Development and preliminary evaluation of a brief epistemic beliefs instrument

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Keywords

Article Info

Abstract

This study was conducted to develop and validate a brief instrument to measure the epistemic beliefs of Singaporean polytechnic students. The Brief Epistemic Beliefs Instrument (BEBI) comprised 12 items, organized in four subscales: Malleable Ability (MA), Need for Effort (NE), Fallible Authority (FA) and Evolving Knowledge (EK). The instrument was completed by both groups of students within the research. An Exploratory Factor Analysis (EFA) was used to explore the latent structure of the BEBI on data from polytechnic A, while a Confirmatory Factor Analysis (CFA) was used on data from polytechnic B. While the EFA indicated a three-factor structure for the instrument (in which the factor Fallible Authority – FA – failed to emerge), the CFA confirmed the original four-factor model proposed. Cronbach's alphas also indicated moderately high levels of internal consistency for the four subscales. These results suggested the internal structure of the instrument to be sound for use within the Singapore population cohort, although the factor structure of the instrument did appear to differ somewhat across samples.

Introduction

In 2014, the Singapore Ministry of Education (MOE) published its 21st Century Competencies (21CC) Framework, which stipulated the need for students to develop specific competencies to meet the challenges and opportunities brought by ongoing demographic shifts and technological advances (MOE, 2014). In response to the release of this framework, the Singapore education system has been moving toward the use of pedagogies which reflect constructivist, rather than more traditional didactic, teaching approaches (MOE, 2008, 2011) Research has indicated, however, that constructivist approaches are likely to benefit some students more than others. In particular, it has been found that students with sophisticated beliefs about knowledge and learning (i.e., epistemic beliefs) may profit more from constructivist learning environments than do others. As such, the ability to assess these beliefs may be important for predicting which students will be able to benefit more from constructivist learning environments.

The term 'epistemic' or 'personal epistemological' beliefs are used within the research literature to refer to the beliefs that students hold about the source, certainty, and organisation of knowledge (Schommer, 1994). These beliefs have been found to relate to thinking, problem-solving and reasoning in important ways (Schraw et al., 2002). Schommer (1990) proposed that epistemic beliefs comprised several more or less independent dimensions. Schommer proposed five sub-constructs of epistemic beliefs: Simple Knowledge, Certain Knowledge, Omniscient Authority, Innate Ability, and Quick Learning. Simple Knowledge referred to a belief that knowledge is simple rather than complex. Omniscient Authority referred to a belief that knowledge is handed down by authority rather than being derived from reason (such as whether parents should be seen as 'always right'). Innate Ability referred to a belief that the ability to learn is innate rather than acquired. Certain Knowledge referred to a belief that knowledge is not tentative, as opposed to the belief that knowledge can change in light of new evidence. Quick Learning referred to a belief that learning occurs quickly or not at all. While Schommer's conceptualisation has attracted some empirical support within the literature, others have suggested that not all five constructs will be relevant in all populations, particularly across cultures (Chan & Elliot, 2000).

Literature review

Epistemic beliefs and learning processes

Epistemic beliefs have been found in numerous studies to affect students' learning processes. For example, empirical research has suggested that beliefs in quick learning prompt oversimplified conclusions, while beliefs in certain knowledge prompt inappropriately absolute conclusions (Schommer, 1990). Further studies have indicated that epistemic beliefs can affect students' levels of engagement in learning, persistence with difficult tasks, comprehension of written work, and coping with ill-structured problems (Schommer, 1994). These attributes relate to higher learning outcomes and are critical to learners' success as societies become more technologically advanced.

Several researchers have also suggested that epistemic beliefs may be an important factor in determining which students will benefit from a shift to constructivist learning environments. Magolda (1992) suggested that a pedagogy that promotes complex thinking must take account of students' personal epistemologies or epistemic beliefs and that students learned better when the learning process matched their ways of knowing. Aligned with this proposition, students with epistemic beliefs based on scientific evidence have been reported from empirical studies to prefer constructivist-oriented learning environments (Tsai, 2000). Windschitl and Andre (1998) similarly reported that students with "simple, quick and certain knowledge" beliefs can find constructivist learning environments frustrating, because there are often no 'right' answers to their questions, and learning will often not be as structured as in more objectivist learning environments. Students who believe that knowledge is fixed (i.e., does not change in response to new findings), certain (i.e., is black and white) and resides in omniscient authority (i.e., is handed down by authority) have also been found to take a more passive role in their learning (Schraw et al., 1995). The latter tendency would also make constructivist environments, in which students are encouraged to take an active role in constructing their own learning experiences and knowledge acquisition, more of a challenge for these students.

Instruments to measure epistemic beliefs

Various instruments have appeared in the literature to measure epistemic beliefs. Two popular instruments are the Epistemological Questionnaire (EQ) devised by Schommer (1990), and the Epistemic Beliefs Inventory (EBI) developed by Bendixen et al. (1998). This section presents a review of these two instruments, as well as the Epistemological Beliefs Survey (EBS). Some adaptations of the EQ for use in Asian contexts are also discussed. In the context of this paper, the terms instrument and questionnaire are used interchangeably.

Epistemological Questionnaire (EQ). Schommer's (1990) EQ is a 63-item survey designed to measure five constructs associated with epistemic beliefs: Simple Knowledge (e.g., "Things are simpler than most professors would have you believe"), Omniscient Authority (e.g., "How much a person gets out of school mostly depends on the quality of the teacher"), Certain Knowledge (e.g., "A good teacher's job is to keep his students from wandering from the right track"), Innate Ability (e.g., "Genius is 10% ability and 90% hard work"), and Quick Learning (e.g., "If you are ever going to be able to understand something, it will make sense to you the first time you hear it"). For each statement, respondents are asked to fill in a circle on an answer sheet, indicating the extent to which they agree with the statement on a five-point Likert scale (1 for Strongly Disagree to 5 for Strongly Agree).

In the initial study in which the instrument was developed (Schommer, 1990), this 63-item questionnaire was completed by 1182 American high school students, of whom 68.2% were

white Americans, 21.5% were African Americans, 5.5% were Asian Americans, 3.4% were Hispanic Americans, and 1.5% were Native Americans. An exploratory factor analysis (EFA) of the scores extracted four factors, pointing to the fact that "epistemological beliefs may be characterised as a set of more or less independent beliefs" (Schommer, 1990, p. 500). The construct of Omniscient Authority was not, however, extracted in this study. Subsequent results published by Schommer (1993) also indicated internal consistencies for the instrument factors to range from 0.51 to 0.78.

Since Schommer's original (1990) paper appeared, however, many researchers who have used the EQ to measure epistemic beliefs have been unable to replicate the factor structure results reported in this study (DeBacker et al., 2008; Schraw et al., 2002). Debacker et al., for example, found low internal consistencies of the EQ item subsets, ranging from 0.11 to 0.44. In their research, the EQ was administered to 935 mainly female (75%) and white (68%) college students. Ages of the respondents ranged from 18-45 years (Mean=20). In addition to the low internal consistencies obtained, according to the researchers, "an EFA of neither item subsets nor individual items produced a factor solution that resembled Schommer's (1990)" (p. 301). While confirmatory factor analysis (CFA) fit indices showed good fit, this was performed on only a six-item subset from the instrument, which represented only two dimensions of the original five proposed.

Schraw et al. (2002) reported factor internal consistencies between 0.53 to 0.79 for the EQ. In their research, Schraw et al. (2002) administered the 63-item EQ to 160 undergraduates in a large Mid-western university in the USA. Respondents were aged between 18 and 46 years (Mean=21.36, SD=4.73), with 12% of respondents being older than 22 years. The factor analysis results did not yield the five hypothesised factors for the EQ without a priori groupings. No CFAs were used in this survey. Given these results, it appears that while the Schommer EQ remains a popular instrument for measuring students' epistemic beliefs, its internal structure has not been confirmed consistently since the original paper in which the instrument was first published.

Epistemic Belief Inventory (EBI). The Bendixen et al. (1998) EBI is a 32-item survey designed to measure the five constructs specified by Schommer (1990), using a shorter (32-item) instrument than the EQ (Schraw et al., 2002). The items within the EBI are similar, but not identical, to the original Schommer EQ items: Simple Knowledge (e.g., "The best ideas are often the most simple"); Omniscient Authority (e.g., "Parents should teach their children all there is to know about life"); Certain Knowledge (e.g., "I like teachers who present several competing theories and let their students decide which is best"); Innate Ability (e.g., "Some people will never be smart no matter how hard they work"); and Quick Learning (e.g., "Students who learn things quickly are the most successful").

In the original study in which the EBI was validated (Schraw et al., 2002), 160 undergraduates of a Midwestern university in the USA completed the instrument. Respondents were asked to rate their agreement with each statement on a five-point Likert scale. Factor analysis of the data yielded the five epistemic belief dimensions, including Omniscient Authority, but with a reduced number of items (three per factor). Furthermore, Cronbach's alphas for each of the factors obtained ranged from 0.58 to 0.68, indicating low internal consistencies for each individual factor. This might reflect the number of items eventually included in each one.

In subsequent research carried out by DeBacker et al. (2008), further problems were identified in the psychometric properties of the EBI. In this research, the instrument was administered to two samples. Sample 1 comprised of 417 college students. The mean age was 22 years, and respondents were mostly female (94%) and white (67%). Sample 2 comprised 378 university undergraduates. The mean age of the sample was 20 years, and again, the sample was mostly female (78%) and white (80%). CFAs were applied to the data from both samples. Fit indices obtained in these analyses were somewhat mixed, with some (e.g., the Root Mean Squared Error of Approximation or RMSEA) indicating adequate fit (0.069 and 0.060 for samples 1 and 2, respectively). Others, however (i.e., the Comparative Fit Index, CFI; the Goodness of Fit Index, or GFI; and the Adjusted Goodness of Fit Index, or AGFI) fell well below suggested cut-off levels in both samples (.79, .83, and .80, and .83, .85, and .83, respectively). Internal consistencies were reported to range from 0.47 to 0.62 for Sample 1 and from 0.50 to 0.68 for Sample 2. Some loadings from the CFA also fell below 0.35, suggesting that these items were not strong indicators of the hypothesised latent structure.

Epistemic Beliefs Survey (EBS). The EBS is an 80-item self-report instrument developed by Wood and Kardash (2002) to measure the same five constructs as Schommer's (1990) EQ. The items used within the EBS are again similar, but not identical, to the original Schommer EQ items. These are designed to measure the factors of Simple Knowledge (e.g., "I like information to be presented in a straightforward fashion; I don't like having to read between the lines"); Omniscient Authority (e.g., "Even advice from experts should be questioned"); Certain Knowledge (e.g., "The only thing that is certain is uncertainty itself"); Innate Ability (e.g., "The really smart students don't have to work hard to do well in school"); and Quick Learning (e.g., "If something can be learned, it will be learned immediately").

The EBS combines the items of EQ and an instrument developed by Jehng et al. (1993), using a five-point Likert scale. In the initial study to evaluate the EBS by Wood and Kardash (2002), 793 students completed the instrument. Of this group, 32.7% were males, 65.4% were females, and the remaining 1.9% were of unknown gender. Ages of respondents ranged from 17 to 52 years, with a mean of 22.35 years. Five factors were extracted in the analysis of these scores: Speed of Knowledge Acquisition (8 items), Structure of Knowledge (11 items), Knowledge Construction and Modification (11 items), Characteristics of Successful Students (5 items), and Attainability of Objective Truth (3 items). Internal consistencies of 0.74, 0.72, 0.66, 0.58 and 0.54 were found for these components of the instruments (respectively).

In a later study, Debacker et al. (2008) reported internal consistencies for the EBS of 0.50 to 0.73, comparable to

those reported by Wood and Kardash (1993). Some factor loadings in the latter study were below 0.35, however, indicating these to be weak indicators of the hypothesised latent factors. In this research, two samples were used. Sample 1 included a sample size of 380. Respondents were mostly females (75%) and white (71%). The mean age of this sample was 24 years. In Sample 2, the sample size was 415. Respondents were again mostly female (73%) and white (72%). The mean age of this sample was 25 years. CFAs were applied to the two samples. RMSEA values were reported to be .050 and .052, respectively, which indicated a reasonably good model fit. However, the CFI, GFI, and AGFI were below cut-off values for good fit (.90, .85, and .83, for Sample 1, and .88, .85, and .83 for Sample 2). As such, these results offered only mixed support for the internal structure of the EBS.

Furthermore, in contrast to the high internal consistency results obtained by Debacker et al. (2008), Schommer-Aikins and Easter (2006) reported relatively low internal consistency for the EBS of between 0.23 to 0.76. In the latter study, the EBS was administered to 107 college juniors and seniors. Both genders were represented (48 males and 57 females). Respondents represented diverse ethnicities and reported a mean age of 23.44 years (SD=3.08). Based on their results, Schommer-Aikins and Easter concluded that the internal structure of the EBS was variable across samples.

Adaptations of the EQ for the Asian context. Over the years, epistemic beliefs researchers have carried out studies across many countries outside North America. Many of these have used Schommer's EQ or an adapted version of the instrument. Examples of such adaptations include those developed by Chan and Elliot (2000) and Youn (2000). In their rationale for developing a culture-specific version of the EQ, Chan and Elliot (2000) noted that the factor structures obtained in studies across countries had not replicated those reported by Schommer (1990). They attributed this to the cultural differences of the respondents, which would prompt varied interpretations of the items (Chan & Elliot, 2004). Youn (2000), in his rationale for developing a more culture-specific version of the EQ, argued similarly that "students' beliefs are shaped by the culture or situation around them" (Youn, 2000, p. 102).

Chan and Elliot (2000) suggested a 30-item adaptation of the EQ for the Asian context. In their research, 352 final year students at the Hong Kong Institute of Education were surveyed. The respondents were aged between 20 and 26 years, with 25% males, 66% females and the rest of the unknown gender. Results confirmed that the four factors of the original EQ could be retained (i.e., Innate Ability, Learning Effort, Authority, and Certain Knowledge). Internal consistencies were reported to range from 0.6 to 0.7.

Research carried out by others such as Chai et al. (2010) and Lee et al. (2013), however, failed to completely replicate Chan and Elliot's (2000) results. For example, only 16 items were retained in Chai et al.'s (2010) study, and 18 were retained in Lee et al.'s (2013) study. Chai et al.'s (2010) study included 445 undergraduate students from a Chinese university. Respondents were represented by 36% males and 64% females, with ages ranging from 19-23 years. The

modified instrument used in this study was a 29-item General Epistemological Beliefs Scale (GEB) which was adapted from Chan and Elliot's (2004) 30-item scale. Seven of the 29 items were removed by Chai et al. (2010) because of low loadings. The 22-item dataset was then analysed using a CFA. Based on this analysis, six items further items were removed, resulting in a 16-item scale with internal consistencies between 0.58 and 0.80 for each of the four subscales. CFAs applied to the reduced 16-item scale produced good model fits (i.e., GFI = .94, TLI = .94, CFI = .95, RMSEA = .043, SRMR = .049).

Lee et al. (2013) also administered a modified version of Chan and Elliot's instrument to 1008 junior secondary school teachers from three Chinese cities. The sample consisted of 258 males (26%) and 746 females (74%). The sample was randomly split into two samples, one used for EFA and the other for CFA. Again because of low loadings, only 18 of the original 30 items were retained. An EFA on the first sample resulted in the retention of 19 items. The CFA on the second sample saw another item excluded, resulting in an 18-item instrument. The CFA on the retained 18 items, however, showed good fit indices (i.e., RMSEA = 0.087, and NFI, CFI, and RFI all > 0.9). Internal consistencies of the subscales were also reported to range from 0.79 to 0.93. Based on these results, while the full version of Chan and Elliot's epistemic beliefs instrument has not consistently been supported, reduced versions of this instrument have received empirical support across multiple studies.

Rationale and aims for the present research

Students' epistemic beliefs are a potentially important construct in education because they predict many aspects of students' learning processes. However, as noted above, there have been problems in the measurement of students' epistemic beliefs using current instruments, which could impede research and practice in Singapore within this area. In particular, much of the research on each instrument has been conducted in a Western context. When these instruments have been used in non-Western counties, the original validation results were often not replicated (Hofer, 2008). This has been attributed in part to the sociocultural contexts of the studies that were conducted (Chan & Elliot, 2000).

The aim of the present study was to develop a brief instrument to measure epistemic beliefs that would be suitable for use in the Singapore context. Given the results obtained by Chan and Elliot (2000), the Brief Epistemic Beliefs Instrument (BEBI) developed in this study focused only on four epistemic belief constructs (Innate Ability; Omniscient Authority; Learning Effort; and Certainty of Knowledge). Items were worded to overcome any English language issues, given the multicultural nature of Singapore as a country. While Standard Singapore English (SSE) is the medium used in schools, Singapore Colloquial English ('Singlish') is also common among students. Care was therefore taken to ensure that the words and sentences used in the survey would be unambiguous in either standard English or 'Singlish'. Item formats were also altered to a statement-based, bipolar scale format. These scales have been found

to reduce acquiescence bias and produce better model fits than Likert scales (Friborg et al., 2006). Seven-point scales have also been found to be more reliable and consistent than Likert-based scales (Wirtz & Lee, 2003). In addition, due to the level of variability anticipated in responses to the questions posed, a seven-point scale was used.

This research was approved by the Human Ethics office of the University of Western Australia (Approval Reference: RA/4/1/8141). Participants were duly informed regarding the anonymous and voluntary nature of the participation.

Method

Participants

Participants were students from two polytechnics, A and B, in Singapore. The sample from polytechnic A was drawn from the School of Information (SOI), while that polytechnic B sample was drawn from Information Technology and Business schools. In all, 421 students from polytechnic A and 271 students from polytechnic B responded to the survey. Following data screening to remove partially completed surveys and instances of clearly disengaged responses (i.e., where the respondent put the same response for all questions), the number from polytechnic A was 350 (83.1%), and from polytechnic B was 205 (75.6%). There were 156 (44.6%) males and 187 (53.4%) females from polytechnic A (7, or 2.0%, did not report their gender). For polytechnic B, there were 93 (45.4%) males and 110 (53.6%) females (2, or 1.0% did not report their gender in this sample). The ages of the respondents ranged between 16 and 25 years, with a mean of 18.0 years (SD=1.58) from polytechnic A and a mean of 18.84 years (SD=1.36) from polytechnic B. All participants were Asians, with the majority being Singaporeans (89.3% for polytechnic A and 91.2% for polytechnic B). The ethnic groups were Chinese, Malay and Indian: 58.2%, 24.5%, and 12.1% (respectively) from polytechnic A, and 83.9%, 9.3% and 3.9% (respectively) from polytechnic B.

Instrument

The Brief Epistemic Beliefs Instrument (BEBI) created in this research includes 12 items, to which students respond using a 7-point bipolar statement rating scale. The BEBI was designed to include four subscales, each with three items, to measure four constructs of epistemic beliefs: Malleable Ability (MA), which represents the opposite of innate ability; Need for Effort (NE), which represents the opposite of Learning Effort (i.e., representing beliefs about the need to invest effort in learning, as opposed to the belief that learning will only be successful if it is easy and effortless); Fallible Authority (FA), representing the opposite of Omniscient Authority; and Evolving Knowledge (EK), representing the opposite to Certain Knowledge. A list of all BEBI instrument statements and their subscales can be found in Table 1. Items were scored from 1-7, with higher scores indicating higher levels of the attribute indicated in the subscale title.

Procedure

Students were invited to participate in the survey at the end of the school day in the first week of the academic year. They were encouraged to complete the survey in the classroom and in one sitting to avoid possible abandonment, a likely scenario when students are interrupted for other tasks. To ensure that all participating classes had the opportunity to complete the survey, however, the survey was left open for up to two weeks. As the students did the survey at the end of the school day, no instructors were present. In addition, no special incentives were offered to respondents to participate.

Prior to the actual survey class session, a time trial was conducted with a small group (n=20 students) from polytechnic A, who did not then participate in the final study. This was done to determine how long the students would take to complete the survey. The time trial indicated that all respondents were able to complete the survey within 15 minutes, which was considered ideal, given that a longer survey could produce fatigue and attendant loss of data quality.

Table 1. Item statements in the BEBI

Dimension	Item Label	Low scoring statement (scored 1 at endpoint)	High scoring statement (scored 7 at endpoint)
Malleable Ability (MA)	BEBI_MA1	How smart you are is fixed at birth.	You can make yourself smarter in life.
	BEBI_MA2	A person can be taught to learn well in any subject.	People are born with the ability to do certain things and not others.
	BEBI_MA3	Some will never have the ability to learn well in certain subjects because learning is innate.	One's ability to do things is not limited at birth.
Need for Effort (NE)	BEBI_NE1	You can generally do well just by depending on others.	The amount you learn depends on your own efforts.
	BEBI_NE2	There are shortcuts to excel in your exams.	You need to study really hard to excel in your exams.
	BEBI_NE3	No matter how hard you try, you may not understand certain concepts.	Understanding concepts requires lots of effort.
Fallible Authority (FA)	BEBI_FA1	The authorities are always correct.	The authorities are not always correct.
	BEBI_FA2	Parents have absolute authority and we should always listen to them.	It is alright not to listen to our parents all the time.
	BEBI_FA3	People who question authority should be silenced.	People have the right to question authority under some circumstances.
Evolving Knowledge (EK)	BEBI_EK1	When disagreements arise between two persons, one of them must be right.	When disagreements arise between two persons, there is no certainty that either person is right or wrong.
	BEBI_EK2	Scientific knowledge is factual and does not change.	Scientific knowledge can change over time.
	BEBI_EK3	Only one teaching method is necessary for the acquisition of specific knowledge.	Teaching methods should differ for different types of knowledge.

Results

To evaluate the internal structure of the BEBI, both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) methods were used. To provide a preliminary assessment internal structure, an EFA was first conducted on data from the 350 polytechnics A participants. A CFA was then conducted to cross-validate the findings of the EFA using data from the 205 polytechnic B participants. All procedures associated with the EFA were conducted using IBM SPSS V25. All procedures associated with the CFA were conducted using LISREL V8.80.

Exploratory factor analysis

The EFA on polytechnic A participants' BEBI scores (n = 350) was performed using a Maximum Likelihood (ML) extraction, as recommended by various authors in the field (e.g., Costello & Osbourne, 2005). Given that the factors were expected to correlate, the factors extracted were rotated to an approximate simple structure using the Direct Oblimin method. Three alternative sources of information were considered in determining the number of factors to retain: Kaiser's eigenvalues greater than one criterion; the Cattell scree plot; and a parallel analysis of obtained eigenvalues.

All three sources were considered to reduce the possibility of over- or under-extracting factors from the 12-item set.

Prior to conducting the EFA, the data were screened to ensure compliance with all relevant EFA assumptions. Skewness and kurtosis coefficients indicated no significant departures from normality in the item distributions, based on Kline's (2005) criteria (values below $|3.0|$ for skewness and below $|8.0|$ for kurtosis). Visual examinations of bivariate scatterplots indicated that the relationships between all item score pairs were linear. Using standard (z) scores, no univariate outliers were identified (all z-scores $\leq |3.0|$), and Mahalanobis distance $x2$ values suggested no significant multivariate outliers at the 0.001 level. Indices of factorability (i.e., the Kaiser-Meyer-Olkin, or KMO, test, and Bartlett's test of sphericity) also indicated that the use of EFA was suitable for use with this score set. With a high case to item ratio of 29.17, the sample used was large enough to yield reliable estimates of correlations among the variables.

The EFA on the data collected indicated three distinct factors, based on Kaiser's criterion, the scree plot, and a parallel analysis (the difference between random eigenvalue and obtained fourth eigenvalue -0.35). Together, these three factors accounted for 60.77% of the item variance (29.27, 18.55, and 12.96% accounted for by the first, second and third factors, respectively). Communalities and oblique-rotated factor loadings obtained in the EFA are shown in Table 2. As indicated, the items BEBI_MA1, BEBI_MA2, and BEBI_MA3, which were intended to measure the construct of Malleable Ability (BEBI_MA), all loaded onto one factor as proposed. The items BEBI_NE1, BEBI_ NE2, and BEBI_ NE3, which were intended to measure the construct Need for Effort (BEBI_NE), similarly loaded onto one factor as proposed. However, all remaining items (BEBI_FA1 through BEBI_FA3 and BEBI_EK1 through BEBI_EK3) loaded onto a single factor. This result suggests that items from the proposed factor Fallible Authority (BEBI_FA) did not form a distinct factor from those in the Evolving Knowledge (BEBI_EK) factor. Cronbach's α coefficients for the factors identified were acceptable, ranging from 0.70 through 0.75 (Nunnally, 1978). Thus, the results of the EFA were similar to those reported by Chan and Elliot (2000), with the construct of Omniscient Authority failing to emerge.

Confirmatory factor analysis

To cross-validate the EFA results using scores from polytechnic B (n = 205), two CFAs were conducted. The first was based on the original factor structure specified, in which the 12 BEBI items measured four different dimensions or aspects of epistemic beliefs (Malleable Ability, BEBI_MA; Need for Effort, BEBI_NE; Fallible Authority, BEBI_FA; and Evolving Knowledge, BEBI_EK). The second was based on the result of the EFA, in which all BEBI_FA and BEBI_EK items loaded on a single factor. The change in chi-square between the two models was then used to evaluate whether the fit of the two models differed significantly. Again, before this analysis, data screening analyses were performed to ensure that all relevant assumptions for CFA in terms of normality, linearity, factorability, and the absence of outlying univariate scores and multivariate score sets were met. These analyses

Table 2. Communalities and factor loadings for the BEBI items

Item	Communality		Pattern Matrix		
	Initial	Extraction	Factor 1: Fallible Authority and Evolving Knowledge	Factor 2: Malleable Ability	Factor 3: Need for Effort
BEBI_FA1	0.46	0.59	**.79**	-.12	.10
BEBI_FA2	0.35	0.45	**.64**	-.21	.28
BEBI_FA3	0.47	0.60	**.77**	-.05	-.19
BEBI_EK1	0.25	0.28	**.43**	.18	-.04
BEBI_EK2	0.36	0.42	**.50**	.27	.03
BEBI_EK3	0.43	0.49	**.50**	.29	-.17
BEBI_MA1	0.42	0.57	.03	**.75**	.02
BEBI_MA2	0.34	0.47	-.11	**.74**	.12
BEBI_MA3	0.38	0.47	.03	**.67**	-.01
BEBI_NE1	0.35	0.47	.12	-.01	**.67**
BEBI_NE2	0.39	0.61	-.10	-.14	**.79**
BEBI_NE3	0.30	0.39	-.02	.01	**.62**

all produced satisfactory results. Given the high case to item ratio of 17.08, the sample size was also deemed large enough to yield reliable correlation estimates.

Despite the results obtained in the EFA, the change in $x2$ between the three- and the four-factor models tested was significant, $\Delta x2$ (3) = 36.20, p < 0.05, indicating that the fit of the original, four-factor model was superior to that of the three-factor model indicated by the EFA. Given this result, the four-factor model was retained here for interpretation. The overall chi-square obtained for the four-factor model was $x2(48) = 90.40$, p < 0.05. A summary of fit indices, both for the four- and the three-factor models tested, are presented in Table 3. Comparing the obtained fit indices shown in Table 3 with recommended cut-offs for each index (see Hooper et al., 2008), the four-factor BEBI model fit the data moderately well and was superior to the three-factor model. The Goodness of Fit (GFI) and Adjusted Goodness of Fit (AGFI) values indicated that the proportion of variance accounted for by the estimated population covariance fell marginally below recommended minimum levels (GFI $\geq$ 0.95 and AGFI $\geq$ 0.90). The Normed Fit Index (NFI) and Non-Normed Fit Index (NNFI) values similarly fell just below the recommended minimum levels (i.e., $\geq$ 0.95, or improvement of fit by 95% relative to the null model).

Table 3. Fit indices for two models of the BEBI

Model	χ^2	df	χ^2/df	GFI	AGFI	NFI	NNFI	CFI	RSMEA	SRMR
Model 1: Four-Factor	90.40	48	1.88	.93	.89	.88	.92	.94	.07	.07
Model 2: Three-Factor	126.60	51	2.48	.91	.86	.84	.86	.90	.09	.08

Values obtained for the Root Mean Square Error of Approximation (RMSEA) (i.e., the square-root of the difference between the residuals of the sample covariance matrix and the hypothesized model), and the Standardized Root Mean Square Residual (SRMR) (i.e., the standardized difference between the observed correlations and the predicted correlation values) fell well within recommended levels (recommended levels $\leq$ 0.08 in both cases). Both the Comparative Fit Index (CFI) and the $x2/df$ also fell well within recommended ranges for determining good fit ($\geq$.90 and $\leq$3.0, respectively). Based on these results, the four-factor

model of the BEBI was deemed to be tenable, despite the results of the earlier EFA. Figure 1 presents path coefficients obtained from the four-factor model tested.

The means and standard deviations of the 12 BEBI items for Polytechnic A and B are shown in Table 4.

Table 4: Mean and Standard deviations

Item	Polytechnic A		Polytechnic B	
	Mean	Standard Deviation	Mean	Standard Deviation
BEBI_MA1	5.41	1.49	5.52	1.37
BEBI_MA2	5.07	1.57	4.85	1.56
BEBI_MA3	5.08	1.41	4.85	1.52
BEBI_NE1	5.19	1.58	2.64	1.65
BEBI_NE2	4.82	1.63	3.19	1.70
BEBI_NE3	4.81	1.52	3.12	1.56
BEBI_FA1	4.71	1.38	4.93	1.40
BEBI_FA2	4.06	1.57	4.34	1.29
BEBI_FA3	5.22	1.30	5.42	1.25
BEBI_EK1	5.04	1.43	5.54	1.26
BEBI_EK2	4.93	1.33	5.10	1.41
BEBI_EK3	5.45	1.27	5.70	1.24

Discussion

Based on the results obtained, the 12-item BEBI developed holds considerable promise for meeting the purpose of this study. As noted previously, while other instruments have appeared within the literature to measure students' epistemic beliefs, these are generally worded for students in a Western context and are unlikely to be suitable for students in other countries (Chan & Elliot, 2000).

The EFA on the dataset from polytechnic A indicated that, contrary to the proposed BEBI structure, only three factors could be distinguished within the BEBI items. This result aligned with those reported by Chan and Elliot (2000) and Schommer (1993). In both of these previous studies, the factor of Omniscient Authority (which was labelled Fallible Authority or BEBI_FA, in the BEBI) did not emerge as an independent factor. In the present study, all BEBI_FA and BEBI_EK items (the latter designed to represent the Certain Knowledge construct in Schommer's 1990 conceptual model) loaded on a single factor. This result suggests that for many students, a belief in Certain Knowledge will be associated with a belief in Omniscient Authority in knowledge. This result is intuitively reasonable, as the level of certainty ascribed to knowledge is likely to be associated with the authority attached to that knowledge.

In the CFA performed on data from polytechnic B, however, the fit of the original four-factor model of the BEBI was found to be superior to that of the three-factor model obtained in the EFA. This result suggests that in polytechnic B, the BEBI_FA factor could be differentiated meaningfully from the BEBI_EK factor. Based on the two sets of results, it seems that the factor of Omniscient Authority (Fallible Authority in the BEBI) may not emerge consistently across samples. This result is aligned with the variable results obtained across different samples in the literature.

Based on the CFA conducted on the polytechnic B data, the four-factor model of the BEBI fit the data moderately well. The fit indices obtained fell either just below or within the recommended cut-off points from the literature. Whilst these results suggest that further work is needed to enhance
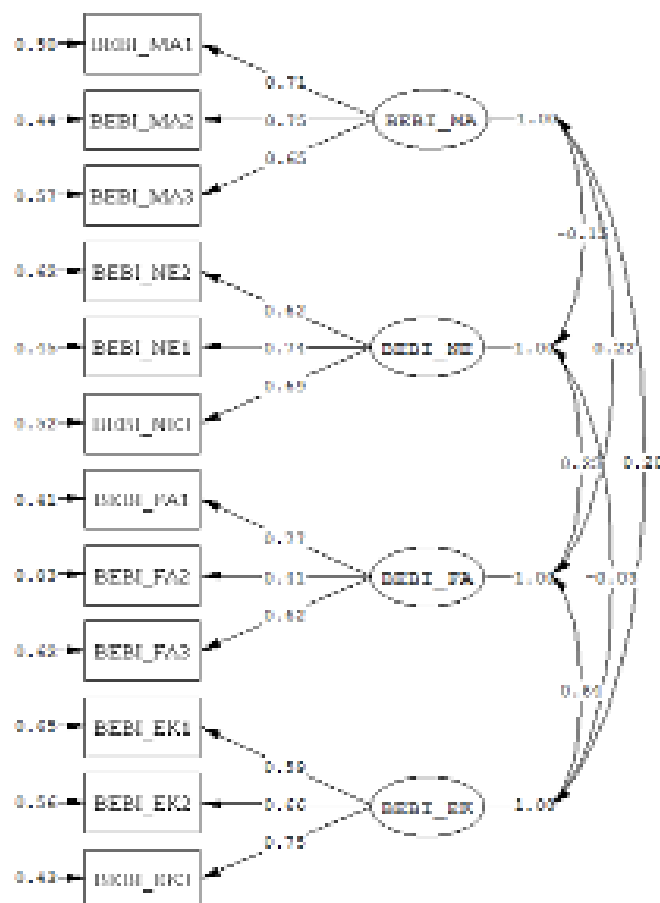

Figure 1. Path diagram for the four-factor model of the BEBI

the instrument before it is used in a broader context, given the brevity of the BEBI, a modified form of this instrument may present an appealing option for educators in Singapore who wish to measure their students' epistemic beliefs.

Students' epistemic beliefs have been found to predict other key learning outcomes such as academic performance, particularly in constructivist learning environments. In light of Singapore's aim to move toward the use of constructivist learning environments such as problem-based learning (PBL) across all levels of education, a short tool such as the BEBI could be particularly useful within this context. Looking beyond Singapore, the BEBI can be translated into different Asian languages and be used in institutions of learning in other countries. In such future developments, however, further refinements to the items used to represent Fallible Authority and Evolving Knowledge should be considered to ensure that these two subscales are empirically distinct.

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