Pintrich, 1997). Persons with a *dualistic view* see statements about reality as either "right" or "wrong"; in case of doubt, experts will be able to provide the correct answers. The dualistic view is succeeded by a conception of *multiplicity*, in which different views on reality are accepted. However, respondents at this stage still assume that future research will provide "correct" answers to unresolved questions. In the third stage, the *relativistic world view*, all knowledge is seen as a human construction that is uncertain and that might be proven wrong; no one approach can be construed to be superior to another. Finally, students may reach the stage of *commitment within relativism* that enables them—while acknowledging that there is no certainty or absolute truth—to commit to specific views of reality and to judge the quality and appropriateness of different approaches to reality accordingly.

Perry's (1970) analyses prompted numerous studies examining the development of epistemological beliefs and their relations to other constructs, and were a catalyst for stimulating

scientific discussion and debate (see Hofer & Pintrich, 2002; King & Kitchener, 1994). The development of standardized questionnaires to tap epistemological beliefs (see Duell & Schommer-Aikins, 2001, for an overview) as a parsimonious alternative to interview-based assessment procedures was a milestone in research on epistemological beliefs. These questionnaires typically cover several dimensions. Perhaps the best-known instrument is Schommer's (1990) questionnaire on "beliefs about knowledge and learning," which covers four dimensions (stability of knowledge; structure of knowledge; speed of learning; ability to learn; see Duell & Schommer-Aikins, 2001). Based on an extensive review of the literature and a thorough theoretical exploration of dimensions used in research on epistemological beliefs, Hofer and Pintrich (1997) argued in favor of focusing on beliefs on the *nature of knowledge* (with certainty of knowledge and simplicity of knowledge as subdimensions) and beliefs on the *nature of knowing* (with source of knowledge and justification of knowledge as subdimensions) as the core dimensions of epistemological beliefs.

The present analysis focuses on the *certainty* dimension. A strong belief in the certainty of knowledge indicates that a student believes scientific theories and results to be certain, "true," and stable. This kind of standpoint is considered to reflect an unsophisticated view of the nature and boundaries of human knowledge, and assumed to have negative consequences for learning (e.g., low-level processing). The certainty dimension is a core component of almost all conceptions of epistemological reasoning (e.g. Hofer, 2000; King & Kitchener, 1994; Schommer, 1990). For instance, it is an essential element of Perry's (1970) description of young college students who—according to his model—believe that there is a "right" answer to everything. The reflective judgment model (King & Kitchener, 1994) maps students' progression from a belief in the certainty of knowledge to a view that knowledge is uncertain and contextual. In Schommer's (1990) questionnaire, the certainty aspect is encapsulated in the "stability of knowledge" dimension (sample item: "Scientists can ultimately get to the truth"). Similarly, in Hofer's empirical studies (e.g. Hofer, 2000), the certainty dimension was identified in factor analyses.

3. The certainty dimension and academic achievement

In the field of education, epistemological beliefs have been an important construct for the past two decades, and have frequently been used to predict achievement or achievement-related behavior (for reviews see Buehl & Alexander, 2001; Hofer & Pintrich, 1997). It has been assumed that—similar to motivational constructs (e.g. Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Trautwein, Lüdtke, Köller, & Baumert, in press)—sophisticated epistemological beliefs will positively affect the learning process, and factors such as the choice of learning strategy (Kardash & Howell, 2000; Köller, Baumert, & Neubrand, 2000; Ryan, 1984) have been proposed as mediating mechanisms. A significant relationship between achievement and epistemological beliefs has indeed been found in several non-experimental and experimental studies (e.g. Hofer, 2000; Ryan, 1984; Schommer, 1990, 1993; Schommer, Crouse, & Rhodes, 1992). However, the strength of this relationship varies across samples and depends to some degree on the dimensions examined.

For instance, in the Schommer (1993) study with more than 1000 high school students, grade point average (GPA) was significantly negatively predicted by the four dimensions covered in the questionnaire (quick learning, stable knowledge/certainty, simple knowledge, fixed ability). When controlling for verbal IQ, however, only the quick learning dimension remained significant. The effect of the quick learning dimension on academic

achievement was confirmed in a longitudinal extension of the Schommer (1993) study by Schommer, Calvert, Gariglietti, and Bajaj (1997). However, neither stable knowledge/certainty nor two other dimensions significantly contributed to the explanation of GPA in either study. Similarly, stable knowledge/certainty beliefs were not significantly related to math test performance in a study with 139 undergraduate and graduate students (Schommer et al., 1992). The stable knowledge/certainty dimension did, however, predict inappropriately absolute conclusions in a study with 86 junior college students who completed several comprehension tasks after reading text passages (Schommer, 1990). Similarly, Kardash and Scholes (1996) reported that beliefs about the certainty of knowledge predicted the types of conclusions drawn by high school students ($N = 96$) after reading mixed evidence on a controversial topic (causes of AIDS). The stronger the students' beliefs in the certainty of knowledge, the more likely they were to draw conclusions that failed to take into account the inconclusive nature of information provided. The certainty dimension was also significantly related to achievement in a study with 326 first year college students (Hofer, 2000). In this study, certainty scores on both a domain-general and a domain-specific measure were the strongest predictors of academic achievement. The higher their certainty scores, the lower the students' academic standing.

Using data from the German extension to the Third International Mathematics and Science Study (TIMSS), Köller et al. (2000; Köller, 2001) examined the physics achievement of upper secondary students at three course levels (advanced physics course, basic physics course, no physics course). To tap epistemological beliefs, they adapted an instrument specifically tailored to physics (Labudde, 1998) that includes a certainty scale (item example: "Knowledge from the field of physics is beyond all doubt") and a dualism scale (item example: "There is only ever one correct solution in physics"). In line with their expectations, the findings showed that, after controlling for course level, certainty was negatively related to physics achievement (partly mediated by lower interest in physics), whereas dualism was associated with less use of elaboration techniques in the learning process.

Taken together, although certainty beliefs have been found to predict academic achievement in several studies, results have not been unequivocal. However, the non-significant findings may in part be attributable to the design of the studies in question. As pointed out by Wood and Kardash (2002), studies on epistemological beliefs often lack the power to detect small to moderate effect sizes. In addition, most studies rely on convenience samples, which may decrease the likelihood of finding significant effects. Moreover, although there likely is a link between cognitive abilities (intelligence) and epistemological beliefs, many studies examining the relationship between epistemological beliefs and academic achievement have not taken cognitive abilities into account. Likewise, characteristics of the family environment that are conducive to academic progress (e.g., socioeconomic standing, cultural capital; see Buchmann, 2002) are often disregarded. Hence, even in the studies that have found a link between certainty beliefs and academic achievement, third variable explanations may apply.

4. The certainty dimension and college majors

Another strand of research has explored the relationship between students' epistemological beliefs and the study fields chosen at college. In their pioneering study, Jehng et al. (1993) administered an adapted version of Schommer's (1990) questionnaire to 386 college

students from what they dubbed "hard" (engineering and business) and "soft" fields of study (humanities, social sciences). Significant group differences were found for the certainty scale, the "omniscient authority" scale, and the "orderly process" scale. Relative to their peers from the "hard" fields of study, students from the "soft" fields of study were more likely to view knowledge as changeable, relied more strongly on their independent reasoning ability (rather than on authorities in the field), and experienced learning as a less orderly process. In line with Perry's (1970) assumption that the school context shapes students' epistemic thinking, Jehng et al. attributed their findings to enculturation processes: "students learn to view knowledge from the same perspective as those around them, in much the same manner that they learn correct diction or learn to distinguish couth from uncouth behavior" (Jehng et al., 1993, p. 25) .

Similar differences between hard and soft fields of study were reported by Paulsen and Wells (1998), who examined 290 college students using the Schommer (1990) questionnaire and differentiating between soft vs. hard and pure vs. applied fields. Students majoring in soft or pure fields were less likely than others to hold naive beliefs in the certainty of knowledge. For instance, engineering students (hard, applied field) exhibited the highest certainty beliefs. In interpreting their findings, Paulsen and Wells stressed the role of disciplinary contexts as socializing agents.

The studies by Jehng et al. (1993) and Paulsen and Wells (1998) point to notable differences in the epistemological beliefs of students enrolled in different fields of study. However, the differences observed between hard and soft fields do not necessarily reflect socialization (or enculturation) effects at university. Given the cross-sectional design of the studies, it is quite possible that the differences between students in different fields of study were present before college entrance. In fact, different patterns of epistemological beliefs may have *caused* students to opt for certain fields of study. For instance, students with strong beliefs in the certainty of knowledge may find fields that seem to be characterized by "absolute," rather than tentative, knowledge to be more attractive. Hence, self-selection rather than socialization effects (see Pulkkinen & Caspi, 2002) may account for differences in the field of study.

However, this line of reasoning is somewhat weakened by the results from a study with 326 first year college students reported by Hofer (2000), who used both a domain-general instrument (based on items adapted from Schommer (1990), & Qian & Alvermann (1995); e.g., "Scientists can ultimately get to the truth") and a domain-specific instrument to tap epistemological beliefs about psychology or science (e.g., "Truth is unchanging *in this field*"; emphasis added). Data were collected in an introductory psychology class, but 147 of the participating students also attended a science course, and several of them had a science major. The domain-specific scales revealed marked differences in the students' views of psychology and science. For instance, there was a difference of almost one *SD* on the certainty scale in within-person analyses, with knowledge being rated as significantly less certain in psychology than in science. Moreover, students majoring in science were more likely to view truth as attainable than those majoring in social sciences. Importantly, however, no significant differences emerged between students majoring in science vs. social sciences on the domain-general certainty/simplicity scale of the general epistemological beliefs instrument. Given that Hofer's participants were first year students, the latter result may indicate that disciplinary differences *in global certainty beliefs* as reported by Jehng et al. (1993) are likely to emerge during the college years, but not before.

5. The present study

In this study, we test two research questions. First, we examine the assumed positive relationship between sophisticated epistemological beliefs and school achievement (e.g. King & Kitchener, 1994; Perry, 1970; Schommer, 1993). As detailed above, studies have not found unequivocal support for a positive relationship between the level of epistemic reasoning and school achievement. The limited empirical support for the assumption that strong certainty beliefs are negatively related to school achievement is of particular interest in the present context. Therefore, we test the question (see Wood & Kardash, 2002) of whether certainty beliefs explain variance in academic thinking and behavior that is *not* accounted for by other constructs, including cognitive abilities, sex differences, and family background. We postulate that school achievement is negatively predicted by certainty beliefs (see Hofer & Pintrich, 2002) and positively predicted by basic cognitive abilities and family background (e.g. OECD, 2001). Moreover, we posit that some of the predictive power of family background and basic cognitive abilities is mediated by certainty beliefs. More specifically, we assume that, because parents differ in their own ability to deal with the uncertainty of knowledge, there will be corresponding differences in the support they are able to provide their children in the development of sophisticated epistemic beliefs. We expect that families with more resources in terms of socio-economic status and cultural capital will, in general, provide more stimulating environments in this respect and be more likely to challenge oversimplified approaches to knowledge. A slightly different rationale applies to the effects of cognitive abilities. We assume cognitive abilities to be negatively related to certainty beliefs because high-ability students are likely to draw more benefit from the same learning environments than low-ability students. Hence, to the extent that school instruction challenges oversimplified knowledge structures, high-ability students should be able to acquire more sophisticated epistemological beliefs than their less able counterparts.

Accordingly, we test a mediator model in which certainty beliefs function as a mediator variable between family background and basic cognitive abilities, on the one hand, and school grades, on the other. Given that effect sizes in research on epistemological beliefs tend to be rather small (see Wood & Kardash, 2002), large samples such as that used in the present study are needed to test such a hypothesis. Our data stem from a large-scale educational assessment that also tapped potential third variables, such as parental education and occupational status, cultural background, and students' basic cognitive abilities.

The second main issue in this article concerns differences in epistemological beliefs among students in or aspiring to different fields of study: Do certainty beliefs vary as a function of the field of study that students pursue or aspire to pursue? Earlier studies have reported that students in "hard" fields tend to exhibit less sophisticated epistemological beliefs than do students in "soft" fields (e.g. Jehng et al., 1993; Paulsen & Wells, 1998). Such results may stem from *self-selection processes* (students who believe more strongly in the certainty of scientific knowledge chose to study hard sciences), from *socialization effects* (soft fields help students to acquire a critical stance in terms of the "truth" of scientific theories), or from a combination of the two effects. Cross-sectional studies of college students, such as the studies by Jehng et al. (1993) and Paulsen and Wells (1998), do not permit selection and socialization effects to be separated analytically (see Pulkkinen & Caspi, 2002). We aim to shed light on self-selection vs. socialization processes by exploring the epistemological beliefs of a large sample of upper secondary and college students on the basis of longitudinal data. If student beliefs already differ at upper secondary level consistent with their *future* field of study, this would support the view that

differences in epistemological beliefs are – at least partly – the result of self-selection processes. If, however, differences between students in various fields are not observed until college level, or if such differences increase during the college years, results would support the socialization hypothesis (see Pulkkinen & Caspi, 2002).

The data we use originate from a large-scale longitudinal assessment study and thus permit the in-depth exploration of our research hypotheses. Besides implementing a standardized questionnaire measure of certainty beliefs, a wealth of information was gathered on student background characteristics (e.g., parental education and socioeconomic status) and basic cognitive abilities were assessed. Students were administered the epistemological beliefs scale twice, once in the final year of upper secondary education and again two years later, when they were enrolled in college.

6. Method

6.1. Sample

The data considered here are drawn from a large, ongoing German study, Transformation of the Secondary School System and Academic Careers (TOSCA), conducted at the Max Planck Institute for Human Development, Berlin, and the Institute for Quality Enhancement in Education at the Humboldt University, Berlin, Germany (see Köller, Watermann, Trautwein, & Lüdtke, 2004, for more information). The data analyzed in the present article stem from students in 90 randomly selected upper secondary schools in a single German state. The schools are representative of the traditional "Gymnasium" school type, which equips students with the qualifications to attend university. Gymnasium students in Germany are a highly selected population in terms of academic achievement, and the same is true of college students (see Kitchener & Wood, 1987). Only about one third of all students in a cohort attend Gymnasium.

A multistage sampling procedure was implemented to ensure that the data were representative. Schools and students were randomly selected. The participation rate of the Gymnasium schools was 100 per cent, and a satisfactory participation rate of more than 80% was achieved at the student level. At Time 1 (T1), the students in the present sample ($N = 2854$; 45% male) were in their final year of upper secondary schooling. Mean age was 19.29 years ($SD = 0.79$). Two trained research assistants administered materials in each school between February and May, 2002. Students participated voluntarily, without any financial reward. At T1, all students were asked to provide written consent to be contacted again later for a second wave of data collection. A total of 1886 students (66.4%) did so, and were contacted two years later by mail. At Time 2 (T2), participants were asked to complete an extensive questionnaire taking about two hours in exchange for a financial reward of 10 euros (about 12 US$). Data from 1495 of the original participants are available for T2; the data of the 1094 students who reported being enrolled in a classifiable field of study (see below) were used for the longitudinal analyses.

6.2. Instruments

6.2.1. Certainty beliefs

The epistemological beliefs questionnaire administered in the TOSCA study is based on items developed by Hofer (2000) and Schommer (1990) and translated and adapted by

Schiefele, Moschner, and Husstegge (2002). Some new items with an explicit focus on the fallibility of scientific theories have been added. A four-category response format (from *totally disagree* = 1 to *totally agree* = 4) was used. A translation of the seven items administered is provided in Fig. 1. Note that the German word "Wissenschaft" (translated as "science") covers both soft and hard sciences. Likewise, the word "Wissenschaftler" ("scientist") is not restricted to the hard sciences. Hence, our global certainty scale applies to knowledge from both the hard and soft sciences. The internal consistency (Cronbach's alpha) of this *global certainty scale* was .75 (T1) and .73 (T2). High scores indicate a belief that scientific knowledge is certain and unchangeable, whereas low scores reflect an awareness of the fallibility and changing nature of scientific theories and knowledge. Thus, high certainty scores denote *low* sophistication of epistemic reasoning.

6.2.2. Cognitive ability

Cognitive ability or, more specifically, reasoning was measured by means of the highly g-loaded *Figure Analogies* and *Verbal Analogies* subscales from the *Cognitive Ability Test 4–13+R* by Heller and Perleth (2000). These scales consist of 25 figural and 20 verbal items in multiple-choice format. The scales are considered to be a test of reasoning that is relatively free of environmental effects. Using the ConQuest software (Wu, Adams, & Wilson, 2000), both subscales were considered simultaneously and scores for individual participants were estimated on the basis of item response theory. These scores indicated a good fit of the combined scale. The reliability (formula by Rost, 1996) of the score was $R_{TT} = .91$. Five item parcels (consisting of 9 items each) were constructed for use in subsequent structural equation modeling.

6.2.3. Final school grade

The *Abiturgesamtnote*, the final overall grade allocated to Gymnasium students, was obtained from participants' school records. Three elements contribute to this final school grade: test scores in a final examination held at the end of upper secondary education; school grades (or achievement points) accumulated over a two-year period in two advanced courses; and school grades accumulated over a two-year period in a number of basic courses. Thus, the final school grade is an unusually broad index of achievement. Moreover, the final school grade is of high importance for the choice of university course. In Germany, students decide which major to pursue at university toward the end of upper secondary school. A good final school grade gives them access to highly valued fields of study, where slots are assigned on the basis of this final school grade.

- » Scientific theories can be proven false at any time (reverse scored)
- » Scientific theories that we presently consider to be correct can be proven false in the future (reverse scored)
- » Even scientific knowledge must be revised time and again (reverse scored)
- » At some stage, scientists will be able to explain the whole world
- » Scientific research shows that for most problems there is one clear-cut answer
- » Scientific laws are universal truths
- » Scientific knowledge is unimpeachable.

Fig. 1. The items of the global certainty scale.

6.2.4. Family SES

Students were asked to report the type of school their parents had attended (*parental education*; coded 0 = lower track, 1 = intermediate track, 2 = highest track), and to provide information on their parents' jobs (parental occupation). These jobs were classified according to the *International Standard Classification of Occupations* (ISCO 88; ILO, 1990). The *International Socio-Economic Index of Occupational Status* (ISEI; Ganzeboom, De Graaf, Treiman, & De Leeuw, 1992) was then used to transform the ISCO scores into internationally comparable ISEI scores. The higher a person's ISEI score, the higher his or her socioeconomic status. In those cases in which scores were available for both the father's and the mother's education and occupation, we decided to include the higher score. Parental education and occupation have been shown to be potent predictors of student academic achievement in a wealth of U.S. and international studies (Buchmann, 2002).

6.2.5. Cultural capital

We also used student reports on the number of books possessed by the family as an additional indicator of the family background. A high number of books is seen as an indicator of cultural capital or learning opportunities (see Buchmann, 2002) and believed to be associated with academic outcomes. The book indicator has been successfully implemented in several large-scale educational assessments (Buchmann, 2002) in addition to—or as a substitute for—measures of family educational background, and its predictive validity for academically related behaviors and outcomes has been confirmed (e.g., TIMSS, PISA). The indicator is almost always based on student self-reports (e.g. OECD, 2001).

6.2.6. Fields of study

At T2, a total of 1495 questionnaires were returned by students enrolled in almost 100 different colleges throughout Germany. The fields of study were catalogued in close conformity with the official German classification (Statistisches Bundesamt, 2001). Departing from this classification, we separated the over-inclusive category of "social sciences" into the three fields of law, business, and social sciences. We dummy-coded the seven study domains that attracted the most students, namely humanities/arts (257), math and natural sciences (241), business (203), engineering (142), social sciences (88), medicine (84), and law (79). A total of 401 participants were enrolled in other subjects (e.g., sports, agriculture, and forestry; $N = 74$ students), in subjects that were unclassifiable, or were not at college at all ($N = 327$). Following the classification scheme used by Jehng et al. (1993), natural sciences, engineering and business can be seen as "hard" sciences, whereas humanities/arts and social sciences can be considered "soft" fields. Law and medicine do not seem to be classifiable as either "hard" or "soft" fields.

German students have to decide on their college majors *before* they enter college, and they typically focus on the curriculum of their chosen major from the very beginning of their studies. In contrast to the United States, few students sample various fields during their first year at college. Thus, it can be assumed that students in different fields were exposed to quite different college environments. At the time the study was administered, the majority of participants had been at college for more than a year. Preliminary analyses indicated that the length of college enrolment had negligible effects on the pattern of results; hence, this variable was not included in the analyses.

6.3. Statistical analyses

In most studies conducted in school settings, individual student characteristics are confounded with classroom or school characteristics because students are not assigned to groups at random. For instance, the certainty score of a specific student might be affected by "individual level" variables such as intelligence, but also by "class level" variables such as teacher expertise. The possible teacher effect introduces a clustering effect that can cause problems in terms of appropriate levels of analysis, aggregation bias, and heterogeneity of regression. Moreover, when the hierarchical nature of a data set is not taken into account, the estimation of standard errors of means and beta coefficients is typically downwardly biased (Raudenbush & Bryk, 2002).

In our study, students were nested within schools at T1. To check how prominent this clustering effect was in our data, we computed the intraclass correlation coefficient (ICC), a measure that pits the variance accounted for by differences between individual students within one school against differences found between schools. For the global certainty score, an ICC of .02 was found, indicating that there was only a moderate impact of specific schools on certainty beliefs. Likewise, the ICC for school grades was below .02, and the ICC for the other variables was low to moderate (all ICCs < .10). Therefore, we decided not to examine possible context effects (e.g., differences in certainty scores due to differential school quality) explicitly in this study. However, in the structural regression analyses reported for T1 data, we used the Mplus software (Muthén & Muthén, 1998–2004) to adjust the standard errors of the beta coefficients for the clustering effects. The Mplus software allows to take the clustering effect into account (using the Type = Complex function) without specifying an explicit level-2 model.

7. Results

7.1. Prediction of final school grades

The overall level of certainty beliefs at T1 ($M = 1.86$, $SD = 0.48$) proved to be fairly low. This indicates high awareness of the borders of human knowledge among these participants, who were at selective schools. Table 1 shows the intercorrelation matrix of certainty beliefs at T1, final school grades, gender, age, family SES, cultural capital, and basic cognitive abilities. Certainty beliefs correlated significantly and negatively with family SES, cultural capital, cognitive abilities, and final school grades. No significant correlation was

Table 1
Intercorrelation matrix of final school grades, certainty beliefs, and five predictor variables

	Gender: female	Age	Family SES	Cultural capital	Cognitive abilities	Certainty beliefs
Age	−.12					
Family SES	.00	−.17				
Cultural capital	−.01	−.11	.52			
Cognitive abilities	−.26	−.18	.05	.17		
Certainty beliefs	−.02	−.04	−.09	−.17	−.18	
Final school grades	.10	−.26	.11	.25	.33	−.23

Notes. Global certainty, family background, and cognitive abilities were specified as latent variables. All correlations $\geqslant .06$ are significant at $p < .05$.

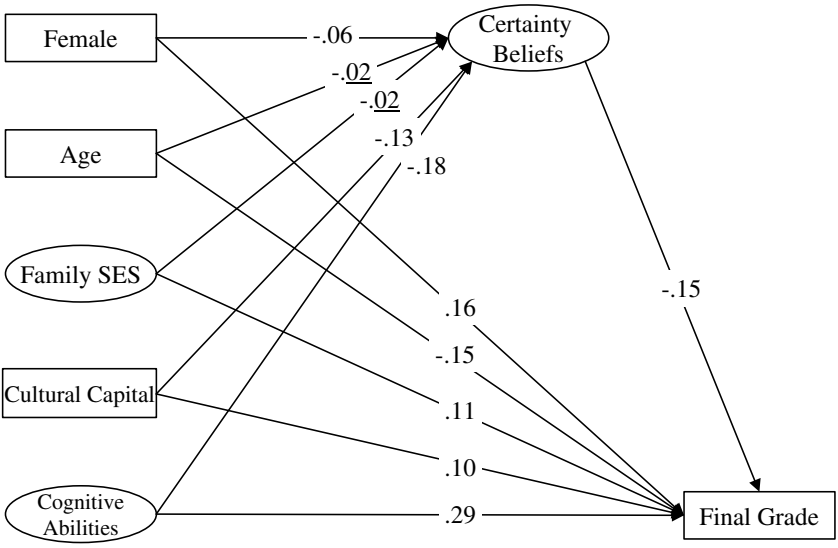

Fig. 2. Predicting final school grades. Results from structural equation modeling. All standardized regression coefficients significant at $p < .05$ unless coefficient is underlined.

found between certainty beliefs and gender or age. Final school grades were significantly related to all other variables—there was a negative correlation with age and certainty beliefs, but a positive correlation with female gender, family SES, cultural background, and cognitive abilities.

Using structural equation modeling, we next examined the role of certainty beliefs as predictors of school achievement. The model shown in Fig. 2 was specified in line with the assumption that certainty beliefs partly mediate the influence of cognitive abilities and family background on final school grades. Family background (latent variable consisting of parental education and socioeconomic status), cultural capital, cognitive abilities (consisting of five item parcels), sex, age, and gender were used as predictors of certainty beliefs (latent variable constituting seven items) and final school grades; the latent certainty beliefs variable, in turn, was specified as predictor of achievement. Correlations among gender, number of books, family SES, cultural capital, and cognitive abilities were freely estimated.[1]

Overall, the fit of this model proved to be good, χ^2 $(df = 115) = 478.47$, TLI = .952, RMSEA = .033, SRMR = .025. The resulting standardized beta coefficients are shown in Fig. 2. Certainty beliefs had a negative effect of $\beta = .15$ ($p < .001$) on final school grades. In turn, certainty beliefs were significantly negatively predicted by female gender, cultural capital, and cognitive abilities. These variables had an additional positive effect on final

[1] We also freely estimated the residual correlations between the three reverse scored certainty items. This modification significantly improved the model fit and indicates a method factor in our global certainty instrument. Although not routinely examined, such method factors are quite common, even in widely used standardized questionnaires (e.g. Marsh, 1996).

school grades. Moreover, family SES had a significant positive direct effect on final school grades, whereas age negatively predicted final school grades.

Taken together, in line with our expectations, we found certainty beliefs to negatively predict school achievement, even when important other variables were controlled. Certainty beliefs partly mediated the impact of cognitive abilities, gender, and cultural capital on school achievement. Given that access to highly valued fields of study is competitive in Germany, the negative effect of certainty beliefs on final school grades was by no means negligible.

7.2. Certainty beliefs and (future) field of study

We now turn to the relationship between students' fields of study and certainty beliefs. Fig. 3 reports means and standard errors of certainty beliefs by measurement point (T1 vs. T2) and field of study at T2. Future business students had the highest certainty scores at T1, and future social sciences students the lowest certainty scores. At T2, social science students again had the lowest certainty scores, while business, engineering, and math/natural sciences students scored highest on certainty beliefs. The most pronounced decline in certainty beliefs was observed among humanities/arts and social sciences students, and a small increase in certainty beliefs was discerned for engineering students only.

Generally speaking, the analyses reported thus far indicate that differences in certainty beliefs among students enrolled in different fields of study were consistent with the soft-hard dichotomy; furthermore, given the decrease in certainty beliefs among humanities/arts students and social sciences students and the slight increase in certainty beliefs among engineering students, the differences between the student groups were more pronounced at T2 than at T1. In short, these results support both the self-selection and the socialization hypotheses. Thus far, however, we have not taken into account the effects of important personal characteristics such as age, gender, basic cognitive abilities, and school achievement on the absolute level of certainty beliefs and change in these beliefs. Moreover, in the analyses reported thus far, we were not able to use latent constructs. Therefore, in an additional set of analyses, we specified a number of structural equation models to predict T1 and T2 certainty beliefs. All analyses were performed using the Mplus 3.1 software.

First, a model was specified with T1 certainty as the dependent variable and the future field of study, gender, family SES, cultural capital, cognitive abilities, and final school

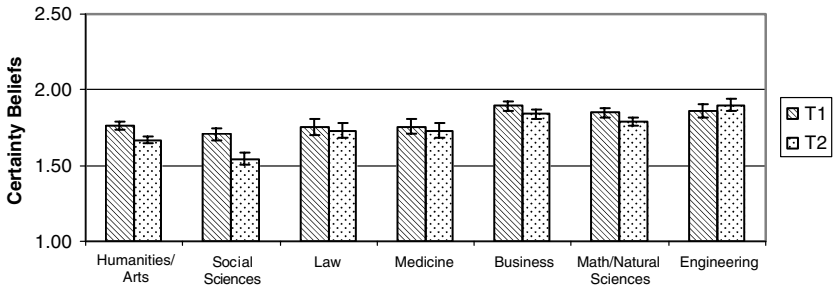

Fig. 3. Means and standard errors (error bars) of certainty beliefs among students with different (future) fields of study at Time 1 (T1) and Time 2 (T2).

Table 2
Regression of certainty beliefs on (future) fields of study, gender, family SES, cultural capital, cognitive abilities, final school grade, and (Model 3) T1 certainty beliefs

Predictors	T1 Certainty beliefs	T2 Certainty beliefs	
	Model 1	Model 2	Model 3
Reference category: Humanities/Arts			
Social sciences	−0.19	−0.34*	−0.26*
Law	0.08	0.20	0.14
Medicine	0.38**	0.46***	0.23
Business	0.33**	0.42***	0.22*
Math/natural sciences	0.39***	0.40***	0.17
Engineering	0.38**	0.63***	0.40***
Gender: female	−0.03	0.00	0.01
Age	−0.01	−0.02	−0.01
Family SES	−0.05	−0.03	−0.01
Cultural capital	−0.04	−0.08	−0.06
Cognitive abilities	−0.18***	−0.05	0.04
Final school grade	−0.18***	−0.24***	−0.14***
T1 Certainty beliefs			0.54***
R^2	.12	.16	.41

Notes. Effects of all dichotomous variables are *y*-standardized. All other effects fully standardized.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

grade as predictors. The future field of study was dummy-coded; accordingly, six fields of study were included in the analysis and the largest group—the humanities/arts students—was used as the primary reference group. The fit of this model proved to be acceptable, $\chi^2(df = 181) = 372.36$, TLI = .931, RMSEA = .031, SRMR = .032. Results are reported in Table 2 (Model 1). Fully standardized regression coefficients are given for all continuous predictor variables; the effects of all dichotomous variables are y-standardized. Hence, for instance, the regression coefficient of .33 for the group of future business students indicates that the certainty beliefs of this group were about one third of a *SD* higher than those of the reference group (humanities/arts students) when controlling for the other predictors variables in Model 1.

In Model 1, four student groups differed significantly from the humanities/arts group: those majoring in medicine, business, math/natural sciences, and engineering. Social sciences students had lower certainty beliefs, but this difference was not significant. Of the additional predictor variables, both cognitive abilities and final school grades negatively predicted certainty beliefs. Hence, the results of Model 1 support the self-selection hypothesis: students aspiring to different fields of study already differed in their certainty beliefs at the end of secondary education.

Model 2 is an exact replication of Model 1, in which T1 certainty beliefs have been substituted by T2 certainty beliefs. The fit of this model proved to be acceptable, $\chi^2(df = 181) = 409.26$, TLI = .921, RMSEA = .034, SRMR = .032. After controlling for a number of student characteristics, students majoring in medicine, business, math/natural sciences, and engineering again differed from the reference group significantly (humanities/arts students). For the engineering students, the difference amounted to almost two thirds

of a *SD*. In addition, social sciences students were significantly lower on certainty beliefs than the reference group at T2. Of the personal characteristics, only final school grades significantly predicted certainty beliefs at T2. The results of Model 2 indicate that differences by field of study were somewhat more pronounced at T2 than at T1, giving some preliminary support for the socialization hypothesis.

Finally, in Model 3, we included T1 certainty beliefs as an additional predictor of T2 certainty beliefs. Residual correlations between identical items at both time points were freely estimated (see Marsh & Hau, 1996). With the inclusion of T1 epistemological beliefs, the effects of the other variables can be interpreted as effects on *change* in epistemological beliefs. Hence, this analysis allows the socialization hypotheses, which states that the differences between soft and hard study fields should increase from T1 to T2, to be tested explicitly. Again, the fit of this model was acceptable, χ^2 ($df = 340$) = 799.98, TLI = .903, RMSEA = .035, SRMR = .039. As shown in Table 2, Model 3 corroborated the findings of Model 2. Certainty beliefs proved to be fairly stable ($b = .54$, $p < .001$). Nonetheless, several significant effects of the field of study were found. Most importantly, relative to students enrolled in humanities/arts and (even more so) in the social sciences, participants majoring in engineering and business acquired a less critical epistemological stance over time. These results clearly support the socialization hypothesis. Of the person characteristics, only final school grades exhibited a significant effect on change in certainty beliefs.

8. Discussion

In this study, responses to a standardized questionnaire tapping certainty beliefs were collected from a large sample of upper secondary and college students. The study yielded two main results. First, certainty beliefs were found to negatively predict school grades, even when controlling for important covariates such as cognitive abilities, gender, and students' family background. Second, we tested whether there was a relationship between certainty beliefs and students' (future) field of study. We found the expected differences between students aspiring to different fields of study at the end of upper secondary school, but these differences were considerably more profound two years later, when data were collected from the same participants, who were now attending college. This pattern of results lends support to both the self-selection and the socialization hypotheses (Pulkkinen & Caspi, 2002) when it comes to epistemological beliefs and fields of study.

8.1. Epistemological beliefs and final school grade

Epistemological beliefs have gained in prominence in educational psychology, partly because of the assumed positive effect of sophisticated epistemological beliefs on achievement. However, empirical support for this relationship has been ambivalent. Some studies only found support for a relationship of this kind in certain dimensions of epistemological thinking (e.g. Schommer, 1993). Moreover, from a methodological point of view, there has been criticism of sample sizes often being too small, and of important third variables, such as intellectual ability, not always being controlled (Wood & Kardash, 2002).

Our data from a large-scale educational assessment that included measures of basic cognitive abilities and family background in addition to our certainty scale found certainty beliefs to be a significant predictor of the final school grade. This finding is of interest for several reasons. First, relative to prior research (e.g. Schommer, 1993), a stronger link was

established between the final school grade and the *certainty* dimension of epistemological beliefs. Second, global certainty beliefs predicted achievement even after controlling for other variables; in fact, certainty beliefs mediated some of the impact of basic cognitive abilities on the final school grade. Thus, we found support for a mediator model, in which global certainty beliefs mediate between family background and basic cognitive abilities, on the one hand, and school grades, on the other.

Given that evidence for positive effects of the certainty dimension of epistemological beliefs on broad measures of student achievement is sparse and has been debated (Schommer, 1993; Wood & Kardash, 2002), the results of this large-scale, representative study are of great relevance. In confirming the theoretically derived achievement hypothesis, the findings support current theorizing on the importance of epistemological beliefs in the learning process as well as our operationalization of these beliefs.

The effect of global certainty beliefs on the final school grade was not very large, but was certainly meaningful. Given that in Germany only the top 30% of students attend Gymnasium schools, our sample was positively biased in terms of intellectual abilities. In a less restricted sample, the effects of certainty beliefs are likely to be even larger. Taken together, our findings lend support to the assumed relationship between epistemological beliefs and school achievement. At the same time, this result is evidence for the validity of our standardized global epistemological beliefs measure.

What are the educational implications of the relationship found between certainty beliefs and academic achievement? Although our study does not cover processes of knowledge acquisition directly, our results do provide indirect support for work (see Hofer & Pintrich, 2002, for an overview) that has highlighted the effects of certainty beliefs on motivation and on cognitive and metacognitive learning strategies in people exposed to scientific information or real-world problems. For instance, the stronger their certainty beliefs, the more likely students are to endorse opinions that do not reflect the inconclusive nature of the information provided (e.g. Kardash & Scholes, 1996; Schommer, 1990). Because strong certainty beliefs prevent students from engaging in in-depth processing of information, they will probably have significant long-term costs. Hence, helping students to acquire a sophisticated beliefs system about human knowledge is an important educational goal in itself and a means of enhancing academic achievement. It is more likely that this objective will be achieved if the materials used in the classroom or lecture hall reflect the tentative nature of human knowledge (see Hofer & Pintrich, 2002).

Exposure to uncertainty might be particularly relevant in the hard sciences. The media often portray findings from the hard sciences as "facts." Some students might be attracted to the hard sciences precisely because they seem to offer facts, and not vague theories or assumptions. It is thus especially important for science education to address the complexities involved in knowledge and knowledge acquisition. In this context, it seems important for college and university teachers to make their students aware that knowledge—as a human construction—is never "certain," but rather the "temporary end-product" of scientific discourse. Science educators could take at least two approaches to rebutting unwarranted certainty beliefs. First, as in the studies by Schommer (1990) and Kardash and Scholes (1996), they could present students with conflicting scientific views of a real-world issue. Second, they could demonstrate—with reference to old textbooks and media coverage—how scientific knowledge that once was thought to be certain has been rendered obsolete by new research. Stomach ulcers would be a good example here. Once thought to be caused by psychosocial factors, Nobel Prize-winning research has since shifted the focus to the role played by bacteria.

8.2. Certainty beliefs and study fields: Selection vs. socialization

Our second main research question was whether epistemological beliefs vary as a function of the field of study that students pursue or aspire to pursue. Earlier studies have reported that students in hard fields tend to exhibit less sophisticated epistemological beliefs than students in soft fields (e.g. Jehng et al., 1993). Such field-specific differences in results may stem (see Pulkkinen & Caspi, 2002) from *self-selection processes* (students who believe more strongly in the certainty of scientific knowledge choose to study hard sciences) or from *socialization effects* (soft fields help students to acquire a critical stance as regards the "truth" of scientific theories). Previous studies were not able to distinguish between these two processes because they were cross-sectional in design and/or restricted to either the high school *or* the college years (e.g. Jehng et al., 1993; Paulsen & Wells, 1998).

Our results support both the selection *and* the socialization perspective. Upper secondary students aspiring to different fields of study differed in their certainty scores. An analysis that controlled for the impact of other potentially important variables (e.g., cognitive abilities, school grades, family background) showed these differences could not be attributed to differences in general cognitive ability or family background. Hence, these results support the self-selection hypothesis. Even more substantial differences were found between the seven study groups two years later, however, reflecting the well-known "hard" vs. "soft" field dichotomy. Given that we controlled for certainty beliefs at T1, these results provide much stronger support for the socialization hypothesis than have previously been reported.

Our study focused on the impact of college majors on the development of certainty beliefs. To test for these effects, we statistically controlled for differences between students who later enrolled in different college majors that were already present at the end of secondary schooling. Most importantly, our design allowed us to control for what we called self-selection effects. It did not, however, allow us to examine the underlying processes that may have led to these self-selection effects. One might argue that the self-selection processes we observed were in fact the result of disciplinary socialization in high school. Given that students in the German school system are allowed to choose two advanced courses, some may have already specialized in the natural sciences during their final years at high school.[2] However, the self-selection processes we observed might also be influenced by stable personal characteristics such as the Big Five personality traits (see McCrae & Costa, 1997), which are known to be linked to achievement-related behaviors (e.g. Marsh, Trautwein, Lüdtke, Köller, & Baumert, in press).

8.3. Strengths, limitations, and suggestions

How strongly do certainty beliefs impact on academic achievement and academic choices? How strongly are they shaped by students' educational environments? The present study allowed us to gain a deeper understanding of the role of certainty beliefs in the academic context. Importantly, we were able to use a large, representative sample of upper

[2] Of course, the cycle of self-selection and socialization processes is likely to have started even earlier. Given that the "socialization effect" of an advanced science course is only possible because students *choose* this course in the first place, the "socialization effects" might be seen as the result of a self-selecting process leading to the selection of specific advanced courses.

secondary students to predict final school grades. Moreover, given that the data set provides information on students' family background and cognitive abilities, we were able to control for these potentially confounding factors. Finally, the two-year longitudinal design of our study (end of high school to early college career) permitted a strong test of the self-selection and socialization hypotheses.

However, we also would like to note some important limitations. First, in terms of the Hofer and Pintrich (1997) classification, the certainty scale used in our study primarily refers to beliefs of the "nature of knowledge" and, more specifically, to the certainty dimension. This is because only this dimension was included in the large-scale study from which our data were drawn. In a similar vein, our study was restricted to a measure of *global* certainty and did not address domain-specific epistemological beliefs. However, recent research (Buehl, Alexander, & Murphy, 2002; Hofer, 2000; Trautwein, Lüdtke, & Beyer, 2004) has highlighted the value of conceptualizing epistemological beliefs as both domain-specific and domain-general beliefs about the structure of knowledge and the nature of knowledge acquisition. We hope that future longitudinal studies on the transition from high school to college will be able to incorporate a broader set of variables than was used in the present context.

Second, our study does not allow the processes that shape certainty beliefs to be examined in more detail. Hence, we did not address the question of how certainty beliefs are shaped by specific academic environments and the way these certainty beliefs impact on achievement and academic choices. Regarding achievement, several studies have pointed to learning strategies and motivation as plausible mediators of the impact of epistemological beliefs (e.g. Köller et al., 2000; Qian & Alvermann, 1995; Schommer et al., 1992). When it comes to academic choices and the effects of academic choices on epistemological beliefs, however, more research is clearly needed.

Third, the use of questionnaires is only one approach to assessing epistemological beliefs (see Hofer & Pintrich, 2002, for an overview) and has been critically appraised (e.g. Bromme, 2005; Trautwein et al., 2004; Wood & Kardash, 2002). Unfortunately, alternative, well-validated assessment instruments such as the Reflective Judgment Interview (RJI; King & Kitchener, 1994; see review by Wood, 1997) are extremely resource-intensive, because participant responses must be obtained by individual interviews and then transcribed and coded by multiple raters. Hence, these instruments are not suitable for large-scale studies. However, tests of epistemic reasoning have recently developed that translate the problem-based assessment procedure used in the RJI into a paper-and-pencil framework (see Krettenauer, 2004). This development will provide an additional approach to testing the relationship between epistemological beliefs, academic achievement, and college major.

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