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High-School Students' Topic-Specific Epistemic Beliefs about Climate Change: An Assessment-Related Study

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Abstract: This study belongs to assessment-related research and aimed to investigate Finnish high-school students' (*n* = 211) topic-specific epistemic beliefs about climate change and whether the Norwegian topic-specific epistemic beliefs questionnaire (TSEBQ) was also valid among Finnish respondents. Thus, research data were not only derived from the TSEBQ but also from topic knowledge tests and students' views on their favorite school subjects and interest in science subjects. Principal component analysis (PCA) showed that the statistical model, originally based on 49 questions, was congruent with the Norwegian four-factor model (Certification, Source, Justification and Simplicity). However, according to the reliability analysis and confirmatory factor analysis (CFA), the performance of the Simplicity factor was unclear. In CFA, the three-factor structure (without Simplicity) was supported. The effects of topic knowledge, topic interest and gender on the TSEBQ factors were examined by using hierarchical regression analysis (HRA). The TSEBQ was shown to be a reliable tool for measuring the topic-specific epistemic beliefs of Finnish students. More specifically, the results support the claim that topic-specific epistemic beliefs can be educationally and culturally bound. HRA showed that students' topic knowledge in chemistry and biology was related to certainty of knowledge and justification for knowing. Moreover, female students performed significantly better in topic knowledge and more often planned to pursue a science career in the future.

Keywords: climate change; factor analysis; Finnish high-school students; interest in science; topic knowledge; topic-specific epistemic beliefs

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1. Introduction

This study concerned topic-specific epistemic beliefs (TSEB) about climate change [1]. Epistemic beliefs on the nature of knowledge and knowing can have important implications for learning and, more generally, for citizens' perceptions of complex phenomena. In particular, misperceptions can undermine citizens' decision-making ability [2]. Epistemic beliefs are typically conceptualized as multilevel constructs by researchers, who differentiate, for example, between general and domain-specific beliefs [3] or between topic-specific beliefs within a single domain [4]. Domain-specific or topic-specific beliefs are expected to possess more explanatory power than general epistemic beliefs [3]. In the domain of natural sciences, climate change is arguably a key topic, as it has been significantly proven, requires multifaceted scientific knowledge, invokes global concern and implies socio-scientific issues concerning all citizens. Discourses on belief systems and climate change issues are stimulated by the conflict between scientific evidence and public perceptions about climate change [5–7]. As reported by Ratinen [8], students have been shown to struggle in constructing mental models for understanding climate change, indicating that learning about and resolving climate change issues are dependent upon not only knowledge but also people's beliefs about the topic [7,9].

In this assessment-related (validation of the instrument and the influence of the other factors on beliefs) study, Finnish high-school students' topic-specific epistemic beliefs about climate change were, firstly, studied by using factor analyses to validate the original topic-specific epistemic beliefs questionnaire (TSEBQ, 1) among Finnish respondents. Secondly, the influences that gender, topic knowledge and topic interest have on beliefs about climate change were examined by using regression analysis.

Empirical studies on the effect of epistemic beliefs on learning have typically concentrated on learning within academic contexts such as schools and universities [4,10–13]. Such studies have yielded evidence that students' epistemic beliefs influence their learning processes and achievements (for example, motivation, text comprehension, learning strategy repertoire and grades). More specifically, academic achievements have been shown to be influenced by beliefs about the structure and certainty of knowledge [10], as well as the certainty and justification of knowledge [11]. Ricco and others [13] found that beliefs about the certainty of knowledge predict science grades and motivational factors, e.g., performance, self-efficacy and task value. Supporting those kinds of learning contents that match the preferred topic epistemic beliefs of students could provide an opportunity to enhance their learning achievements [14].

Regarding students' prospective careers, general scientific abilities, such as scientific reasoning, are important not only for learning science-related issues but also—and especially—for successfully accomplishing open-ended, real-world tasks [15,16]. Scientific reasoning skills are related to cognitive abilities and can be developed by adequate training and concerted practice, e.g., by using inquiry-based science instruction to support scientific reasoning abilities [17–19]. Such training and practice can have long-term impacts on students' academic achievement. A comparative study of Chinese and US students revealed that content knowledge differs from scientific reasoning skills [20]. Later, Muis and others [21] demonstrated that the types of learning strategies students use to study content concerning climate change mediate epistemic beliefs about such content. Moreover, they showed that learning outcomes can predict learning strategies, while the relations between learning outcomes and epistemic emotions can be mediated by learning strategies.

2. Theoretical Background

2.1. Topic-Specific Personal Epistemology

Epistemology refers to research related to the nature and origin of knowledge and knowledge as such [22]. Conceptually, "epistemic" refers to the analysis of the origins of knowledge, while personal epistemology refers to individualized perceptions and beliefs about not only the nature of knowledge but also the sources and factors influencing both knowledge and learning [1,23]. Importantly, personal epistemologies have been found to influence the formation and content of epistemic beliefs of individuals [24]. Cognitive dissonance—that is, contradictions between two cognitions—has been shown to promote changes in one's personal epistemology [25].

According to Schommer [26], a general personal epistemology consists of independent beliefs concerning three knowledge dimensions (Certainty, Simplicity and Source of knowledge) as well as beliefs related to the speed of learning and reinforcement of abilities. Both Schommer [26] and others [27] empirically explored the dimensionality of personal epistemology by using factor analysis (12 subsets of 63 items as variables) and identified certain and simple knowledge dimensions. The resulting Schommer Epistemological Questionnaire (SEQ) was thereafter tested with additional factor analyses in several studies [28–31], but no uniform results concerning epistemic beliefs were generated. In response, Bråten and others [1] conducted a study specifically addressing topic-specific epistemic beliefs by using a novel questionnaire (TSEBQ).

Theoretically, the present study was based on the dimensionality of personal epistemology as applied by Bråten and others [1]. Personal epistemology refers to individualised epistemic beliefs about knowledge and knowing [32,33], and as such it is assumed that one's personal epistemology will comprise individualised beliefs about the basic aspects of knowledge, such as the *certainty* and *simplicity of knowledge*, and the nature of knowing, such as the *source of knowledge* and the *justification of knowing* [32]. Each of these dimensions is alleged to manifest somewhere along a scale from naive to sophisticated beliefs in the minds of individuals. Furthermore, as Bråten and others [1] demonstrated, topic-specific epistemic beliefs can be culturally bound. As the TSEBQ was developed in the context of Norway, which is a Nordic country, education and culture were considered appropriate as starting points for this study regarding Finnish high-school students instead of Spanish education and culture used by Bråten and others [1]. The similarities and differences towards the Norwegian and Spanish factor models [1] have also been statistically examined the beginning of the study.

2.2. Climate Change as Topic Knowledge or Interest and Associated Epistemic Beliefs

The present study specifically focused on Finnish high-school students' topic-specific epistemic beliefs concerning climate change. Climate change is undoubtedly one of the most serious and pervasive threats to humankind and ecosystems worldwide [34]. As such, it is vitally important to assess epistemic beliefs concerning climate change within the domain of the natural sciences. As a socio-scientific issue (SSI), climate change is exceedingly complex, and its comprehension is reliant upon a consideration of interrelationships between science and society [35]. When approaching and seeking to resolve climate change-related issues, researchers confront and must account for multiple sources of information. They must make decisions regarding whether the information constitutes valid forms of knowledge and whether there is sufficient evidence upon which knowledge claims can be made, and in this respect the epistemic nature of such information must be scrutinised. In order to make these decisions, epistemic cognition processes are key [33,36]. Sinatra and Chinn [37] described these processes as cognitive manifestations of the individuals' epistemic beliefs, which according to Hofer and Pintrich [32] concern knowledge and knowing.

Students' knowledge about climate change in all ages has been found to be incomplete and to contain many misconceptions about, for example, the link between climate change and other environmental problems, such as ozone depletion and pollution [8,38–41]. Conflicting and uncertain knowledge about climate change necessitates different learning strategies from the perspective of science subjects, such as scientific reasoning skills, critical thinking, system thinking and argumentation [42–44]. In their study, Muis and others [21] found that the students who believed that the justification of knowledge requires critical evaluation and the integration of multiple information sources experienced higher levels of enjoyment and curiosity and lower levels of boredom when confronted with conflicting information about climate change. According to these researchers, lower levels of anxiety and frustration among these students were attributable to a belief in uncertain knowledge, whereas lower levels of confusion were predicted by a belief in the active construction of knowledge.

Students' overall interest in science topics tends to decline over the school years to adolescence [45–47]. Students' interest in science in relation to climate change content and education can be examined with respect to several issues, for example, beliefs of knowledge and interest in topic knowledge or in science as a possible future career path. In earlier studies, Sjöberg [48] has reported that students' interest in climate change is associated with positive emotions such as forward-looking excitement emotion. Moreover, such interest is also associated with autonomous preferences for topics, objects or activities [49–51] which means, for example, freedom of study or act as well as with deep learning about the issue [49,51,52] and long-term and repeated engagement with the topic over time [53–55]. Carman et al. [56], who found a link between students' perceptions of climate change risk and topic interest, also showed that hands-on science activities played larger roles in the development of students' interest in the effects of climate change on forests than on their perceptions of, e.g., climate change risk. Interest in science or in climate change in relation to the nature of knowledge was the focus in the study of Bråten and others [1] who found that personal interest and engagement in issues and activities associated with climate change positively predicted beliefs about the justification for knowing. To the best of the authors' knowledge, students' future career plans with respect to the science subjects have not been studied in connection to climate change or in relation to the nature of knowledge and knowing.

2.3. Climate Change Education in Finnish High-School Curriculum

The national core curricula for schools (e.g., [57,58]) can be seen as a reflection of the Finnish educational culture and society and form, in this case, the Finnish school frame for understanding climate change. In the Finnish high-school curriculum, climate change is part of the transversal competence themes, and it is mentioned in any subjects [57–59]. Climate change is brought up as value-based issues, "Students understand the importance of their own activities and global responsibility in mitigating climate change . . . ". It is also mentioned in connection to the topic Sustainable Lifestyle and Global Responsibility: "the student knows the factors influencing climate change and they are aware of the significance for the environment and human activities." For individual subjects, climate change is mentioned in the main contents of biology "Ecology and Environment" studies, which states the ecological effects of climate change, and in the main contents of geography "World in Change" studies, according to which the studies deal with climate change [57].

For teachers, there are two models on how to help them to build up their teaching methods regarding climate change, which are the so-called bicycle model [38] and process model [8]. The bicycle model outlines climate change in all dimensions: It is a whole but, in order to function and stay in motion, the bicycle needs every single part of it and an active user. The process model concerning climate change helps teachers to outline the breath, multidimensionality and comprehensiveness of climate education, which in turn facilitates the integration of different aspects of climate change into education [8]. In these models, the knowledge and thinking skills form the basis for climate change. In particular, the bicycle model [38] pays attention to the other educational views such as values, motivation, identity, emotions, actions, anticipatory hope and people's world views.

3. Research Questions

Bråten et al. [1] demonstrated considerable cross-cultural generalizability—i.e., between Norwegian and Spanish undergraduate students' epistemic beliefs—in the dimensionality of personal epistemology with regard to the Certainty, Source and Simplicity of knowledge as well as the justification of knowing. However, some cultural distinctions in factor structures were also identified. Based on these outcomes, the following two research questions (RQs) were formulated in the present study:

RQ 1. To what extent is the four-factor model based on Finnish high-school students' answers to questions regarding topic-specific epistemic beliefs about climate change congruent with Bråten et al.'s [1] model?

RQ 2. To what extent do the variables topic knowledge, topic interest and gender predict the Finnish high-school students' composite scores on the factors included in the TSEBQ?

There were two means to answer to these research questions. On the one hand using factor structure to evaluate epistemic beliefs about climate change in Finnish high-school students and, on the other hand, using regression analysis to determine the influences that gender, topic knowledge and topic interest have on beliefs about climate change. Practically, this required statistically assessing how well the structure of the questionnaire functioned and how the corresponding sections (e.g., items and factors) of the questionnaire can be found in the Finnish study.

4. Study Design and Material and Methods

4.1. Participants and Settings

The target population of high-school students were based on voluntary public schools in Southwestern Finland, and both voluntary teachers and their students were willing to participate. Respondents (n = 211; 16–18 years old, mean age 17.1 years and standard deviation of age 0.72; 60.2% female and 39.8% male) in this survey, with quantitative approaches, were second year senior high-school students from three different schools (one rural and two situated in a small town) in Southwestern Finland. All students were enrolled in self-selected, advanced-level biology and chemistry courses and followed the Finnish National Core Curriculum [57] in their studies. This course is an example of the integrated studies organised by every high-school according to the national curriculum. In this case, the course was partly based on a virtual learning environment.

4.2. Data Collection

4.2.1. Procedure

The data collected in this study comprised part of the SciLeS (Science Learning for Future Schools) project [60,61]. Participation in the study was voluntary, and informed consent forms were signed and collected from each participant or the participant's legal guardians. At the beginning, the biology and chemistry teachers from their respective schools signed up for the study with the permission from the principal of the school. After that, specific permission from each student and their legal guardians was requested. All permissions for the students were received, and no one needed to be excluded from the study. The participating students were studying the environmental status of the Baltic Sea in a virtual learning environment (virtual laboratory) called the Virtual Baltic Sea Explorer (ViBSE) [62]. Before administrating the selected measures, participants were briefly instructed about the tests. The survey questionnaire data were gathered from the students prior to their studies in the ViBSE environment and, finally, were subjected to statistical tests.

4.2.2. Measures

Three sets of tests were administered: the TSEBQ (direct and reverse translation into Finnish) concerning climate change [1] and topic knowledge in biology and chemistry (TKBC) assessment divided into two tests. Students' grades in biology and chemistry were collected, and the mean grade was assessed (BiChe mean grade). The students also completed an at-home interests in science subjects' questionnaire (ISSQ), which also assessed their future career plans and included questions about basic information, such as gender and age. A detailed description of the measures used is given below.

Personal epistemology (RQ1) was measured using the TSEBQ (49-item, 10-point Likert scale, 1 = strongly disagree, 10 = strongly agree), which was adapted to also measure the four different dimensions of epistemic beliefs about climate change via the 49 questionnaire items as follows: certainty of knowledge (12 items)—knowledge about issues concerning climate is constantly changing (statement 5); Simplicity of knowledge (12 items)—within climate research, accurate knowledge about the details is the most important (statement 11); source of knowledge (12 items)—to understand climate problems, it is not sufficient to only read what experts have written about them (statement 18); and justification of knowing (13 items)—to find out whether what I read about the problems is trustworthy, I try to compare knowledge from multiple sources (statement 23), or to check whether what I read about climate problems is reliable, I try to evaluate it in relation to other things I have learned about the topic (statement 48) [1].

On the adapted TSEBQ, the dimension of certainty of knowledge (12 items) about climate change ranged from the belief that absolute truth exists with certainty (e.g., [61]) to the belief that knowledge is tentative and evolving (e.g., knowledge about issues concerning the climate is constantly changing). The dimension of Simplicity of knowledge about climate change (12 items) ranged from the belief that knowledge is an accumulation of facts (e.g., within climate research, accurate knowledge about the details is the most important) to the belief that knowledge is characterized as a collection of highly integrated concepts or even complex theories [9]. The third dimension, source of knowledge (12 items), varies from the belief that knowledge originates outside the self in external authoritative sources from which it can be transmitted to the belief that the self is a knower with the ability to construct knowledge in interaction with others. The fourth dimension, justification of knowing, concerns how individuals evaluate knowledge claims, ranging from the belief that knowledge can be justified on the basis of what feels right, first-hand experience, authority, etc., to the belief that rules of inquiry or reason should be used, and that one must personally evaluate and integrate sources and critically assess expert opinions [1].

In order to measure the students' topic knowledge of biology and chemistry content (i.e., the TKBC assessment), two tests containing multiple-choice, open-ended and diagram interpretation questions were developed by two researchers and two high-school teachers specialized in science education. Although each of these domain tests was in some ways distinct, they both assessed the same kinds of knowledge and skills, and they both included six main questions and a maximum of four secondary questions. The maximum score for both TKBC tests was also the same: 20 points.

The ISSQ developed for this study included questions about favourite subjects (categories: no science fields/no science interest; secondary science field; one primary science field plus other subjects; more than one primary science field) and students' future career plans (categories: uncertain in a science career; confident in a science career in subjects such as medicine, geography, mathematics and psychology; environmental science subject; biology, chemistry and physics).

4.2.3. Statistical Analyses

In analyzing the TSEBQ, Bråten et al. [1] used the following procedure to determine the factor structure: (1) With all 49 items, Cronbach's alpha and corrected item-total correlations were computed, and items with low correlations ($r < 0.10$) were excluded (2) for the remaining items. The same treatment was repeated for the remaining items until none of the items was excluded; (3) furthermore, in principal component analysis (PCA), some of the items were left out because of low <0.35 loadings or loadings onto several factors. In that procedure, the final factor structure contained four factors/dimensions with 24 items, corresponding to the assumed four-dimensional model of epistemic beliefs. In the present study (Finnish high-school students/SciLeS data), the examination of the factor structure and the analyses concerning the items started by using corresponding procedures for all 49 items. After that, the factor structure of the Bråten et al.'s final solution with 24 items and four factors (Certainty, Simplicity, Source and Justification) was applied to test the structural validity of the research settings. The results and properties of that was examined and the factors were used in the further analyses.

The first analysis, PCA with oblique rotation, assessed the dimensionality of topic-specific beliefs concerning climate change via composite scores on the TSEBQ. The ultimate aim of this analysis was to use the multi-dimensional data derived from the composite scores to present central features without losing important information. By using PCA, all the present factors explained as much of the variation as possible. PCA is used when the researcher has a preconceived idea of the structure concerning the studied issue, and the goal is to retain all the variables. PCA was first used to explore the structure of the items and to identify the weakly performing items. Afterwards, a more restricted factor model, a confirmatory factor analysis (CFA) model, was tested to determine how well the model without cross-loadings (included as low estimates in PCA) fit the data.

The starting point was a comparison of the Finnish data with the Norwegian example from Bråten et al. [1]. The Norwegian example was chosen because both Norway and Finland are Nordic countries with similar social and educational systems. Based on this assumption, it was assumed that the structure obtained from the Norwegian data would be close to that obtained from the Finnish data. Finally, the solution that was obtained was compared with the structure based on the Spanish data.

CFA is used when the suitability of a hypothesized model is being investigated and when the goal is to determine whether the data provide support for an already existing model, as was the case in the present research.

Hierarchical regression analysis (HRA) was used to test relations between three of the TSEBQ factors (Certification, Source and Justification) and how well they were predicted by the variables gender, topic interest or topic knowledge of the subjects. The fourth factor, Simplicity, was too unreliable to be used. Composite scores of these factors (computed as the average of the TSEBQ results, 10-point Likert scale, 1 = strongly disagree, 10 = strongly agree) were used stepwise in relation to gender (first step), with the other variables being tested in a second step using topic knowledge 1 (BiChe mean grade), topic knowledge 2 (BiChe test, sum max 40), topic interest 1 (future career plans—no science/science) and topic interest 2 (favourite subjects—no science subjects/one or many science subject) as variables.

In the confirmatory factor analysis, the software Mplus 8 was used. Other analyses were carried out by using IBM SPSS Statistics 26 and Stata 15.

5. Results

5.1. Congruence of Bråten and Others (2009): Norwegian Model with the Respective Four-Factor Model Based on Finnish Students' Answers (TSEBQ) Regarding Topic-Specific Epistemic Beliefs about Climate Change (RQ1)

5.1.1. Principal Component Analysis (PCA)

The results concerning students' answers on the TSEBQ analyzed by PCA showed that, by starting with all original 49 items and the PCA-procedure similar to Bråten et al. [1], the previous found structure could not be reproduced. However, when the same set of items that was found in the final solution of the four-factor structure in the Bråten et al.'s [1] Norwegian model, the model results seemed more congruent.

The internal consistency for the 49 items on the TSEBQ was analyzed before PCA. The value of the Cronbach alpha was reasonably high $\alpha = 0.79$. The corrected item-total correlations ranged within interval [0.05, 0.45]. Only three of the items had values lower than 0.10. The KMO measure and Bartlett's test showed that the data were suitable for principal component analysis (KMO = 0.65, Bartlett's test of sphericity $\chi^2(1176) = 2921.60$, $p < 0.001$). The solution reached, with all 49 items and procedure similar then Bråten et al., was not interpretable and did not follow the theory of the four factors in TSEBQ. Thus, PCA-analyses were next carried out with the previously validated set of 24 items and four factors. For these items, the Cronbach's alpha was 0.66. Corrected item-total correlations ranged in interval [0.02, 0.39]. The KMO measure and Bartlett's test showed that the data with these 24 items were suitable for PCA (KMO = 0.63, Bartlett's test of sphericity $\chi^2(276) = 844.72$, $p < 0.001$). In the beginning of this study, attempts were made to phase out, step by step, and/or separately remove the less-functioning items using PCA, for example, item 40 (to gain real insight into issues related to climate, one has to form one's own personal opinion relative to what one reads; Simplicity of knowledge) and item 36 (within climate research, there are connections among many topics; Simplicity of knowledge). However, this caused ambiguity in the factor structure, so they were not removed. Item 31 (knowledge about climate problems is indisputable; reversed statement; certainty of knowledge) did not show a factor loading on any of the factors, so it was removed (also low item-total correlation r = 0.06). Finally, in the four-factor PCA-solution, the set with mostly the same set of items used by Bråten and others [9] on Norwegian data was shown to also work for the SciLes data, except for item 31 which was excluded. Thus, 23 of 24 items were used in further analyses.

In the four-factor structure with the remaining 23 items (Table 1), item loadings were at the reasonable level and well-structured. Factor structure has many similarities to that of the solution of Bråten et al. [9] for Norwegian data. However, seven items [11,14,17,27,36,40,49] loaded in different factors. The factor loadings reached for the respective categories varied between 0.84 and 0.49 (all items with <0.30 loadings were excluded).

5.1.2. Goodness-of-Fit of the Factor Structure

CFA was employed to test the goodness of fit of the factor structure using the Finnish SciLes data in which a clearer (restricted, with cross-loadings fixed to zero) structure was used. The analysis revealed that the four-factor model with these data did not work (model estimation did not converge on the factor structure in the Norwegian model).

Table 1. Four-factor structure and item loadings of principal component analysis (PCA): the item numbers refer to statements in the topic-specific epistemic beliefs questionnaire (TSEBQ).

Item		*M*	*SD*	Loadings			
				Factor 1: Certainty	Factor 2: Simplicity	Factor 3: Source	Factor 4: Justification
45	Ce	7.15	1.96	**0.74**			
34	Ce	5.14	2.15	**0.57**			
38	Ce	5.97	1.38	**0.66**			
28	Ce	6.22	1.88	**0.65**			
5	Ce	7.19	1.77	**0.58**	−0.36		
41	Ce	6.71	2.08	**0.54**			
10 r	Si	3.20	1.74		**0.67**		
11 r	Si	6.60	1.99			0.59	
20 r	Si	4.91	1.88		**0.52**		
33 r	Si	5.46	1.60		**0.49**		0.35
14 r	J	4.11	2.06		**0.43**		
27 r	J	5.64	1.84			**0.54**	
2 r	So	4.46	1.98			**0.51**	
3 r	So	7.21	1.96			**0.67**	
29 r	So	4.71	1.73			**0.61**	
26 r	So	6.15	2.04			**0.66**	
48	J	7.38	1.65				**0.78**
49	So	7.33	1.71				**0.78**
40	So	5.78	1.84				**0.65**
44	J	7.06	1.80				**0.71**
30	J	6.82	1.94				**0.51**
36	Si	7.75	1.48		−0.52		**0.39**
17	So	5.91	2.06				**0.38**

Items numbered as in Bråten et al. (2009). r = reversed statement. ce = a certainty item in Bråten et al. (2009) and, correspondingly, si = simplicity; so = source; and j = justification. Extraction: Principal components. Rotation: Direct oblimin loadings < 0.30 were excluded.

In order to examine the reason for the low convergence of the four-factor model, an analysis of composite scores of the four factors was performed. The analysis showed low reliability for *Simplicity* by using the SciLeS data (Cronbach's alpha was 0.33 for *Simplicity* vs. 0.70–0.76 for the other factors (Table 2).

Table 2. Descriptive statistics of the composite scores used in hierarchical regression analysis (HRA).

Component [1]	*M*	*MD*	*SD*	*Min*	*Max*	*Cronbach's Alpha*
Certainty	6.44	6.33	1.40	1.83	10.00	0.70
Simplicity	4.98	5.00	1.10	1.00	7.83	0.33
Source	5.63	5.60	1.37	1.60	8.60	0.63
Justification	6.80	7.00	1.39	1.00	10.00	0.76

[1] Composite (mean) score variables. *N* = 174–176 (non-missing cases).

Based on this result, Simplicity (low reliability) was excluded from further analyses. Finally, due to its low loading on any of the factors, item 17 (I understand issues related to climate better when I think through them myself, and not only read about them; source of knowledge) was also removed.

The factor structure concerning the resulting three-factor model (i.e., without the Simplicity factor) with 17 items was then estimated by using the CFA model, and its goodness of fit was good after item 17 was removed (χ^2 [df = 114, *N* = 176] = 5.336, *p* = 0.025, RMSEA = 0.04, CFI = 0.92, TLI = 0.91 and SRMR = 0.07). Cut-off values for an acceptable model fit were as follows: *p*-value (χ^2–test) > 0.05, χ^2/df < 2; RMSEA < 0.08; CFI > 0.90; TLI > 0.90; SRMR < 0.08 [63–65].

Confirmatory factor analysis (CFA) of the topic-specific epistemic beliefs questionnaire (TSEBQ) was performed in order to test whether the use of the SciLeS data provided support for the original model of Bråten et al. [1] (Figure 1).

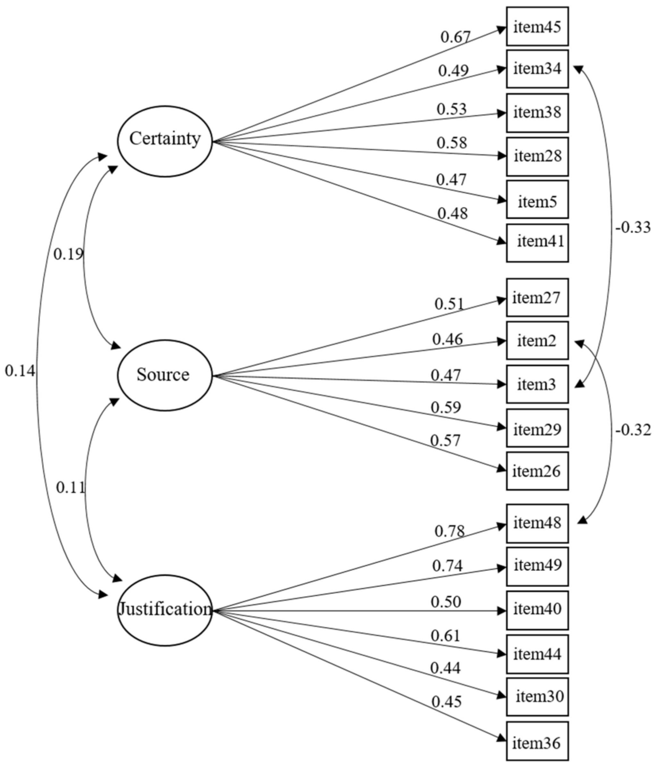

Figure 1. Estimated three-factor confirmatory factor analysis (CFA) model.

The final factor structure with three factors (*Certainty*, *Source* and *Justification*) and respective item loadings corresponded to the factor structure of Bråten et al. [1], except for four items [27,36,40,49] which loaded different factors. Thus, the CFA provided evidence that the TSEBQ used in the Norwegian model for the three factors of *Certainty*, *Source* and *Justification* was also valid when applied to the SciLes data. In the CFA, the statement in the TSEBQ concerning the SciLes data was not congruent with the factor loadings in the Spanish data (data not shown here).

5.2. Topic Knowledge, Topic Interest and Gender as Predicting Factors for Source, Certainty and Justification (RQ2)

Group statistics of the composite scores for *Source*, *Certainty* and *Justification* showed insignificant differences between genders (2-tailed t-test for equality of means; data not shown). Students with future science career plans had significantly higher composite scores for *Justification* (M = 7.21, SD = 1.15 vs. M = 6.43, SD = 1.48; $t(89) = 2.72$, $p = 0.008$), which is in line with the results for Spanish students. Those with only one favourite science subject had significantly higher composite scores for *Source* (M = 6.08, SD = 1.15 vs. M = 5.52, SD = 1.19; $t(91) = 2.31$, $p = 0.023$).

Weak but significant correlations were observed for the composite score of *Justification* with biology/chemistry grades and with the results of the students' BiChe mean grade and BiChe test.

Female students (M = 11.19, SD = 3.18) performed significantly better than males (M = 9.80, SD = 2.48) when tested for topic knowledge in biology and chemistry (i.e., TKBC assessments): $t(152.62) = 2.98$, $p = 0.003$. Based on their answers on the ISSQ, they were also significantly more likely to plan a future science career (52.5% vs. 30.2%; $\chi^2(1) = 5.08$, $p = 0.024$).

The results based on HRA revealed that the composite (mean) scores of the TSEBQ factors concerning the students' topic-specific epistemic beliefs about climate change depended on predicting the variables topic knowledge 1 (mean grade) and 2 (BiChe test), topic interest 2 and gender. Pairwise correlations and descriptive statistics of the variables are shown in Table 3.

Table 3. Zero-order correlations and descriptive statistics of the variables used in the hierarchical regression analysis (HRA).

Variables	1.	2.	3.	4.	5.	6.	7.	8.
1. Certainty (scale: 1–10)	-							
2. Source (scale: 1–10)	0.16 *	-						
3. Justification (scale: 1–10)	0.08	−0.18 *	-					
4. BiChe mean grade (scale: 4–10)	0.14	0.13	0.28 **	-				
5. BiChe test (scale: 1–40)	−0.04	−0.15	0.37 ***	0.31 **	-			
6. Gender (0 = male, 1 = female)	−0.14	0.01	0.09	0.22 *	0.22 *	-		
7. Future plans: Science (0 = no/1 = yes)	−0.09	−0.16	0.28 **	0.27 *	0.25 *	0.35 *	-	
8. Favourite subject: Science (0 = no/1 = yes)	−0.04	−0.24 *	0.07	0.35 **	0.09	−0.01	0.31 *	-
M	6.44	5.63	6.80	8.15	10.68	0.60	0.43	0.51
SD	1.40	1.37	1.39	1.26	3.01	0.49	0.49	0.50
f: value 0/1	-	-	-	-	-	84/127	59/45	51/53

For binary variables, correlations are calculated as point-biserial or tetrachoric correlations using Stata packages *Polychoric* and *Sg20*. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Regression analyses (Table 4) showed that students' topic knowledge in chemistry and biology (BiChe test) was linked to *certainty of knowledge* ($p < 0.05$) and *justification of knowing* ($p < 0.05$). Significantly higher composite scores of *source of knowledge* were associated with topic knowledge in biology and chemistry (BiChe mean grade; $p < 0.05$) and lower with topic interest 2 (favorite subject science; $p < 0.05$).

6. Discussion

The present assessment-related study examined Finnish senior high-school students' topic-specific epistemic beliefs (TSEB) about climate change and whether the TSEBQ developed by Bråten et al. [1] could be validated in a Finnish high-school educational culture by using factor structure to evaluate TSEBs about climate change. Furthermore, the relations between topic-specific epistemic beliefs, gender, scientific reasoning skills, topic knowledge in biology and chemistry, topic interest in favorite school subjects and domain interest in future career plans were studied by using regression analyses.

This study followed a structure similar to that in Bråten et al. [1] in which the dimensionality of students' personal epistemology was examined with respect to climate change. They showed that the theoretical framework of Hofer and Pintrich [32] was appropriate for quantitatively assessing personal epistemology on a topic-specific level. Additionally, they performed a PCA on statements contained in the TSEBQ and on composite scores obtained from the questionnaire, completed by Norwegian university students, in relation to four factors (Source, Certainty, Simplicity of knowledge and justification of knowing), as well as on composite scores in relation to three factors (excluding Simplicity) when the TSEBQ was completed by Spanish university students. These factors were found to correspond to the categories in Hofer and Pintrich's study [32]. The results of the present study confirmed that the theoretical model of Bråten et al. [1] was also adequate enough for use in examining the personal epistemologies and topic-specific epistemic beliefs of Finnish high-school students concerning climate change.

Statistical analyses concerning the factor structure of the TSEBQ were essential to the current study. According to the PCA results, the loading pattern of the statements on the TSEBQ was comparable to that of the Norwegian data [1]. Furthermore, there were many more variations in the structure and pattern of the factor loadings with regard to the epistemological nature of knowledge and knowing in the Spanish students' data (analyses made at the beginning of study; data not shown here). The internal consistency of the TSEBQ was good for the subscales certainty, source of knowledge and justification of knowing in Finnish data. The formulation of the Simplicity factor was shown to be unclear, and its reliability was demonstrated to be low. Similarly, the CFA modelling showed that the four-factor structure did not fit the Finnish data, but that the goodness of fit of the three-factor structure (for the subscales Certainty, Source and Justification) was adequate. Based on these statistical results, it can be concluded that the statistical model obtained based on Finnish students' answers was congruent with the three-factor structure that Bråten et al. [1] found in the Norwegian data.

Table 4. Hierarchical regression analysis (HRA) summary for variables (gender, topic knowledge and topic interest) predicting TSEBQ factors *Source*, *Certainty* and Justification.

Variables and Steps	*B*	95% CI for *B*		*SE B*	*B*	R^2	ΔR^2
		LL	*UL*				
Dependent variable: Source							
Step 1:						0.01	
Gender (female)	−0.13	−0.86	0.60	0.36	−0.06		
Step 2:						0.20	0.19
Topic knowledge1 (BiChe mean grade)	0.43 *	0.06	0.91	0.18	0.44 *		
Topic knowledge 2 (BiChe test)	−0.07	−0.17	0.03	0.05	−0.25		
Topic interest 1 (future plans: science)	−0.27	−1.00	0.47	0.36	−0.13		
Topic interest 2 (favourite subject: science)	−0.88 *	−1.64	−0.12	0.38	−0.41 *		
Dependent variable: Certainty							
Step 1:						0.01	
Gender (female)	−0.07	−0.89	0.75	0.41	−0.03		
Step 2:						0.18	0.17
Topic knowledge 1 (BiChe mean grade)	0.39	−0.04	0.81	0.21	0.35		
Topic knowledge 2 (BiChe test)	−0.12 *	−0.23	−0.01	0.05	−0.37 *		
Topic interest 1 (future plans: science)	0.31	−0.53	1.15	0.41	−0.13		
Topic interest 2 (favourite subject: science)	−0.70	−1.57	0.17	0.43	−0.29		
Dependent variable: Justification							
Step 1:						0.01	
Gender (female)	−0.22	−1.12	0.68	0.44	−0.08		
Step 2:						0.34	0.33 **
Topic knowledge 1 (BiChe mean grade)	−0.13	−0.55	0.28	0.21	−0.11		
Topic knowledge 2 (BiChe test)	0.19 *	0.08	0.30	0.05	0.54 *		
Topic interest 1 (future plans: science)	0.58	−0.24	1.40	0.41	0.22		
Topic interest 2 (favorite subject: science)	−0.21	−1.06	0.64	0.42	−0.08		

CI = confidence interval; *LL* = lower limit; *UL* = upper limit. BiChe = Biology and Chemistry. * $p < 0.05$, ** $p < 0.01$.

Based on the analysis of factor loadings and the developed model, it can be confirmed that the present study yielded evidence that the TSEBQ designed by Bråten et al. [1] for assessing Norwegian data in a Norwegian educational environment is also appropriate for examining topic-specific epistemic beliefs about climate change in the Finnish high-school educational culture.

HRA was carried out to investigate how well the variables of topic knowledge, topic interest and gender among Finnish students predicted the TSEBQ factors of Source, Certainty and Justification. Students' epistemic beliefs concerning source of knowledge were associated with topic knowledge 1 (mean grade), while their epistemic beliefs concerning justification of knowing were associated with topic knowledge 2 (knowledge in biology and chemistry). These results are congruent with those of Leiserowitz [9] and Poortinga et al. [7] in which the ability to learn and solve climate change issues was linked not only to knowledge but also to people's beliefs regarding the topic. The current results are also in line with those of Cano [10] and Mason et al. [11], where it was demonstrated that academic achievements are influenced by the Structure and Certainty of knowledge as well as by the justification of knowing.

The following results were interpreted on the basis of Hofer and Pintrich's [32] personal epistemology and Bråten et al.'s [1] findings on topic-specific epistemic beliefs. The Finnish results revealed that the better the Finnish students' outcomes in biology and chemistry tests were, the lower their Certainty of knowledge was. A possible explanation for this is that the more the students knew, the less they believed that absolute truth exists. Instead, the students may have come to believe that knowledge is tentative and constantly evolving. Students' higher learning outcomes on biology and chemistry content tests promoted the justification of knowing in that the students had to evaluate and integrate information sources and had to critically assess expert opinions. The Finnish students who mentioned science as their favorite subject less often believed in the importance of the source of knowledge as the sole means by which knowledge can be transmitted, suggesting that, in their minds, the self is the knower with the ability to construct knowledge in interaction with others. Epistemic beliefs on the source of knowledge were connected to the Finnish students' interest in science by means of having at least one favorite science subject. These findings support Berding's [14] observation that learning outcomes can be improved by supporting the preferred beliefs of students. Finnish students showed interest in science as a future career, and this finding was positively connected to the justification of knowing, which means that these students felt that it was important to justify knowledge on the basis of what feels right and on first-hand experience.

Gender had no effect on the composite scores of Certainty, Source and Justification, which means that gender did not predict epistemic beliefs concerning climate change among Finnish high-school students. This result is in line with Cano [10], who found that beliefs in simple and certain knowledge did not reflect differences between male and female secondary school students; however, girls generally displayed more realistic and elaborate epistemological beliefs than boys. Finnish female students performed significantly better in topic knowledge of biology and chemistry. Ratinen and Uusinautti [66] found that knowledge of climate change among the Finnish female elementary and high-school students predicted climate change mitigation. Finnish female students were also shown to be more likely than their male counterparts to choose science as a future career.

Finally, the assessment of the structure of the questionnaire by Bråten and others [1] and the corresponding evaluated sections such as items and factors by means of the three factor model showed statistical similarity to Norwegian study; thus, the questionnaire is proven to show validity for use in Finnish circumstances.

7. Limitations, Reliability and Future Research

The number of Finnish respondents (n = 211) in the current study was nearly the same as that in the study by Bråten et al. [1]: 225 Norwegian students and 216 Spanish students. This supports the reliability and validation of the answers on the TSEBQ using factor analyses. No statistical comparison was made between these two study groups. Bråten et al. [1] examined undergraduate students in psychology and education at the post-secondary level, whereas the present study assessed high-school students. However, this study showed that TSEBQ is valid among Finnish high-school students although target groups differed for example in age.

In the PCA, statement 17 had to be excluded due to its low loadings on the factors. Analysis of composite scores showed that the reliability of the Simplicity factor was too weak. However, the findings for the three other factors were consistent with those in the Norwegian model of Bråten et al. [1]. With these limitations in mind, the results can be considered reliable, and the statements on the TSEBQ can be regarded as reflecting Finnish high-school students' epistemic beliefs concerning the nature of knowledge and knowing with respect to climate change in the Finnish educational culture.

The properties and previously found structure of the TSEBQ have been examined for the study Finnish high-school students' group argumentation, learning outcomes and productive disciplinary engagement in connection to climate change issues in a virtual learning environment. Thus, it is plausible to argue that the TSEBQ as it was validated in previous studies is a reliable tool for measuring high-school students' topic-specific epistemic beliefs in a Finnish educational and cultural environment.

TSEBQ has been validated for the study of Finnish high-school students' epistemic beliefs, and thus future studies could use the present results to study Finnish students' group argumentation, learning outcomes and productive disciplinary engagement in connection to climate change issues in a virtual learning environment.

8. Conclusions and Implications

The statistical model based on 49 questions (TSEBQ) showed congruence with the Norwegian model but not with the Spanish model. The structure of the four-factor model was comparable to that of Bråten et al. [1] (in the Finnish data, based on 23 items; in the Norwegian data, based on 24 items). The analysis of composite scores showed that the reliability to the Simplicity factor was too weak; therefore, it was excluded. In the CFA, the three-factor model (Certainty, Source and Justification) and the respective item loadings were shown to be identical to the findings of Bråten and others [1] concerning the factor structure without Simplicity. Thus, it is plausible to argue that the TSEBQ as it was assessed in previous studies is a reliable tool for measuring students' topic-specific epistemic beliefs in a Finnish high-school environment, which is the most important implication of this study by means of other studies regarding this target group and the future research. The results of the study support the claim that topic-specific epistemic beliefs may be not only educationally bound but also culturally bound. This can be regarded as the first implication of this study. Second, despite the fact that the Finnish students in the present study were all interested in science, as they had self-selected advanced-level chemistry or biology courses, the outcomes imply that their epistemic beliefs on the nature of knowledge and knowing were not optimal. Thus, more attention should be paid in science education to cultivate students' beliefs to empower their agency as well-informed, critical citizens.

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