Epistemological Beliefs and Scientific Reasoning in Finnish Academic Upper Secondary Education

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The guiding idea in this paper was to study how scientific reasoning correlates with epistemological beliefs and academic achievement. Based on the study at hand, we argue that the nature of epistemological beliefs is still more the product of the level of scientific reasoning than the other way round. As a practical implication we propose that teacher training programmes should consider epistemological beliefs not only as an important aspect that all learners and teachers should be aware of, but it should be recognised as a central factor that affects our formal and informal learning and teaching in all content areas of knowledge.

Introduction

The study of adolescents' beliefs and conceptions concerning knowledge and learning has gained increasing attention and popularity since the early 1990s. For the past few decades, the research paradigms of the implicit theories of ability on the one hand and epistemological beliefs on the other (Dweck 1999; Schommer-Aikins 2004; Bråten & Strømsø 2005) have been the prominent approaches in the study of individual variation in learning and knowledge acquisition, the related beliefs, and their influence on academic achievement. More precisely, the implicit theories of ability refer to the students' views about the modifiability of intelligence (Dweck 1999), whereas epistemological beliefs refer to the speed of knowledge acquisition, relationships between success and hard work, learning to learn skills, and so forth (Schommer-Aikins 2004). The related object of research, namely the set of beliefs concerning knowledge and learning, is often termed *personal epistemology*.

The research related to the development of cognition and its promotion within the very same target group has received even more attention and is still one of the most vexing questions in the field of educational psychology (Kuhn 2008). In spite of the diversity of theoretical approaches, most cognitive developmentalists favour the stagewise theory of the development of cognition. The best-known system of developmental stages has been articulated by Piaget (1972) who discussed how students gradually acquire and build knowledge from the level of concrete thinking towards formal operation thinking (Piaget 1972). The emergence of formal operations at around 12–15 years involves reasoning based on hypotheses, independently of concrete objects, which for Piaget means that 'the real is subordinated to the realm of the possible' (Piaget 1972; 2006). However, the development of complex thinking does not necessarily follow such a linear course. It has been argued (cf. Harter 1999) that from early adolescence onwards, students' epistemological beliefs, in other words, beliefs concerning learning and knowing, have an increasing effect on their learning acquisition behaviour (Schommer-Aikins 2004). Briefly, as with cognitive development in general, epistemological beliefs also develop as a product of environmental influences, such as informal and formal learning experiences, as well as modelling and feedback provided by significant others.

To our knowledge, regardless of the robust scientific evidence for the existence of the Piagetian developmental stages, few studies have tried to combine and study the association between students' epistemological beliefs and their level of scientific reasoning. The purpose of this study is to demonstrate how the students' level of scientific reasoning skills and academic success can be predicted on the basis of their views concerning knowledge and learning, or in other words, their epistemological beliefs.

As noted above, two different approaches can be identified in the research on epistemological beliefs (see Bråten & Strømsø 2005). The first approach focuses on students' implicit theories of intelligence. According to this approach, some students are found to have an incremental theory of intelligence and conceive intelligence as a malleable construct that can be controlled and increased by training, while other students seem to hold an entity theory of intelligence believing that intelligence is a fixed and uncontrollable trait (Dweck 1999). The other approach focuses on an epistemological belief system consisting of more or less independent epistemological beliefs that are conceptualised as beliefs concerning the simplicity, certainty, and source of knowledge, accompanied with beliefs related to the control and speed of knowledge acquisition (Hofer & Pintrich1997; Schommer 1990). In fact, the last two belief dimensions (control and speed of knowledge acquisition) are more or less in line with Dweck's formulation (see Pintrich 2002).

Despite some conceptual differences in these paradigms, somewhat similar results have been obtained. The general trend in the results has been that students' beliefs may in fact predict learning and accordingly, academic achievement (Bråten & Strømsø 2005). However, epistemological beliefs are considered to develop on the basis of environmental influences, whereas implicit theories of intelligence have been shown to be rather stable, with the exception of targeted interventions for individuals endorsing the entity theory (Dweck 2008). The present study follows the epistemological beliefs approach due to its developmental perspective more in line with Piaget's theory.

The study of epistemic beliefs was started by Perry (1970), who studied students' beliefs from a developmental point of view, suggesting that the development of a person's epistemological beliefs progresses through the stages of dualism, multiplicity, and relativism (Perry 1970; Yang & Tsai 2012). Inspired by Perry's work on personal epistemology, Schommer (1990) argued for a multidimensional model, where epistemological beliefs do not simply mirror a person's cognitive development unidimensionally. Instead, personal epistemology has several dimensions, which are more or less independent. Schommer (1990) has proposed five such dimensions of epistemological beliefs, originally formulated as the 'structure, certainty, and the source of knowledge, and the control and speed of knowledge acquisition'. In the present study these dimensions are referred to as: (1) simplicity/complexity; (2) certainty/tentativeness; (3) reliance of authority/criticality; (4) impossibility/possibility of learning to learn; and (5) quickness/effort of learning. Although Schommer criticises the Perryan framework for viewing personal epistemology as a unidimensional reflection of cognitive development, she does not deny the link between cognitive development and personal epistemology altogether. Indeed, the main difference from the Perryan viewpoint is that 'sophisticated' personal epistemology can take a variety of forms in the five different dimensions, while there should nevertheless be some correlation between the dimensions.

As was suggested above, Schommer's paradigm combines elements from both the epistemic belief tradition (Perry 1970) and the implicit theories of intelligence tradition (Dweck & Leggett 1988). Schommer adopts the three dimensions of structure, certainty and source from Perry's epistemic beliefs. The two other dimensions, speed and control, show more affinity with Dweck and Leggett's conception of the implicit theory of ability (cf. Chen 2010, p. 17). Indeed, Hofer and Pintrich (1997) argue that the latter two beliefs concern ability and learning rather than knowing proper (see also Buehl & Alexander 2001). Kitchener (2011) claims that the dimensions not referring directly to knowledge, but to its acquisition or learning, are included somewhat arbitrarily. Admittedly, the terms 'epistemological belief' and 'personal epistemology' are conceptually somewhat vague, but we would argue that learning is in any case a relevant perspective on knowledge. Namely, learning would seem to form a central part of a student's relation to knowledge, which is the overall object of research in the study of personal epistemology. One could also formulate the Schommerian point of view as combining the two senses of knowing as distinguished by the philosopher Gilbert Ryle (2009 [1949]): knowing-that (declarative, knowledge) and knowing-how (procedural, ability).

In studies of personal epistemology, the model of cognitive development is usually adopted from Jean Piaget's work. Piaget introduced the framework of genetic epistemology with its four main stages: (a) the sensori-motor stage (0–2 yrs); (b) the preoperational stage (2–7 yrs); (c) the concrete operational stage (7–11 yrs); and (d) formal operational stage ([11–16 yrs and older]; Piaget 1963; Wadsworth 2004). It is argued and demonstrated in numerous studies that thinking is qualitatively different on the higher level compared with the lower level, and those levels can be identified by criterion-referenced tests (Shayer 2008).

The respondents in the present study were upper secondary school students from 16 to 19 years and thus, according to the theory, in the formal operational stage. However, as Shayer (2008) has shown there is great variation within the age-cohort. The differences between students have shown to be associated with school achievement, but although girls have in general been observed to perform academically better than boys, no gender difference has been encountered with regard to scientific reasoning (e.g. Hotulainen, Thuneberg, Hautamäki & Vainikainen 2014). The observed variation in relation to age is considered to be rooted in differences of intellectual stimulation in children's environments and to be dependent also on personal interest and experiences – formal thinking is then not necessarily applied all the time or across all domains. (Piaget 1972; 2006.) Indeed, Piaget (1972) proposes several factors that are responsible for cognitive development, such as: (a) maturation/heredity; (b) active experience; (c) social interaction; and (d) general progression of equilibrium. With regard to the cognitive equilibrium, we argue that those informal and formal learning situations which question students' acquired thinking patterns (i.e. cognitive conflicts) have a central role in pushing students towards new levels of thinking (Adey & Shayer 1994; Inhelder & Piaget 1958; cf. also Illich 1980). Indeed, studies on thinking skill programmes using Piagetian teaching methods have shown that kindergarteners' and schoolers' cognitive development can be accelerated when learning environments have been modified accordingly (Adey & Shayer 1994; Hattie 2009; Hotulainen & Hienonen 2014; Kuusela 2000).

Quantitative studies on epistemological beliefs have not been carried out in Finland previously. Sormunen (cf. 2004; 2008) has studied students' personal epistemology qualitatively, within the context of science education, whereas the Schommerian approach adopted here is quantitative and not domain-specific. It is thus interesting to study the applicability, in the Finnish context, of Schommer's predictions and the five dimensions of epistemological beliefs that are named as: (1) simplicity/complexity; (2) certainty/tentativeness; (3) reliance of authority/criticality; (4) impossibility/possibility of learning to learn; and (5) quickness/effort of learning. Furthermore, it is interesting to see if students' epistemological beliefs might express the five dimensions formulated by her. Namely, for instance, Chan and Elliott (2002) claim that cultural differences could account for differences in epistemological beliefs, albeit a closer inspection from this intercultural perspective is beyond the scope of the current study. Thus, the study mainly focuses on the relation between epistemological beliefs and the level of scientific reasoning skills.

The following two research questions were set:
1. Are epistemological beliefs and scientific reasoning skills defined in terms of Piagetian developmental stages associated with each other among Finnish academic secondary students?
2. Are there any differences in the dimensions of epistemological beliefs between students participating in a more traditional mixed-ability school setting and students in a selective school setting?

Method

The participants (N = 136, 77 girls, mean age = 17 y. 3 m.) of the study were situated in two different upper secondary schools in Helsinki. One of the participating schools is an ordinary public school with a mixed-ability system and does not have a strict entrance or selection criteria (minimum admission of general point average [GPA] 7.9 in 2011 and 2013), while the other one is a more selective private or independent (non-municipal) school (minimum admission GPA 9.1 in 2011 and 2013). The study at the independent school was authorised by the headmaster. For the study at the public school, we acquired the necessary permission from the municipal authorities (City of Helsinki Education Department, Opetusvirasto), as well as written permission from the guardians of all students under 18 years.

In order to group the students according to Piagetian cognitive operational levels, we needed to recode the initial raw scores of the scientific reasoning test. Following a Piagetian distinction, the students were divided into three different groups according to the following criterion: group 1 (scores 0–3, n = 32, 24%), group 2 (scores 4–5, n = 72, 53%), and group 3 (scores 6–10, n = 31, 23%). These subgroups were named respectively as representing: (a) the early concrete operational level (Group EC); (b) the concrete operation level (Group C); and (c) the formal operation level ([Group F]; J. Hautamäki, personal communication, 20 May 2014).

Measures

Three different measures were used: (a) epistemological beliefs; (b) scientific reasoning; and (c) self-reported school achievement.

Epistemological beliefs. A set of epistemological beliefs was assessed using a translated Finnish version of Schommer's (1990) epistemological questionnaire named Epistemological beliefs – FIN (EQ-F), comprising 62 items. Students indicated the degree to which they agreed or disagreed with the statements using a 5-point Likert-type scale. Prior to factor-analysing the data, we computed the internal consistency (Spearman-Brown) to study if the used 62 items of the translated questionnaire (EQ-F) measure the same general construct (see Tang, Cui, & Babenko, 2012). The overall internal consistency coefficient of the 62 items was .78, with item–total correlations ranging from -.38 to .68. Four items had negative item–total correlations, and nine items had item-total correlations of less than .10. Following Wood and Kardash's (2002) recommendations, these 12 items were eliminated from further analyses. The coefficient for the remaining 50 items was .80.

Principal component analyses were performed for the 50 items. As we expected the factors to be correlated, we chose to conduct oblique rotation in each analysis. Estimates for the pooled sample are reported below. The initial analysis yielded 17 factors with eigenvalues greater than 1, which explained 68.25% of the total sample variation. Inspection of the scree plot suggested a five-factor solution, with one large factor with an eigenvalue of 7.18, two other factors with eigenvalues greater than 3, and two factors having eigenvalues greater than 2.00. The remaining 13 factors had eigenvalues ranging from 1.81 to 1.03.

As the size of the eigenvalues and the scree plot appeared consonant with a 5-factor solution, we decided to run the forced t-factor solution with the earlier analysis. After this analysis, 10 items were eliminated because they did not load at least .35 on any of the five factors or they loaded equally much on more than one factor. This final five-factor solution consisted of 40 items and explained 36.88% of the total variance. The names and number of items per factor and the reliability estimates (Cronbach's alpha) of each factor are as follows:

1. Knowledge is simple rather than complex (Simplicity of knowledge, 19 items; α = .60).
2. Knowledge is certain rather than tentative (Certainty of knowledge, 6 items; α = .60).
3. Knowledge is handed down by authority rather than derived from reason (Reliance on authority, 4 items; α = .62).
4. The ability to learn is innate rather than acquired (Innateness of ability to learn, 6 items; α = .43)
5. Learning is quick or not at all (Quickness of learning, 5 items; α = .56).

These factors were also Schommer's five hypothesised epistemological beliefs on which the questionnaire EQ-F was originally based (Schommer 1990). However, the reliability of EQ-F suffers from remarkable deficits. Especially the reliability of the innateness of the ability to learn factor does not allow further statistical analysis. In general, results related to EQ-F should be interpreted very carefully and cautiously. In view of future studies more precise analyses are necessary in order to gain higher reliabilities with respect to the studied variables. Also, we did not you use back translation to check the correctness of the translation, which may have caused some of the deficits related to EQ-F.

Scientific reasoning. The students' level of scientific reasoning was measured by the Formula 1 test. The test measures the mastery of the control of variables, which is the central scientific reasoning task a person at the formal operational level should be able to perform. The test is a second-generation modified group version (Hautamäki 1989; 2000) of the original Scientific Reasoning Tasks, the Pendulum (Shayer 1979; Shayer & Wylam 1978). The Formula 1 test has been widely used in Finnish studies, and the results have not indicated any differences based on gender (Hautamäki, Kupiainen, Marjanen, Vainikainen, & Hotulainen 2013; Hotulainen et al. 2014). In the test, the respondents compare combinations of four variables: F1 drivers, cars, tires and race tracks, with two possible values for each (e.g. Michelin or Bridgestone for tires). The respondents are supposed to infer how the effect of a certain variable, e.g. tires, can be determined on the basis of two given sets of values. The idea is that in order to determine the effect of a particular variable, the other three variables must have the same values in both sets. In the test, the two sets are either given (as in the example below) and the respondent is asked whether the effects of certain variables can be determined on their basis, or the respondent is asked to construct one or both of the sets so that a particular variable can be isolated. An example from the test is provided below:

Example item from the Formula 1 test

Comparison pairs:	*driver*	*car*	*tires*	*race*
	Räikkönen	McLaren	Michelin	Monaco
	Hamilton	Ferrari	Michelin	Monaco

Question: On the basis of the above pairs, can one determine the…

	no	yes
effect of the driver?	1	2
effect of the car?	1	2
effect of the tires?	1	2

Note. The correct answers are 1, 1, 1.

The ten items were coded dichotomously and summarised as the Scientific Reasoning test score. The reliability of the test was (Cronbach's alpha) .84.

Self-reported school achievement. The self-reported school achievement (S-GPA) was computed as the mean of three self-reported school subjects (Finnish language, first foreign language and mathematics). The students were asked to report their latest course marks for these subjects. We did not have access to students' official school marks. For this reason, we are for instance not able to determine the effect of a student's line of study in mathematics on S-GPA, i.e. whether she follows a basic or advanced syllabus. Here the S-GPA is used as an estimate of school achievement. The reliability of self-reported school achievement was (Cronbach's alpha) .66.

The test was carried out during school days in regular classrooms. The booklet comprised two parts: a Formula 1 test and Epistemological beliefs questionnaire (EQ-F). The students first completed the Formula 1 test and then proceeded to the questionnaire EQ-F, as the Formula 1 test was thought to require greater intellectual effort than the questionnaire. The subjects were encouraged to do their best and to spend the time needed to find the solutions for the test. It was also mentioned that in the Formula 1 test there was usually only a single correct solution to each part of the test, while there were no right or wrong answers in EQ-F. The test was carried out in approximately 30 minutes.

Pearson's r was used for analysing significant relationships between two or more study variables. We also carried out a multivariate analysis of variance (MANOVA) for the relationship between the independent variables (student's age, gender and school) and dependent variables ($n = 7$), including the epistemological beliefs (5 factors) and the performance related dimensions (2): scientific reasoning and self-reported school achievement. The necessary assumptions for MANOVA were checked by the test for homogeneity of variance and Box's M test. Differences of school context were analysed by means of the independent sample t-test. In correlational analyses, the significance level for the hypothesis testing was $p < .01$ due to multiple correlations, and for the group difference analysis $p < .05$. Due to the large number of dependent variables, the consequent number of significance and post hoc (Bonferroni) tests, the likelihood of making a Type I error increased. Notwithstanding the Bonferroni correction, the reader should be cautious in interpreting the results of the pair-wise comparisons that were significant between p < .05 and p > .001 levels (Abdi, 2007). The effect sizes (2) of these comparisons were calculated by dividing the difference between means of the comparison groups by the weighted standard deviation to yield a standard score (Cohen, 1977). According to Cohen (1977), the values of 2 between 0 to 0.3 indicate a small effect, values between 0.3 and 0.6 a moderate effect, and values over 0.6 a large effect.

Results

In this section, first, the descriptive statistics of the used study measures will be introduced. Second, the correlation between different subdimensions will be presented and discussed briefly in the light of the theoretical assumptions. The goal of this section is to describe the instrumental properties of the used measures and how they worked among the study population. This background information concerning the formed variables drawn from the Epistemological beliefs questionnaire (EQ-F) and their interaction with other dependent variables should facilitate the interpretation of the results in relation to the study questions. Below, in Table 1, the means (M) and standard deviations (S.D.) of the epistemological belief dimensions, scientific reasoning, and self-reported school achievement are presented by gender. It should be noted that the epistemological beliefs formulated by Schommer are the opposite of what one would expect from an academically successful student. Thus, broadly speaking the scores below 3 indicate a conception of knowledge as complex, open to critique, tentative, developing, and requiring an effort (i.e. the Schommerian 'sophisticated epistemological beliefs'). Accordingly, scores above 3 indicate a conception of knowledge as simple, based on authority, certain, and acquired through an innate ability, quickly – in other words the 'naive' outlook. However, one should bear in mind that according to Schommer, these aspects are primarily independent dimensions of epistemological beliefs, not expressions of a single, uniform attitude (Schommer 1990).

As one can see in Table 1, the EQ-F scores were situated slightly below the mean score 3 with the exception of the dimension Quickness of learning (M = 3.41). In other words, on average, the students were adjusted to so-called sophisticated epistemological beliefs. Provided that girls generally perform and adapt academically better than boys, independent sample t-tests were run for the three variables in Table 1, due to observable differences in mean scores. One statistically significant (Bonferroni corrected alpha .05 / 3 = .017) difference was found: boys had statistically, a significantly (t(133) = 2.14) more sophisticated view concerning the quickness of learning than girls.

	Girls		Boys			In all	
	M	S.D.	M	S.D.	p / η2	M	S.D.
Epistemological beliefs							
1. Simpilicity of knowledge	2.90	0.45	2.90	0.47		2.90	0.45
2. Certainty of knowledge	2.82	0.58	2.70	0.60		2.77	0.59
3. Reliance of authority	2.40	0.51	2.39	0.51		2.39	0.51
4. Cannot learn to learn	2.28	0.49	2.33	0.54		2.30	0.51
5. Quickness of learning	3.41	0.45	3.25	0.37	*/.34	3.34	0.42
Performance dimensions							
6. Scientific dimensions	4.75	2.32	5.14	2.40		4.91	0.42
7. Self-reported school achievement	7.71	0.92	7.47	0.78		4.91	2.36

Note: M = Mean, S.D. = Standard deviation, * = p < .05

Table 1: Descriptives of epistemological beliefs, scientific reasoning, and self-reported school achievement by gender.

A correlation analysis was conducted in order to clarify the relation between these variables. Several correlations in Table 2 are of interest here. First, the epistemological belief dimension related to the factor Simplicity of knowledge seemed to be associated statistically significantly with all the other epistemological belief dimensions, with the exception of the dimension Cannot learn to learn. This can be partly accounted for by the relatively large number of items loaded on the factor in question. Second, on average there were negative correlations between the epistemological beliefs and both performance-related dimensions as expected. Third, there was positive association between the two performance-related dimensions, namely between Scientific reasoning and Self-reported school achievement.

	1	2	3	4	5	6	7
Epistemological beliefs							
1. Simpilicity of knowledge	-						
2. Certainty of knowledge	.54**	-					
3. Reliance of authority	.20*	.15	-				
4. Cannot learn to learn	.08	.07	.14	-			
5. Quickness of learning	.37**	.20*	.16	-.07	-		
Performance dimensions							
6. Scientific dimensions	-.22**	-.23**	-.10	-.02	-.20**	-	
7. Self-reported school achievement	-.23**	-.31**	-.24**	-.06	-.15	.16*	-

Note: * = p %lt .0,1, * = p < .001.

Table 2: Correlations between epistemological beliefs and performance-related dimensions.

The first research question concerned the relationship between students' epistemological beliefs and their level of scientific reasoning. As we were already able to observe from Table 2, there was a significant negative correlation between three epistemological beliefs dimensions – Simplicity of knowledge, Certainty of knowledge, and Quickness of learning – and the raw scores of the scientific reasoning test. These results indicate that epistemological beliefs such as entertaining a conception of knowledge as complex, open to critique, and requiring an effort were associated with higher scientific reasoning (i.e. more sophisticated epistemological beliefs).

To study whether there are differences in epistemological beliefs between levels of cognitive operation, namely the Early concrete operational level (Group EC), the Concrete operation level (Group C), and the Formal operation level (Group F), we performed a multivariate analysis of covariance (MANCOVA) for the three epistemological dimensions that correlated with scientific reasoning (Table 2). In addition, the performance dimension of Self-reported school achievement was included in the MANCOVA and gender was used as a covariant. The MANCOVA with the three epistemological dimensions and Self-reported school performance as dependent variables indicated a significant multivariate effect, with Wilks' Lambda yielding .90, $F(6,246) = 2.20$, $p < .05$. Statistically significant differences between the three groups are shown in Table 3 below.

	Group EC		Group C		Group F					
	M	S.D.	M	S.D.	M	S.D.	ANOVA	Comparison	p	h2
1. Simplicity of knowledge	2.92	0.39	2.98	0.44	2.69	0.50	F=4.27 p=0.016	EC vs C EC vs F C vs F	0.225 0.051 0.004**	 0.51 0.63
2. Certainty of knowledge	2.82	0.52	2.86	0.63	2.54	0.51	F=3.43 P=0.036	EC vs C EC vs F C vs F	0.649 0.064 0.011*	 0.54 0.54
3. Quickness of learning	3.33	0.40	3.44	0.38	3.12	0.47	F=6.56 p=0.002	EC vs C EC vs F C vs F	0.200 0.048* 0.000***	 0.48 0.78
4. Self-reported school performance	7.48	0.85	7.51	0.85	7.97	0.81	F=3.42 p=0.036	EC vs C EC vs F C vs F	0.901 0.030* 0.016*	 0.59 0.55

Table 3: Epistemological beliefs and Self-reported school achievement by scientific reasoning grouping.

As we were able to observe, the univariate F tests showed there were statistically significant between groups differences in three epistemological belief dimensions (see Table 3): namely Simplicity of knowledge, Quickness of learning, and Certainty of knowledge. In these findings the difference was parallel. There was a statistically significant difference between students belonging to the Group C and students belonging to the Group F, showing that students of the latter group had more sophisticated beliefs in the dimensions in question. Differences between Group EC and Group F were parallel but only marginally ($.05 < p < .10$) significant. This is probably due to the fact that group C is much larger than Group EC, which affects the explanatory power of the test. Furthermore, the effect sizes in the group comparisons between Group EC and Group F on the one hand and between Group C and Group F on the other manifested similar differences. Also, the grouping had a parallel effect on Self-reported school performance showing that students belonging to Group F outperformed the other two groups.

The second research question concerned differences in epistemological beliefs and performance-related variables between students schooled in the ordinary upper secondary school and students of the selective upper secondary school.

	Ordinary school					
	Mean	S.D.	M	S.D	p	η2
Epistemological beliefs						
1. Simplicity of knowledge	2.92	0.43	2.86	0.51		
2. Certainty of knowledge	2.85	0.62	2.62	0.49	*	0.40
3. Reliance on authority	2.49	0.51	2.21	0.42	**	0.58
4. Cannot learn to learn	2.21	0.56	2.12	0.56		
5. Quickness of learning	3.34	0.44	3.36	0.64		
Performance dimensions						
6. Scientific reasoning	4.83	2.23	5.10	2.63		
7. Self-reported school achievement	7.28	0.74	8.34	0.64	***	1.49

Note. Significant differences between scale means at * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 4: Means and standard deviations for epistemological beliefs and performance-related variables.

Table 4 shows the mean responses to each variable for the two samples. As can be seen, there were minimal differences between the two samples in regard to the five epistemological belief dimensions. However, a MANOVA with the five epistemological dimensions as dependent variables indicated a significant multivariate effect, with Wilks' lambda yielding 0.90 $F(5,128) = 2.71$, $p < .05$. A univariate follow-up with the Bonferroni test indicated that the school setting had an effect on Certainty of knowledge $F(4,36)$, $p < .039$ and Reliance on authority $F(1,129) = 8.48$, $p = .01$, showing that in both dimensions students of the selective school were more likely to entertain more sophisticated epistemological beliefs. When the two performance variables were used as dependent variables a significant multivariate effect was found, with Wilks' lambda yielding = 0.659, $F(2,125)$ $p < .001$. A univariate follow-up indicated that the school setting also had an effect on Self-reported school achievement $F(1,129) = 63{,}86$, $p < .001$, meaning that students of the selective school reported higher grades than students of the ordinary school.

Discussion

The results of the present study indicate that epistemological beliefs provide relevant information in relation to the level of formal operations. Three of the five variables that were used as measures showed significant differences between the different level groups. These variables were simplicity/complexity of knowledge (1), certainty/tentativeness of knowledge (2), and quick learning/effort (5). In all of these cases, inclination towards the latter, 'sophisticated' poles of the variables predicted a higher stage of scientific reasoning. In relation to the simplicity/complexity variable, a similar result was obtained by Bird (2005).

The study seems to indicate that an incremental view of knowledge is associated with a high level of formal operations (group F of the scientific reasoning task) as well as with academic success. In this sense, the fifth variable Quickness of learning would seem to summarise the three variables: the complexity and tentativeness of knowledge would both seem to imply an incremental conception of learning – that it requires time and effort. Indeed, Quickness of learning was also the one with which the other variables correlated the most. However, as was noted above, the students with a high level of formal operations were only relatively more inclined to think of learning as requiring an effort than the students with a lower level of formal operations. Indeed, in absolute terms they also were on average slightly inclined towards the view that one either learns at once or not at all.

This interpretation was partly supported by our results related to the second study question. Despite equal performance in scientific reasoning, the students of the selective school had more sophisticated epistemological beliefs which can be seen in the statistically significant differences in regard to the factors Certainty of Knowledge and Reliance on Authority. The results indicate that more sophisticated epistemological beliefs are associated with higher academic achievement. However, without follow-up data we are not able to assess the effect of the promotion of such beliefs by the school staff, but such promotion has been observed to facilitate learning (Bråten & Strømsø 2005).

At present, we would argue that epistemological beliefs are still more a consequence of the cognitive level and the level of scientific reasoning than the other way round. Namely, it seems intuitive that a student can develop sophisticated epistemological views by effectively learning new skills and acquiring new knowledge, but it does not seem possible that she could gain new skills and knowledge simply by changing her opinions. Still, it would seem that even if one cannot dispense with the hard work of learning, there is some reciprocity between epistemological beliefs of a person and her cognitive abilities and performance. It could be helpful to see sophisticated epistemological beliefs not as important in themselves but as expressions of an intellectual orientation and directedness which favours learning and intellectual development. Further studies are needed to gain a more comprehensive picture about the formation and development of epistemological beliefs and their possible influence on learning.

It is also important to acknowledge the limitations of the present investigation and to evaluate how these may influence the generalisability of the results. More specifically there were remarkable deficits in the reliabilities concerning EQ-F. For this reason the results of that section should be interpreted with caution. Furthermore, the non-significant findings between Group EC and Group C might indicate that the definition of Group EC based on raw scores from the scientific reasoning test (Formula 1) was not accurate, and it would be more appropriate to compare students who have acquired the formal operational level to those who have not. Also, the limitations of a single cohort design could not be bypassed within this study frame. Thus, certain societal conditions and contemporary events might have an effect on the study results. For future studies, there is a plan to re-examine and correct the encountered deficits and to study the development of epistemological beliefs and scientific reasoning using a longitudinal study set-up.

In conclusion, we note that by increasing the students' awareness of themselves as learners and knowers the teacher can also transfer some of her responsibility to the students, as it thus becomes more natural for them to appreciate the variety of learning methods and their own active role in the process of learning and knowing. This is in tune with another contemporary trend of promoting the self-directedness of learning – for we learn best when we are active ourselves.

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