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FACTOR STRUCTURE OF A SELF-REPORT QUESTIONNAIRE DETERMINING THE EPISTEMIC BELIEFS OF PRIMARY SCHOOL AND KINDERGARTEN STUDENT TEACHERS IN THE SCIENCE DOMAIN

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ABSTRACT

The presented empirical study deals with the issue of the epistemic beliefs of primary school and kindergarten student teachers in the science domain. In relation to science education, epistemic beliefs are closely connected with the concept of nature of science (NOS). The aim of the study was to find and analyze the factor structure of the translated self-report questionnaire "Epistemic Beliefs About Science" (EBS) in the Czech sociocultural environment. The EBS was translated as recommended for cross-cultural research and then piloted in March 2021. The main data collection was conducted online via Google Forms in May 2021 through convenience sampling (N = 427) at six universities in the Czech Republic. We performed a confirmatory factor analysis to verify the model. Fit indices reached acceptable or good values for acceptance of the generated model (CFI = .955, TLI = .945, RMSEA = .060, SRMR = .052). Correlations between individual dimensions are also presented. The reliability for both the original form of the instrument and for the resulting model was higher than 0.75 for all subscales. The results are discussed in the context of foreign empirical studies. It can be stated that the modified version of the EBS is applicable in the Czech sociocultural environment for the research sample.

KEYWORDS

science education, epistemic beliefs, factor analysis, student teacher, nature of science

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Introduction

Contemporary life is characterized by almost unlimited access to information sources, albeit with varying levels of reliability. Thus, there are situations in which an individual decides to attribute knowledge to something; in the process of this attribution, the individual considers what the acceptable degree of uncertainty in the knowledge construct is or evaluates their degree of trust in the attributed source.

As Feucht (2017, p. 8) concisely stated, "No matter what knowledge people absorb and for what reasons, they might be challenged to verify the trustworthiness and relevance of the incoming information before making an informed decision or coding it into long-term memory." Bråten et al. (2011) emphasized that when constructing knowledge from a variety of sources, as is currently typical, the starting point is the application of epistemic strategies such as assessing the reliability and quality of the source of information and supporting claims. These epistemic strategies are an essential skill for an individual's future behavior, as subsequent actions – such as preparing for tests, generating arguments, and assuming points of discussion – will depend on how the individual perceives, stores, and then uses the relevant information.

Epistemic beliefs[1] that we, in the context of teaching science, focus on in this contribution refer to individual beliefs about how knowledge and the process of knowing affect and are affected by the learning process, including how knowledge is defined, constructed, and evaluated, where knowledge is stored, and how knowledge emerges (Hofer, 2004). A correlative meta-analysis by Greene et al. (2018) analyzed 132 non-experimental studies involving 55,418 respondents demonstrating a low ($r = 0.16$) but statistically significant ($p < 0.001$) correlation between epistemic beliefs and diverse learning aspects (argumentation, conceptual understanding, declarative knowledge in the subject), with a stronger correlation found in the domain specificity (specificity of epistemic beliefs and specificity of the tool determining the learning performance in the context of the domain) than in the general domain approach. For this reason, we consider it crucial to examine and develop the epistemic beliefs of individuals within the context of the characteristics of a respective discipline.

1 In this work, in agreement with Schommer-Aikins (2004) and Muis (2007) and in order to unify the nomenclature, we use the term "epistemic belief" although we are aware of other terms such as "personal epistemology" (Hofer & Pintrich, 1997), "epistemic cognition" (Greene et al., 2008), "epistemic resources" (Hammer & Elby, 2003), and "epistemic thinking" (Kuhn & Weinstock, 2002).

Many experts are engaged in research into epistemic beliefs in science education in connection with various aspects of learning, e.g., self-regulated learning (Pamuk et al., 2017), reading comprehension (Yang et al., 2016), achievement (Alpaslan, 2019), and learning approaches (Chiou et al., 2013). In the context of science education, epistemic beliefs are closely linked to the concept of nature of science (NOS) (Elby et al., 2016), defined as the way of knowing (Lederman, 2007), or directly as the epistemology of science (Tsai & Liu, 2005). In the theoretical part of this text, we discuss individual models of epistemic beliefs with an emphasis on the links between epistemic beliefs and important learning aspects in the context of the subject of science. The empirical part of the study is focused on an analysis of the factor structure of the translated self-report questionnaire "Epistemic Beliefs About Science" (EBS) (Conley et al., 2004) in the Czech sociocultural environment. The EBS is the most commonly used quantitative self-report questionnaire for capturing epistemic beliefs in the science domain (Lee et al., 2021). We believe that it is necessary not only to find new ways to determine the level of epistemic beliefs of individuals, but also to determine the reliability and validity of existing tools in other sociocultural environments.

1. Models of epistemic beliefs

Beginning in the 1970s, research on epistemic beliefs focused on identifying developmental trajectories. In the 1990s, there was a shift in attention towards the potential facilitation of epistemic beliefs in pupil and student understanding, reasoning, thinking, learning, and performance (Hofer & Pintrich, 1997). Greene et al. (2018) presented a classification of four models of epistemic beliefs: developmental, dimensional, academic-discipline informed, and philosophically informed. In the following passages, with some overlaps with other models due to the general theoretical anchoring, we discuss primarily the dimensional model, as the self-report questionnaire used in this study falls into this category.

Developmental models (e.g., Kitchener & King, 1981; Kuhn et al., 2000; Perry, 1970) are based on the (neo)Piagetian tradition emphasizing linear cognitive development. In various terminological nuances, developmental models refer to three epistemic positions (Barzilai & Ka'adan, 2017; Schraw, 2013):

i) Objectivism (realism, dualism, absolutism). At this level, knowledge is perceived as an objective and factual construct that can be excerpted directly from the experience of external observable reality; all individuals share the same knowledge base.
ii) Subjectivism (relativism, multiplism). At the beginning of this level, knowledge is perceived as a unique and individual construct, and for this reason all views have the same weight. There is no absolute truth.

iii) Criterialism (contextualism, evaluativism, objectivism-subjectivism). At this level, knowledge is perceived as an individual and social construct that can, however, be objectified through evidence. This is inextricably linked to the methodological processes of research in a given discipline (coordination of knowing and known processes). This is theoretically the most sophisticated level.

The long-standing assumption that children in the context of the developmental aspect of cognitive development are not capable of a certain type of learning experience (including activation of epistemic strategies) is currently being revised in the context of science teaching (Kawasaki et al., 2004) and also in the context of history teaching (VanSledright, 2002). Gradually, researchers have emerged who argue that epistemic beliefs are a (multi)dimensional construct and that their development is nonlinear: one dimension may be naive; another may be more sophisticated. Schommer-Aikins (Schommer, 1990; the EQ) is considered a pioneer in this direction, postulating a total of five dimensions of epistemic beliefs: stability of knowledge (certainty, stability, certain knowledge – knowledge is absolute, knowledge is static rather than changing); knowledge structure (simplicity, structure, simple knowledge – knowledge is a set of isolated facts as compared to a set of coherent and complex concepts); knowledge source (omniscient authority – knowledge comes from an external authority or is actively constructed by the individual); learning control (innate ability – whether the ability to learn is innate or acquired), and learning speed (quick learning – learning process is quick or gradual). The last two dimensions have not been included in the theoretical framework by some researchers (e.g., Hofer & Pintrich, 1997) who assert that these two dimensions are not epistemic. Schraw and other authors (the EBI; Bendixen et al., 1998; Schraw et al., 2002) followed the five-dimensional model of Schommer-Aikins. Hofer and Pintrich (1997) composed areas of beliefs about the nature of knowledge, consisting of the dimensions of certainty and simplicity, and the nature of knowing, consisting of the dimensions of knowledge source and knowledge justification – evaluation of knowledge claims, i.e., standards and criteria by which people substantiate their beliefs. Perception of knowledge as a coherent concept (Schommer, 1990) and perception of knowledge as a temporary and dynamic construct are seen, within the framework of multidimensional models, as more sophisticated beliefs[2] since the latter allows an individual to open up the

2 At present, diverse nomenclature is used to refer to a more or less developed level of epistemic beliefs (constructivist or empiricist beliefs: Hashweh, 1996; more or less mature: Rukavina & Daneman, 1996; Stoel et al., 2017; more or less appropriate: Wiley et al., 2020).

possibility of a new interpretation (King & Kitchener, 1994; Kuhn, 1991). Alexander (2005) directly stated that epistemic beliefs should be targeted in teaching in the context of "complexity, sophistication and uncertainty of knowledge" (p. 38). Less sophisticated epistemic beliefs are considered when an individual perceives an external authority, not themselves, as a source of knowledge (Conley et al., 2004). This view is based on the Piagetian tradition in which cognitive development in childhood is mainly determined through one's own experience, rejecting the function of an adult who provides primarily verbal knowledge and second-hand information (Harris, 2001). However, this view is currently being significantly questioned, as people have relied on testimonies and information from others for millennia (Chinn et al., 2011). We emphasize that sophisticated beliefs include flexibility and adaptability reflecting contextual conditions. For example, it is not very sophisticated to doubt that the Earth is (almost) round (Elby & Hammer, 2001). Dimensional models were initially associated with a general domain approach, and the items, measured with Likert scales, in the self-report questionnaires corresponded to this; for example, "Truth means different things to different people" is item # 2 in the Certain Knowledge dimension in the Epistemic Belief Inventory (EBI) (Bendixen et al., 1998). Subsequently, a group of researchers trying to dimensionally contextualize the items in relation to the relevant discipline was profiled. The Discipline-Focused Epistemological Beliefs Questionnaire (DFBEQ) by Hofer (2000) can be considered an initiating instrument, followed by the emergence of other instruments, including the EBS (Conley et al., 2004); the Epistemic and Ontological Cognition Questionnaire (EOCQ) (Greene et al., 2010); and the Justification for Knowing Questionnaire (JFK-Q) (Fergusson et al., 2013). Self-report questionnaires built on the domain-specific nature of epistemic processes already, in a sense, interfere with models based on domains. The nature of academic disciplines has led many researchers in the field of epistemic beliefs to research "connections with understanding of discipline knowledge and specific actions in the discipline, such as scientific research, historical argumentation, or activities related to comprehension of expert texts" (Juklová, 2020, p. 42). This starting point is based on the assumption that a more sophisticated epistemic level in a given discipline is a prerequisite for adaptive (effective) action in a given area. Thus, epistemic beliefs are situational and context sensitive (Muis et al., 2016). Central to these models are problem-solving and critical (strategic) thinking research conducted by experts that to some extent questions the general domain nature of epistemic beliefs, as expert knowledge is primarily domain-specific (Shreiner, 2014). Samarapungavan et al. (2006) demonstrated, using the example of teaching chemistry, that epistemic beliefs and the practices associated with them are specific and cannot be effectively transferred to other sciences. This corresponds to the results of a qualitative survey by Greene and Yu (2014) among biology and history experts (e.g. in the context of perception of higher order knowledge: biologists – relations x historians: interpretation) and to the conclusions of a meta-analysis by Greene et al. (2018), in which individuals tended to justify knowledge in the domain of history on the basis of authority, but relied on logic in the domain of science. In summary, individuals in different disciplines develop different epistemic positions (Hofer, 2000; Muis et al., 2006). Many researchers are now calling for a deeper grounding of the theoretical basis of epistemic beliefs in educational psychology research into the original philosophical framework (AIR theoretical model[3]; Chinn & Rinehart, 2016; Greene et al., 2008; Murphy et al., 2007). The construct of epistemology in pedagogical-psychological research often focuses on the construct of knowledge, but epistemology involves more than knowledge (epistemic goals, values, structures, outcomes, positions, wisdom, understanding, virtue, …). A significant proportion of researchers focus on the epistemic component of the justification of knowledge; some believe it is "the central question of philosophical epistemology" (Greene et al., 2008, p. 146). This component of epistemology has also been operationalized into self-report questionnaires: justification based on authority, personal perspective, and the use of multiple sources as evidence in the JFK-Q (Ferguson et al., 2013) and similarly in the EOCQ (Greene et al., 2010).

2. Epistemic beliefs in the context of science

An important goal of science education is the development of student scientific literacy, which includes different components: content knowledge, scientific inquiry, and NOS (Peters-Burton, 2016). NOS usually refers to the epistemology of science: science as a way of knowing or the values and beliefs inherent to the development of scientific knowledge (Lederman, 2007). Empirical studies have shown that epistemic beliefs in the context of science predict conceptual change, scientific inquiry, intrinsic motivation, quality of laboratory practices, understanding of science texts, activation of metacognition, and learning practices (Bendixen, 2016; Cano, 2005; Chen, 2017; Ding, 2014; Hsu et al., 2014; Lin et al., 2013; Lising & Elby, 2005; Schiefer et al., 2020; Yang et al., 2016). Interventional studies focusing on the development of the epistemic

3 Aims and values, epistemic Ideals, and Reliable processes for achieving epistemic ends; the dimension of justifying knowledge falls into the component of epistemic ideals, expressing the standards that individuals should meet.

beliefs of students, shifting from the belief that answers to questions are found with authorities to the belief that answers are obtained through research, showed that successful intervention can be undertaken in first graders (Herrenkohl, 1999; Smith et al., 2000; Solomon et al., 1996), and this also includes work with web interfaces (Herrenkohl et al., 2011). Through self-assessment scales and interviews, Edler (2002) found that both naive and sophisticated levels of epistemic beliefs appear in fifth graders. Pupils perceived theories as potentially evolving, appreciating the roles of thinking, justification, and experimentation in science. However, the interview results indicated that students believed that the purpose of science education was to implement projects and activities rather than explain phenomena. Pupils perceived themselves as passive objects; the sources of knowledge for them were external authorities, such as books, teachers, and family members. Conley et al. (2004), in a 9-week intervention for fifth graders, increased the sophistication levels of the dimensions of source and stability; their study also found that children with lower socioeconomic status had more naive epistemic beliefs.

Research showed that in order to develop an understanding of NOS of primary school pupils, it is necessary for their teachers to have a good understanding of the concept and know how to teach it (Akerson et al., 2009). Some studies demonstrated that both primary school teachers (Hanuscin et al., 2010) and students of primary school teacher training are able to develop strategies for developing their students NOS through deliberate intervention (Akerson & Volrich, 2006; Deng et al., 2011). One important aspect for the development of pupil NOS is the development of the teacher's skills in the field of scientific inquiry, which is not an "an automatic or easily facilitated process" (Herrenkohl et al., 2011, p. 2). Wallace and Kang (2004) demonstrated how teachers' beliefs influenced research inquiry practices in science classes. The sustainability of epistemic standards was documented 3 months after a 4-week intervention (Hatfield, 2015). Pupils, students, and their teachers should develop thinking habits that include these beliefs: scientific knowledge can change over time and is based on empiricism (hypothesis formulation; prediction, critical testing, data analysis, and interpretation; and review and evaluation of evidence and methods); there is no single right research method (it is always partially influenced by the researcher's subjectivity, influenced by imagination and creativity, and is socioculturally rooted; Abd-El-Khalick et al., 2017; Deng et al., 2011). Research in the field of the influence of teachers' epistemic beliefs on the organizational forms and teaching methods used, including their influence on the epistemic development of pupils, has not produced completely clear results. Some studies have demonstrated an influence (Norton et al., 2005; Tsai, 2002); others have not (Schraw & Olafson, 2003). Wu et al. (2020) concluded, on a sample of kindergarten teacher training students, that the scientific epistemic beliefs of teachers had predicted their beliefs about teaching and subsequently their pedagogical content knowledge. Correlation studies by Deng et al. (2014, 2017) also demonstrated a link between the epistemic beliefs of teacher training students and their beliefs about teaching. A direct influence of teachers' epistemic beliefs on their class work has not yet been extensively studied. One exception is the qualitative study by Barnes et al. (2020), in which teachers evaluated student work through a think-aloud protocol, concluding that teachers' epistemic cognition directs their interpretation and practices in assessment tasks. A study by Barger et al. (2018) further demonstrates that a student-centered learning environment leads to the development of student epistemic beliefs.

Despite the partially ambiguous findings in the influence of teachers' epistemic beliefs on their teaching practices and secondarily on pupils' own epistemic beliefs and performance, we consider it important to pay attention to this phenomenon since, from our point of view, this issue has been poorly developed in the Czech environment. This finding also applies to the of pre-primary and primary teacher training students who are the respondents in this study. This demographic is specific to the Czech Republic for several reasons: i) students are most often recruited from secondary educational schools where science subjects based on a rigorous approach are left behind in favor of soft disciplines, ii) a wide range of skills needs to be developed within the university education of these students because, unlike their second-level and third-level colleagues, they are more holistic about their approach (all or most subjects are taught by one teacher and they must therefore be properly prepared in them), iii) due to the standard profile of kindergarten and primary school teachers, their training at universities is relatively uniform.

3. The issue of the operationalization of dimensional models for measurements in self-report questionnaires

Schraw (2013) listed six methodological approaches (questionnaires, interviews, vignettes, essays, concept maps, and multidimensional scaling methods) that can be used to identify epistemic beliefs. We focus here on self-report questionnaires because the subject of the empirical part of this study is to determine the factor structure of a self-report questionnaire. Greene et al. (2008) drew attention to the use of explanatory factor analysis and listed studies in which this statistical method was used. According to the authors, this caused discrepancies in findings in subsequent studies, especially in situations in which researchers used confirmatory factor analysis (also Hofer & Pintrich, 1997). Factor analyses usually generated fewer than five factors (using the EQ tool without the source dimension: Schommer, 1990; 1993), factors other[4] than those postulated by Schommer emerged (Jehng et al., 1993: Orderly process; Schraw et al., 2002: Incremental learning, Integrative Thinking). Only some items clearly loaded the postulated dimensions; some items loaded factors with unacceptable reliability (less than 0.70; Schraw, 2013), and structural differences (including failure to confirm the initial dimensionality of instruments) are even more evident when applying an instrument outside English-speaking countries (Bråten & Strømsø, 2005; Bromme et al., 2010; Ordoñez et al., 2009). Both the original and modified versions of the EQ tool and other tools built on similar foundations (EBI – 32 items: Bendixen et al., 1998; within optimization: 28 items: Schraw et al., 2002) usually explain the relatively low percentage of data variability (EQ, EBI – less than 40%; Schraw, 2013) and similar problems with reliability and item loading of factors occur. In the context of EBI, reliability ranges between .58 and .87, and only 15/28 items loaded the factors postulated by Schommer (Bendixen et al., 1998; Schraw et al., 2002). In connection with the use of Likert scales for answering individual items, it is problematic to interpret the mean values, and within the bipolar dimensional concept it has been argued that if an individual expresses their disagreement, it does not automatically mean that they express agreement (Greene & Yu, 2014). Within understanding of more sophisticated epistemic beliefs on a linear level (objectivism – subjectivism – criterialism), it is problematic to interpret the answer to the item "Ideas in science sometimes change" (#15; Conley et al., 2004, p. 203) because subjectivists and even criterialists will agree with the statement. This approach has led some researchers to grasp the positions of objectivism and subjectivism not as bipolar positions, but as two dimensions (Peter et al., 2016). Also, convergent validity within the use of two tools for determining epistemic beliefs does not clearly draw conclusions in the context of correlations between identical dimensions (DFBEQ and EBI – Simplicity dimensions; Cazan, 2013). The findings of Hofer's (2000) research on a sample of university students empirically showed that items from the dimensions of certainty and simplicity factored together, and that it should therefore be a single dimension (similarly Schommer-Aikins et al., 2002). An additional concern is the danger that answers will be generated with a view toward social desirability (Bartels & Magun-Jackson, 2009).

4 The extraction of factors other than those originally expected also applies to other tools. Within the EBI, for example, definitude and perseverance dimensions are extracted (Bromme et al., 2010).

4. Research methodology

4.1 Aim of the study

The aim of the study was to determine and analyze the factor structure of the translated EBS self-report questionnaire (Conley et al., 2004) in the Czech sociocultural environment and in students of primary school teacher training and of kindergarten teacher training (hereinafter referred to as "students").

4.2 Self-report questionnaire used

The EBS self-report questionnaire was created by Conley et al. (2004) and was originally intended to determine the epistemic beliefs of primary school pupils; however, in subsequent years it was used in its original and/or a modified form with older respondents. It is a four-dimensional self-report questionnaire (Table 1), developed within the framework of a partial adaptation and elaboration of the five-dimensional model by Elder (2002), who had synthesized the conclusions of research on epistemic beliefs in science and postulated seven key points representing the nature of knowledge and understanding (e.g. the role of evidence and experiments).

Table 1
Description of dimensions, number of EBS items, and item examples

Dimension		**Description**	**Number of items**	**Item example**
Nature of knowledge	Development	Science (as a scientific discipline) is unchanging, static (theory does not change) x changes based on new data and evidence (theory changes).	6	#16 *New discoveries can change what scientists think is true*
	Certainty	In science, there is one correct answer x more correct answers to complex problems	6	#6 *All questions in science have one right answer*
Nature of knowing	Source	Belief that scientific knowledge springs from external authorities.	5	#1 *Everybody has to believe what scientists say*
	Justification	Belief in how individuals justify knowledge (in the tool and in the context of the role of experiments for statement evaluation)	9	#24 *Good answers are based on evidence from many different experiments*

The EBS contains 26 items (statements), to which the respondent expresses the degree of agreement through a 6-point Likert scale (1 = strongly disagree to 6 = strongly agree). The EBS was used in its original or adapted form in different countries for diverse age groups[5]. In the section on data interpretation, we discuss the findings of this study in relation to foreign research on university students.

4.3 Translation of the EBS

When translating the EBS, we followed the protocol recommended in cross-cultural research. Cross-cultural validation involves determining whether a tool that originated in a particular sociocultural context is meaningfully applicable and therefore equivalent for use in another sociocultural framework (Huang & Wong, 2014). Klassen et al. (2009) presented three steps: (1) translation and back translation into the original language (translation-back translation process), (2) involvement of bilingual or multilingual individuals who can be considered as experts in the relevant research domain (so that the translation is correct not only linguistically but also valid in terms of its substance), (3) evaluation of whether changes in translations (change of sentence structure and wording) reflect only the consideration of sociocultural and linguistic differences and do not distort the original meaning of the research tool (meaning-based approach). In the first step, we addressed two academics (ISCED 8) with language level C2 (postgraduate study of English). The back translation was again done by two academics (ISCED 7 and 8, both with language level C2). In the second step, we contacted a bilingual translator (ISCED 7) who also teaches at secondary school and is an expert in the field of educational psychology. This expert was also present in the final third step, during which the construct of epistemic beliefs was discussed with an expert (associate professor) engaged in education of foreigners, plurilingualism, Czech language didactics, onomastics, and phraseology. The EBS was piloted (March 2021) on a sample of eight primary school teachers (seven women, one man) and five kindergarten teachers (four women, one man) through a cognitive interview (Karabenick et al., 2007):

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5 For example: a 4-point Likert scale with 29 items for 10th graders in Germany (Kampa et al., 2016); 22 items for 11th and 12th graders in Namibia (Shaakumeni, 2019); merging two scales (C + D) into one in research with German university students (Lang et al., 2020).

1. Understanding the item: asking the participant how they interpret the item.
2. Item-related information: asking the participant to describe the experience, thoughts, and feelings associated with the item and with the concepts in the item.
3. Answer choice: asking the participant to justify the answer they would choose.

4.4 Research sample

The research sample (N = 427) was obtained by convenience sampling and included students from six Czech universities (N_{UJEP} = 79, N_{UK} = 127, N_{MUNI} = 107, N_{UO} = 34, N_{TUL} = 15, N_{UPOL} = 65). In terms of gender, it was, due to the monitored fields, an unbalanced sample with nine men and 418 women. In terms of study focus, 149 respondents studied kindergarten teacher training and 278 studied primary school teacher training. Within the sample, 163 respondents studied in a full-time study program and 264 were in a combined study program. Students of all years of study were included. An idea of the length of teaching experience of the respondents can be obtained from Table 2. The age of the respondents was not monitored. The main data collection was carried out online (Google Forms) in May 2021 during the COVID-19 pandemic[6]. The questionnaire was sent to students by contact persons from the guaranteeing departments of the respective universities.

Table 2
Length of respondents' teaching experience

Length of teaching experience	*N*
none	122
less than a year	118
1–3 years	97
4–6 years	56
7–9 years	26
more than 10 years	8

[6] Pursuant to § 184a of the amendment to the Education Act No. 561/2004 Coll. (Novela školského zákona č. 561/2004Sb, 2004) online education is given by a government decree de lege for all the schools concerned in connection with the applicable government decree. The methodological recommendation of the Ministry of Education, Youth and Sports (information on the operation of schools from April 12, 2021) recommends that schools do not expose students to stress after their return to school and that they pay particular attention to revising the curriculum in the first weeks and months (MŠMT, 2021).

4.5 Data analysis

As the factor structure of the EBS is known from foreign research, a confirmatory factor analysis (CFA) was performed on data from the Czech Republic. Within the CFA, the model fit indices recommended by Brown (2015) were monitored. The following is an overview in which the limit value for a good model fit, as recommended by Hu and Bentler (1999), is always in brackets: Comparative Fit Index (CFI, .95), Tucker-Levis Index (TLI, 0.95), Root-Mean-Square-Error of Approximation (RMSEA, $< .06$) and Standardized Root Mean Squared Residual (SRMR, $< .08$). We did not monitor χ^2, the values of which are significantly influenced by the number of respondents. The reliability of the individual subscales of the instrument was determined by calculating the Cronbach's alpha coefficient, both for the original form of the instrument and for the new validated model. The values of the alternative reliability coefficient, McDonald's ω, which is based on factor loadings, are also presented for this model (Hayes & Coutts, 2020). Data analysis was performed in IBM SPSS Statistics 27 and IBM SPSS Amos 27 Graphics.

5. Results

The CFA results based on the factor structure of the complete EBS demonstrate an insufficient model fit (CFI = .876, TLI = .863, RMSEA = .075, SRMR = .072) and thus the impossibility of its use in such a form (see Figure 1).

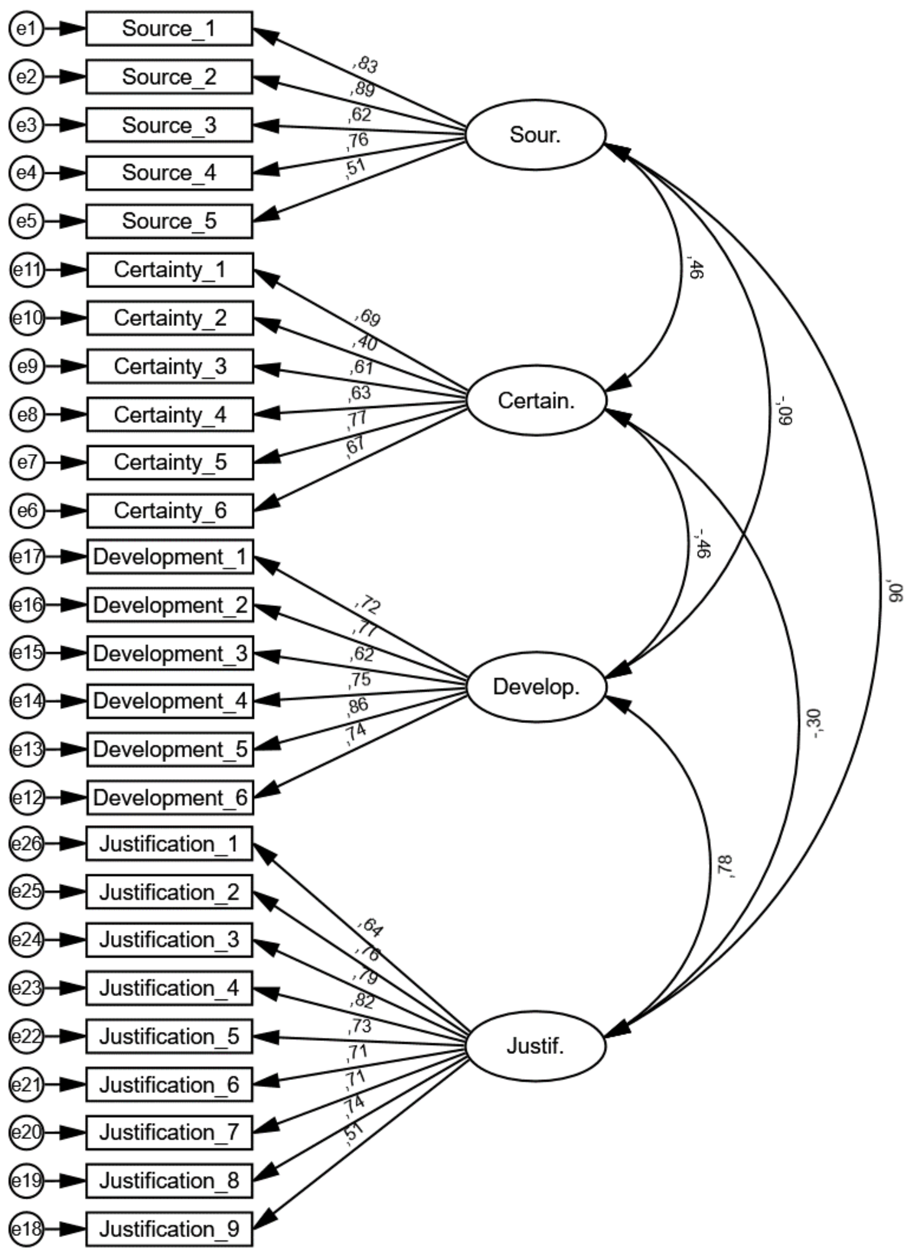

Figure 1
CFA for original version of EBS

Therefore, items with loadings lower than .70 by at least .05 were removed from the model; this limit is considered to be excellent by DiStefano and Hess (2005). The covariance between errors within the same factor was also taken into account when adjusting the model. We took this step primarily to maintain items that are close to each other and thus to maintain a sufficient number of items (items with marked covariance in errors can be redundant to each other; Harrington, 2008). The resulting model can be found in Figure 2.

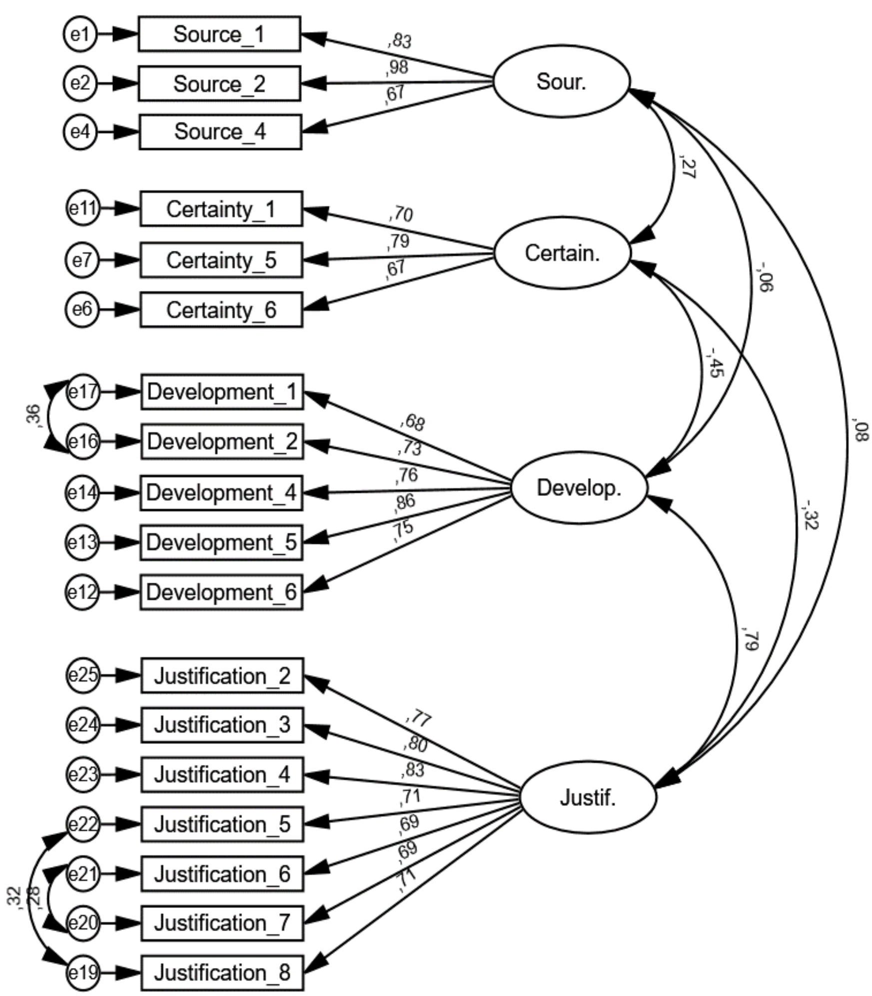

Figure 2
CFA for the final version of EBS

The model fit of the presented model is as follows: CFI = .955, TLI = .950, RMSEA = .060, SRMR = .052. These results reflect a good model fit and are fully acceptable (see Hu & Bentler, 1999). Reliability was determined both for the original form of the EBS and for the newly created model. Table 4 shows that the reliability values reached completely acceptable levels. We also present the values for the Czech version of the whole EBS, as mere high reliability cannot be the only prerequisite for use in research.

Table 4
Reliability values (Cronbach's α, McDonald's ω)

Scale	**α (CZ, complete EBS)**	**α (CZ, new model)**	**ω (CZ, new model)**
Source	.85	.85	.86
Certainty	.77	.76	.76
Development	.88	.88	.89
Justification	.90	.90	.90

In the following analyses, the data obtained in the final form of the EBS (Appendix 1) were used. Table 5 shows the results of the descriptive statistics for the four monitored dimensions. The respondents reached the highest values in the justification dimension and the lowest values in the certainty dimension.

Table 5
Descriptive statistics

Scale	**Mean**	**Std. Dev.**	**Median**
Source	3.56	.93	4
Certainty	2.02	.73	2
Development	4.94	.83	5
Justification	5.03	.74	5

Correlation among the individual subscales is evident from Table 6.

Table 6
Correlation among individual subscales (Pearson correlation). Two correlation measurements from the original study by Conley et al. (2004) of fifth graders are shown in parentheses.

	Source	**Certainty**	**Development**
Source			
Certainty	**.29**(**.76**; **.69**)		
Development	−.09(**.29**; **.36**)	**−.37 (.26; .28)**	
Justification	.05 (.12; .17)	**−.26** (.17; .17)	**.66 (.47; .50)**

Note: Bold values are significant at the $p < .01$ significance level. Underlined values are significant at the $p < .05$ significance level.

The individual universities were not compared for several reasons. The numbers of respondents from individual universities were significantly different and furthermore our ambition was not to compare the universities. Another reason was the relative uniformity of the training of kindergarten and primary school teachers; existing differences were unlikely to lead to different results.

6. Data interpretation and discussion

This study aimed to identify and confirm, on a sample of university students of primary school and kindergarten teacher training, the factor structure of the adopted foreign EBS (Conley et al., 2004), which is the most frequently used quantitative self-report questionnaire for determining the epistemic beliefs of individuals in the domain of science (Lee et al., 2021). The original form of EBS is divided into four factors (source, certainty, development, and justification). The same structure of the instrument was proved in the Czech conditions, although the final form of the instrument is shorter than the original. Items that the CFA identified as problematic were excluded from the final Czech version of the instrument due to the low loading of a specific factor. The resulting model consists of these items (number of items retained / number of original items): source 3/5, certainty 3/6, development 5/6, and justification 7/9.

We further relate the results to foreign studies, presented in Table 7. The internal consistency of individual subscales (α) in the new model acquired good values (source .85, certainty .76, development .88, justification .90); this is not the rule in foreign studies (below the value $\alpha < .70$ for the factor of source: Bahçivan, 2014; Liang & Tsai, 2010; for the factor of certainty: Bahçivan, 2014; for the factor of development: Demirbağ & Bahçivan, 2021; Yang et al., 2013; and for the factor of justification: Yang et al., 2013).

Czech students of primary school and kindergarten teacher training tend to trust external authorities as sources of knowledge (source mean 3.56), which is in line with other foreign studies (Bahçivan, 2014; Liang & Tsai, 2010; Yang et al., 2019). We found only one study in which respondents tended to disagree that knowledge came from external authorities (Yang et al., 2013). At the same time, Czech students tend to perceive knowledge more as an uncertain (evolving) construct with the existence of a plurality of knowledge schemes (there is not necessarily one correct answer to scientific questions, nor one most appropriate way to get the right answer; certainty mean 2.02). This result is at variance with foreign studies (Bahçivan, 2014; Liang & Tsai, 2010; Yang et al., 2019). The results of this study are in agreement with Yang et al. (2013). Although the averages of the values obtained from these factors are to some extent contradictory (source agreement, certainty disagreement), the factors correlate significantly with each other (.29). This can be interpreted as follows: with the growing belief that the originator of knowledge is an external authority (not oneself), the probability increases that the person concerned will perceive knowledge as a stable and unchanging construct (existence of one correct answer). This finding is consistent with the findings of Yang et al. (2013) who found statistically significant correlations between the authority knowledge factor of the modified EQ and the certain knowledge (.52) and simple knowledge (.43) factors of the EBS.

The development factor is in opposition to the certainty factor, which is also supported by the significant negative correlations (−.37) in this study. Development expresses that knowledge is a variable construct (e.g. in the context of time and new discoveries). A statistically significant correlation value was found between the development factor of the EBS and the simple knowledge factor (−.47) of the modified EQ. A negative but not statistically significant correlation value was also found with the certain knowledge factor (−.12; Yang et al., 2013). Czech students expressed a relatively high value of consensus with this concept of knowledge (mean 4.94), similar to other foreign students (Bahçivan, 2014; Liang & Tsai, 2010; Yang et al., 2013, 2019).

The last factor, justification, refers to the way that knowledge is justified (in the EBS, this is narrowed down to the role of experimentation). A statistically significant correlation value was found between the justification factor of the EBS and the simple knowledge factor (−.63) of the modified EQ (Yang et al., 2013). Czech students rated the importance of experimentation for acquisition of scientific knowledge (mean 5.03) relatively positively, which is again in line with other foreign studies (Bahçivan, 2014; Liang & Tsai, 2010; Yang et al., 2013, 2019). This factor showed a significant negative correlation with the certainty factor (−.26), which can be interpreted as meaning that the more an individual is convinced that knowledge is certain (stable and unchanged), the less they will appreciate the role of experimentation in acquiring scientific knowledge. A statistically significant correlation between the justification factor of the EBS and the certainty and authority knowledge factors of the modified EQ tool was not found in Yang et al. (2013).

The factors of development and justification correlated significantly together (.66). Thus, there is a probability that the more an individual is convinced that knowledge is evolving, the more important the role of experimentation will be in acquiring scientific knowledge.

In the context of the correlations found between the individual dimensions of this study (including those cited above) and the original research of fifth graders (Conley et al., 2004), discrepancies are evident. Conley et al. (2004) revealed, in two measurements except for one case, a significant correlation between the individual dimensions at the $p < .05$ or $p < .01$ level. Proponents of dimensional models (as covered in the section "Models of Epistemic Beliefs") argue that epistemic beliefs are a (multi) dimensional construct and their development is nonlinear (one dimension may be more naive and another may be more sophisticated). It is possible to assume that fifth graders are less able than adult research participants to understand or appreciate the dimensions of potential change in ideas and theories in science (the development dimension) due to its demand for a higher degree of abstraction (#12 D: Some ideas in science today are different than what scientists used to think) including questioning claims from external authorities (source dimension) based on data and evidence through experimentation (justification dimension) (similar to Yang et al., 2013). However, in the justification dimension, significant correlations with the certainty and source dimensions are revealed in the study by Conley et al. (2004) when choosing a significance level of $p < .01$. It is possible that questions (#24 J: Good answers are based on evidence from many different experiments) related to the role of an experiment (justification dimension) are closer to younger students, as primary school students prefer first-hand experience when justifying knowledge (Sandoval & Cam, 2010).

Empirical research shows domain-specific differentiations. Barzilai and Weinstock (2015) state that in sciences built on an exact basis, knowledge is perceived as more certain, more objective, and less based on personal reasoning than in the soft sciences; for example, questioning (uncertainty) occurs sooner in the domain of history than that of biology. This is also supported by proponents of development models. Kuhn and Weinstock (2002) argued that the transition from objectivism to subjectivism would occur earlier in areas in which personal reasoning is on an inexpressible level (aesthetics) than in areas related to the objective judgments of the surrounding world and associated with principles of exact sciences (mathematics). We do not know any cross-sectional study that analyzes the correlates in the dimensions of the EBS tool across diverse age groups. Based on the literature cited above and the figure below (Table 7), we can conclude that epistemic beliefs increase with age (Pirttilä-Backman & Kajanne, 2001) and follow the educational path taken (Greene et al., 2008). We note, however, that cognitive maturation is not the only condition for development; Kienhues et al. (2016) directly stated that "epistemic change might occur quite rapidly and does not depend on cognitive maturation" (p. 319).

Table 7
Epistemic and Ontological Cognitive Development Model

	Ill-Structured Domains			
Age/Educational Level	**Position**	**SC**	**JA**	**PJ**
4–12	Realism	Strong	Strong	Strong
12–early college	Dogmatism or	Weak	Strong	Weak
	Skepticism	Weak	Weak	Strong
Middle to late college	Rationalism	Weak	Moderate	Moderate
Postundergradueate education	Rationalism	Weak	Moderate	Moderate
	Well-Structured Domains			
Age/Educational Level	**Position**	**SC**	**JA**	**PJ**
4–12	Realism	Strong	Strong	Strong
12–early college	Realism	Strong	Strong	Strong
Middle to late college	Dogmatism or	Weak	Strong	Weak
	Skepticism	Weak	Weak	Strong
Postundergradueate education	Rationalism	Weak	Moderate	Moderate

Note. SC = simple and certain knowledge dimension; JA = justification by authority dimension; PJ = personal justification dimension (Greene et al., 2008).

Table 8
Selection of studies in which the EBS was used on a sample of university students. Number of respondents, country of research, and main results in the context of reliability and mean scores (if accessible)

Study	**Respondents**	**State**	**Main results Reliability (mean scores)**
Bahçivan (2014)	310 pre-service science teachers	Turkey	S = 0.68 (3.73) C = 0.66 (3.78) D = 0.71 (3.87) J = 0.82 (4.02)
Demirbağ & Bahçivan (2021)	612 pre-service science teachers	Turkey	S = 0.78 C = 0.75 D = 0.69 J = 0.84
Liang & Tsai (2010)	407 college students	Taiwan	S = 0.69 (3.13) C = 0.76 (3.40) D = 0.82 (3.71) J = 0.77 (3.65)
Yang et al. (2013)	32 university students	Taiwan	S = 0.81 (2.45) C = 0.79 (2.65) D = 0.58 (4.42) J = 0.66 (4.23)
Yang, Bhagat & Cheng (2019)	59 Indian + 67 Taiwanese university science students	India, Taiwan	S = (3.25) C = (3.58) D = (4.29) J = (4.35)

Note: S = Source; C = Certainty; D = Development; J = Justification

In the interpretation of the results, it is necessary to take into account the sociocultural context. Structural differences (including failure to confirm the initial dimensionality of tools) are evident when implementing a tool outside English-speaking countries (Bråten & Strømsø, 2005; Ordoñez et al., 2009), in which case Hofstede's (1991) cultural dimensions theory can be used as a starting point for potential explanations of discrepancies in the field of epistemic beliefs. In a study of 15 countries with a minimum sample of 400 students of primary school teacher training in each country, Felbrich et al. (2012) concluded that individualistically oriented societies (United States, Germany, Switzerland, etc.) showed a higher tendency to perceive mathematical knowledge as a product of social processes open to discussion (mathematics as a dynamic process), compared to collectivist societies (Russia, Thailand), which perceived mathematical knowledge more as the acquisition of fixed sets of concepts and procedures (mathematics as a static science). A review of 106 studies (between 2004 and 2013) conducted by Yang (2016) in the context of epistemic beliefs and science education supported the existence of differences based on different sociocultural systems to the detriment of societies emphasizing collectivism and promoting conformity, which were connected with less sophisticated epistemic beliefs and higher difficulty in changing their epistemic views. A number of studies suggested that most teachers take a subjectivist position in the context of developmental epistemic models, and a minority an objectivist or criterialist position, both in Asia and in Euro-Atlantic countries (Cheng et al., 2009; Deng et al., 2014). Respondents to this study perceived scientific knowledge as a tentative, potentially evolving, and dynamic construct (rather, they refused to perceive scientific knowledge as a stable and certain construct) and appreciated the role of experimentation in acquiring scientific knowledge. Consistent with the studies by King and Kitchener (1994) and Kuhn (1991), it can be concluded that in the context of dimensional epistemic models, the respondents participating in this study are at a relatively sophisticated epistemic level (relatively high average values in the development and justification dimensions and conversely a low average value in the certainty dimension). At the same time, however, it should be noted that the respondents were more inclined to report that scientific knowledge springs from external authorities. According to some authors, this phenomenon indicates a rather less sophisticated level of epistemic beliefs (Conley et al., 2004; King & Kitchener, 1994; Kuhn, 1991); other authors question this interpretation based on the argument that people have relied on testimony and information from others for millennia (Chinn et al., 2011).

6.1 Research limits

In connection with the use of Likert scales in answering individual items, it is considered problematic to interpret the median values; within the bipolar dimensional concept, it has been argued that if an individual expresses their disagreement, it does not automatically mean that they express agreement and vice versa (Greene & Yu, 2014). In this study, for example, it may be a conviction of individuals that knowledge comes more from external authorities (source mean 3.56), which does not automatically mean that knowledge cannot come from dynamic activity of the individual (from themselves). In the intentions of the linear understanding of the sophistication of epistemic beliefs (objectivists – subjectivists – criterialists) it is problematic to interpret the answer to the item "Ideas in science sometimes change" (Conley et al., 2004, p. 203), because both subjectivists and criterialists will agree. This approach led some researchers to grasp the positions of objectivism and subjectivism not as bipolar positions, but as two dimensions (Peter et al., 2016), which in the case of the EBS is evident in the opposing dimensions of certainty and development. In the context of a theoretical background, Greene et al. (2008) pointed out that the nature of knowledge dimension (certainty and development) corresponds to personal ontology rather than personal epistemology. Schraw (2013) listed six methodological approaches (questionnaires, interviews, vignettes, essays, concept maps, and multi-dimensional scaling methods) that could be used to identify epistemic beliefs. Only one of these approaches was used in this study. It would be appropriate for the results of this study to triangulate (validate) with other approaches, even when considering the dangers of social desirability in the genesis of responses (Bartels & Magun-Jackson, 2009). As mentioned at the end of the previous section, the sociocultural context must be taken into account. The questionnaire was taken from a study that took place in the U.S. sociocultural environment. This environment differs significantly from the Czech environment in upbringing, education, and perception and intellectual understanding of the world, which are to some extent determined by culture and language (Hamamura et al., 2008). In this context, despite the rigorous methodological approach to the translation of individual items, it is possible that there was a semantic shift between the original and the translated version. It can be speculated that the interpretation of the meaning of individual items was strongly burdened by the context, e.g. Cam et al. (2012) attributed low values of internal consistency to cultural differences and weak translation.

An indisputable factor in most pedagogical research is the selection of a research sample. Despite our efforts and addressing all relevant universities, it was not possible to obtain all the relevant respondents. Therefore, we had to rely on convenience sampling.

The psychometric properties of quantitative self-report questionnaires continue to be discussed, as does the variability of empirical findings across studies and contexts (Greene et al., 2018).

6.2 Future directions

It was not the ambition of this study to create a specific series of recommendations for the educational reality; however, this is the direction that future research should take. In particular, we propose the search for links between epistemic beliefs and essential aspects of learning and teaching processes (academic achievement / performance, problem solving ability, argumentation, learning and teaching approaches, self-regulated learning, metacognition, and the proper use of research approaches, etc.). Specifically, for example, sophisticated epistemic beliefs of university students predict the quality of evaluations of contradictory scientific information, including the negative link between certainty and performance (Lang et al., 2021). At the same time, it is possible to research the strength of links between the dimensions of the EBS and other self-report questionnaires connected to related/similar disciplines (biology – Epistemic Beliefs in Biology – EBB questionnaire: Liang & Tsai, 2010; chemistry – Epistemological Beliefs Instrument towards Chemistry: Yildiran et al., 2011). Further research could also lead to a verification of the form of the EBS presented by us in other relevant demographic groups (e.g. students of exact sciences teacher training, or younger respondents, as the EBS was originally intended for 5th graders). It could also triangulate the results with other methodological procedures recommended in determining the epistemic beliefs of individuals.

Conclusion

The study presents the Czech form of the Epistemic Beliefs About Science self-report questionnaire, demonstrates its reliability, factor structure, and usability for the target group of university students of primary school teacher training and kindergarten teacher training. In the Czech environment, the EBS has a shorter form (18 items), but retains the same structure (source, certainty, development, and justification factors) as the original EBS.

To understand science, it is necessary to involve epistemic practices such as generating questions, suggesting procedures, collecting and interpreting data, generating claims and evidence, exposing conclusions to critical discussion, comparing ideas from alternative sources, analyzing contributions of others, and considering changes in ideas. There is a need to develop students' epistemic beliefs across ISCED levels by developing scientific arguments based on research processes and to provide students with many opportunities to defend and debate the results of their own research (Akkus et al., 2007). This approach is not only tied to the domain itself, nor relevant to work in this domain; it is a general cultivation of the human mind. As Scharrer et al. (2012) showed, lay people are more inclined to accept ostentatiously simple arguments than more complex ones, are more confident in evaluating this information, and are less inclined to seek expert help after reading simple arguments as opposed to more demanding ones. We believe that the development of epistemic beliefs is not only important in the context of learning and teaching, but also for the functioning of an individual in a modern democratic society.

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Appendix A

Epistemic Beliefs About Science. Original items and Czech translation

Number of the item and dimension	Original text of the EBS item (Conley et al., 2004, p. 202–203).	Czech translation
# 1 S*	Everybody has to believe what scientists say.	Každý musí věřit tomu, co vědci říkají.
# 2 S*	In science, you have to believe what the science books say about stuff.	Ve vědě musíš věřit tomu, co o tom říkají vědecké knihy.
# 3 S	Whatever the teacher says in science class is true.	Vše, co učitel v hodinách přírodovědy říká, je pravdivé.
# 4 S*	If you read something in a science book, you can be sure it's true.	Když čteš něco v knize o přírodovědě, můžeš si být jistý, že je to pravdivé.
# 5 S	Only scientists know for sure what is true in science.	Jenom vědci s jistotou ví, co je v přírodovědě pravdivé.
# 6 C*	All questions in science have one right answer.	Na všechny otázky v přírodovědě existuje jedna správná odpověď.
# 7 C	The most important part of doing science is coming up with the right answer.	Nejdůležitější součástí bádání v přírodovědě je přijít na správnou odpověď
# 8 C	Scientists pretty much know everything about science; there is not much more to know.	Vědci poměrně všechno vědí dobře o přírodovědě – již toho není více k objevení.
# 9 C	Scientific knowledge is always true.	Přírodovědná znalost je vždy pravdivá.
# 10 C*	Once scientists have a result from an experiment, that is the only answer.	Jakmile mají vědci výsledek z experimentu, je to jediná odpověď.
# 11 C*	Scientists always agree about what is true in science.	Vědci vždy souhlasí o tom, co je v přírodovědě pravdivé.
# 12 D*	Some ideas in science today are different than what scientists used to think.	Některé současné myšlenky o přírodovědě jsou odlišné od těch dřívějších (co si vědci mysleli v minulosti).
# 13 D*	The ideas in science books sometimes change.	Myšlenky v knihách o přírodovědě se někdy mění.
# 14 D	There are some questions that even scientists cannot answer.	Existují nějaké otázky, na které ani vědci nedokáží odpovědět.

# 15 D*	Ideas in science sometimes change.	Myšlenky v přírodovědě se někdy mění.
# 16 D*	New discoveries can change what scientists think is true.	Nové objevy mohou měnit to, co si vědci myslí, že je pravdivé.
# 17 D*	Sometimes scientists change their minds about what is true in science.	Vědci někdy mění své názory na to, co je v přírodovědě pravdivé.
# 18 J	Ideas about science experiments come from being curious and thinking about how things work.	Informace z přírodovědných experimentů bádání vycházejí z toho být zvědavý a uvažovat nad tím, jak věci fungují.
# 19 J*	In science, there can be more than one way for scientists to test their ideas.	V přírodovědě existuje pro vědce více, než jeden způsob, jak testovat své nápady
# 20 J *	One important part of science is doing experiments to come up with new ideas about how things work.	Jednou z důležitých součástí přírodovědy je dělat experimenty pro nalezení nových nápadů o tom, jak věci fungují.
# 21 J *	It is good to try experiments more than once to make sure of your findings.	Je dobré zkoušet experimenty více, než jednou, aby se zajistila správnost výsledků.
# 22 J *	Good ideas in science can come from anybody, not just from scientists.	Dobré nápady ve vědě mohou vzejít od kohokoliv, nikoliv pouze od vědců.
# 23 J *	A good way to know if something is true is to do an experiment.	Dobrý způsob, jak poznat v přírodovědě pravdu, je dělat experimenty
# 24 J *	Good answers are based on evidence from many different experiments.	Dobré odpovědi jsou založeny na důkazech z mnoha rozmanitých experimentů.
# 25 J *	Ideas in science can come from your own questions and experiments.	Nápady ve vědě mohou pocházet z tvých vlastních otázek a experimentů.
# 26 J	It is good to have an idea before you start an experiment.	Je dobré mít názor před tím, než započneš experiment.

Note: S = Source, C = Certainty, D = Development, J = Justification; * Items resulting from the analysis, recommended for the Czech version of the EBS.