Namibian pre-service science teachers' scientific epistemic beliefs

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Abstract

This study aimed to validate the adapted scientific epistemic beliefs (SEB) questionnaire and assess the development of scientific epistemic beliefs of pre-service science teachers enrolled in the primary science education programme at two campuses of a university in Namibia using paper and pencil method. The study employed quantitative methods to collect data. Data was obtained from a sample of 457 (40% male; 60% female) pre-service science teachers. The study adapted the scientific epistemic beliefs questionnaire developed by Conley, Pintrich, Vekiri and Harrison (2004). The adaptation entailed shortening the questionnaire to mitigate redundancy suspected in the original questionnaire. The self-reporting Likert scale questionnaire comprised four dimensions of beliefs: source; certainty; development; and justification of scientific knowledge. The adapted questionnaire had reasonable reliability with the Cronbach's alpha of subscales ranging from α = .51 to .73 and the overall reliability of α= .74. Model fit analysis yielded good statistical fit for the data. The results showed that the questionnaire worked reasonably well with the Namibian sample used given the good model fit for the data, reliability and strong measurement invariance. The study found no statistically significant differences in beliefs in terms of gender. However, there were statistically significant differences in beliefs about source and justification of scientific knowledge in terms of year of study. Understanding the nature of scientific knowledge has been shown to be beneficial in learning science. Understanding what scientific knowledge and practices entail is critical to developing pre-service science teachers' epistemic insight. For this reason, pre-service science teachers should be exposed to the epistemic aspect of scientific literacy during their training.

Keywords: *scientific epistemic beliefs, measurement invariance, pre-service science teachers*

Introduction

In line with the national science curriculum in Namibia, science teachers are expected to be scientifically literate professionals (Ministry of Education, 2010). One of the components of scientific literacy is the understanding of the nature of scientific knowledge. However, the primary science education teacher training programmes in Namibia do not explicitly emphasise this aspect of scientific literacy. The training mainly focuses on subject content knowledge and omits the important epistemic aspect of scientific inquiry which is believed to help students develop 21st century skills (Gu & Belland, 2015). The scientific epistemic beliefs (SEB) of teachers has been found to affect both their practice and their students' beliefs about nature of science (Kaya, 2017). Scientific epistemic beliefs are domain-specific views about nature and acquisition of scientific knowledge, how scientific knowledge is produced, how reliable and valid that knowledge is and how it is shared (Conley, Pintrich, Vekiri, & Harrison, 2004; Kaya, 2017). Scientific epistemic beliefs of teachers are critical for their professional development. These beliefs were found to influence how they approach the scientific knowledge during teaching and learning and how they construct that knowledge in their practice (Tsai, 2006; Wahbeh & Abd-El-Khalick, 2014).

The absence of the epistemic aspect of scientific inquiry can be traced back to primary science education teacher training in Namibia. Despite far-reaching consensus on identifying the curricular relevance of the meta-knowledge about science (nature of science) to enhance scientific literacy (García-Carmona & Acevedo Díaz, 2016; Lederman, 2007), its inclusion in the science teacher training programmes is largely implicit. Students need to develop sophisticated scientific epistemic beliefs in order to understand the nature of scientific knowledge and how such knowledge is constructed (Gu & Belland, 2015). This understanding needs to be inculcated in students while they are in primary school. After all research show that the integration of science meta-knowledge at this level of schooling yields positive learning outcomes (Akerson & Donnelly, 2010). Therefore, there is a need to ensure that pre-service primary science teachers acquire the same understanding during their teacher training. In other words, the pre-service science teachers' training programmes for primary education should emphasise the understanding of the nature of scientific knowledge.

One way to ascertain pre-service science teachers' understanding of the nature of scientific knowledge is to assess their scientific epistemic beliefs. To achieve this, reliable and valid measures are required. Numerous epistemic beliefs measures have been developed and adapted in recent years (Buehl, Alexander, & Murphy, 2002; Conley et al., 2004; Murphy, Edwards, Buehl, & Zeruth, 2007; Schraw, Bendixen, & Dunkle, 2002; Tsai, Jessie Ho, Liang, & Lin, 2011). However, a review of relevant literature suggests that these measures were either developed or adapted in the western world and Asia. None of such measures were tested nor developed in the cultural context of Namibia.

The aim of this study was to validate the adapted scientific epistemic beliefs (SEB) questionnaire developed by Conley et al. (2004) with a view to assess Namibian pre-service primary school science teachers' scientific epistemic beliefs. The study attempted to answer the following research questions:

1. How is the reliability of the adapted scientific epistemic beliefs questionnaire in the Namibian context?
2. Does the data confirm the four-dimension hypothesised model?
3. Does the data support measurement invariance in terms of gender?
4. Is there a difference in mean levels of scientific epistemic beliefs in terms of gender and year of study?

Scientific epistemic beliefs

Epistemology is an aspect of philosophy that is concerned with the nature of human knowledge and reasoning (Muis, Bendixen, & Haerle, 2006). Educational researchers study epistemology in terms of individual's perspective. They focus on beliefs individuals possess about how knowing occurs, how knowledge is justified and how these affect individuals' cognitive processes (Gu & Belland, 2015). However, different terminologies referring to beliefs that people possess about the nature of knowledge and knowing such as epistemic beliefs, epistemological beliefs, personal epistemology and epistemic cognition can be found in the literature. This suggests that there is no consensus regarding the terminology of this concept (Greene, Azevedo, & Torney-Purta, 2008; Hofer, 2004).

According to Kitchener (2002), epistemic beliefs are beliefs about knowledge and knowing, including the source or justification of knowledge, whereas epistemological beliefs are beliefs about the field of epistemology or beliefs about the study of knowledge. Though personal epistemology or epistemological beliefs are used by most researchers in some measures of beliefs, it could be construed that such measures were aimed at the type of beliefs that Kitchener referred to as epistemic beliefs (Murphy et al., 2007). For this reason, the term epistemic beliefs are adopted for this study to refer to pre-service teachers' beliefs about scientific knowledge and knowing. Greene et al. (2008) suggest that epistemic beliefs develop continuously from a naïve orientation to a more sophisticated position though in an unorganised way. Such beliefs begin with absolutism through multiplism and evaluativism. Absolutism is concerned with beliefs that knowledge is absolute and certain. Multiplism entails beliefs that knowledge is subjective and the evaluativist views knowledge as evolving, actively constructed and justified with evidence (Kienhues, Bromme, & Stahl, 2008).

On the side lines of the general characterisations of epistemic beliefs is a suggestion that domain-specific epistemic beliefs are more pertinent and influential in academic learning (Muis, Bendixen, & Haerle, 2006). For this reason, this study was located in the science domain. Conley et al. (2004) proposed that scientific epistemic beliefs have four dimensions. The four dimensions are source (science knowledge comes from authority or experts); certainty (science knowledge has only one answer); development (science knowledge is evolving and changing); and justification (science knowledge should be based on evidence from different experiments and observations). Epistemic beliefs have been associated with learning and academic achievement in science (Cano, 2005; Stathopoulou & Vosniadou, 2007; Trautwein & Lüdtke, 2007). These studies highlighted the importance of exploring students' views about the nature of scientific knowledge with a view to helping them better understand science concepts. Studies that involved elementary students (e.g., Elder, 2002; Conley et al., 2004) provided conflicting results. Elder's study revealed that students perceived science knowledge as changing (development) and derived from experiments (justification).

The study by Conley and colleagues found no significant changes in beliefs regarding the changing nature (development) and justification of scientific knowledge, though they found that higher achievement in science was associated with more sophisticated beliefs. Moreover, similar studies done with upper secondary students showed more consistent results (Liang & Tsai, 2010; Stathopoulou & Vosniadou, 2007; Trautwein & Lüdtke, 2007). This is perhaps not surprising because earlier work on epistemological thinking (Kuhn, 1988) asserted that it was not easy to identify epistemological thinking among younger students. However, this assertion was contradicted by Wellman's (1992) work on children's theory of mind, suggesting that epistemological thinking begins at an early age and hence it should continue developing (Chandler, Hallett, & Sokol, 2002). The foregoing conflicting findings could be attributed to science teachers themselves not paying attention to the epistemic aspect of scientific literacy and such deficiencies could have trickled down to the students. Research shows that pre-service science teachers often do not get direct exposure to the epistemic aims and values of science (Kelly & Erduran, 2019).

In hindsight, this study attempts to instigate debate and research pertaining to ideas about the nature of scientific knowledge in the Namibian science education practices at the teacher education level. For this reason, it focused on pre-service science teachers as these are the future science teachers in primary schools in Namibia.

Adaptation of the SEB questionnaire

The original questionnaire was developed for a particular culture and in the present study it has been adapted for a different culture. This necessitates a cross-cultural validation. Cross-cultural validation entails ascertaining whether instruments that were originally developed in a particular culture are meaningfully applicable and thus equivalent for use in another culture (Huang & Wong, 2014). It has often been applied in psychological studies in which self-reporting measures are adapted for use in languages other than the original one. However, in the present study, both the original and the adapted versions were in English. Cultural difference exists only in terms of geographical location: the original questionnaire was developed in the USA and the adapted version was used in Namibia (Africa). Huang and Wong (2014) asserted that it might be challenging to adapt an instrument in a culturally relevant and comprehensible form while maintaining the meaning of the original items. In the context of the present study, the adaptation entailed the removal of items that were deemed repetitive in an effort to shorten the questionnaire. Shortening the questionnaire was deemed beneficial as it could reduce redundancy suspected in the original questionnaire as well as mitigating respondents' fatigue. Wordy items were rephrased. Some words such as "stuff" were replaced with "things" for clarity. The development dimension showed lower reliability (α = .66) compared to other three dimensions in the original SEB questionnaire. For this reason, the item "Ideas in science sometimes change" was replaced with one that read "Scientific ideas may change because technology may lead to new findings".

The original version of the SEB questionnaire consisting of 26 items can be found in the Conley et al. (2004) article published in the *Contemporary Educational Psychology Journal*. The final adapted questionnaire had 22 items in total (Table 1).

Table 1: Comparison of items composition

Dimensions of beliefs	Original SEB (no. of items)	Adapted SEB (no. of items)
Source	5	4
Certainty	6	5
Development	6	6
Justification	9	7
Total	26	22

Due to the adaptation of the questionnaire and the use of a sample different from the original one, it is recommended to examine the psychometric properties of the adapted instrument in order to assess its measurement precision and validity (Schraw, Bendixen, & Dunkle, 2002). Previous studies that used the same questionnaire (Liang & Tsai, 2010; Tsai, Jessie Ho, Liang, & Lin, 2011) confirmed its factorial structure suggesting that we could formulate an a priori hypothesis to test the questionnaire's factorial structure signifying that the four dimensions of beliefs proposed by Conley et al. (2004) should form distinct factors. Hence only confirmatory factor analyses were used to assess measurement model fit for the data in the present study.

Methods

Participants and procedure

A sample consisted of 457 (40% male; 60% female) pre-service science students from two campuses of a university in Namibia. Sampling was inherently voluntary and convenient because the aim of the study was not to generalize findings but rather to obtain sufficient sample suitable for advanced statistical analysis to examine psychometric properties of the adapted questionnaire. All participating respondents were enrolled in the Bachelor of Education (honours) programme, majoring in Primary School Science Education. The sample comprised pre-service science teachers from year one to year four. With assistance of the two lecturers, pre-service science teachers responded to the items using the paper-and-pencil method. Each item had to be answered by means of circling the number corresponding to the option that best described their beliefs. Pre-service teachers' responses were captured manually and incomplete questionnaires were discarded, hence no missing data in the dataset. On average, respondents spent approximately 10 minutes to complete the questionnaire. Provision was also made on the SEB questionnaire to collect some background data such as gender and year of study. To promote candid responses to the questionnaire, respondents were assured that their identities would remain anonymous and participation was voluntary.

Instrument

The 22-item questionnaire was adapted from the scientific epistemic beliefs questionnaire (Conley et al., 2004). Respondents were asked to indicate their level of agreement with the statements on beliefs about scientific knowledge. Items were unambiguously short, declarative statements without jargon. Each item was a five-point Likert scale of temporal frequency (Glynn, Taasoobshirazi, & Brickman, 2009), wherein 1= strongly disagree; 2 = disagree; 3 = not sure; 4 = agree and 5 = strongly agree. The questionnaire comprised four dimensions of beliefs and examples of items are given in brackets: source (Whatever the teacher says in science class is true); certainty (All questions in science have one right answer); development (Existing ideas in science may change as scientists come up with new ones); and justification (Good answers are based on evidence from many different experiments). Items were worded in both positive and negative directions, however, items that were negatively worded; all from the two naïve dimensions e.g., source and certainty were reverse scored so that a high score on a particular dimension indicates more sophisticated beliefs. The adapted questionnaire was given to one university lecturer of English and Linguistics who proof read and approved the language usage.

Data analysis

The reliability of the scales was assessed using Cronbach's alpha coefficient (Summers & Abd-El-Khalick, 2017), using the statistical package for social sciences (SPSS) version 25. Based on previous studies that used the same questionnaire (e.g., Liang & Tsai, 2010; Tsai, Jessie Ho, Liang, & Lin, 2011), an assumption was made that the factorial structure confirmed by such studies through exploratory factor analysis should be sufficient for us to formulate an a priori hypothesis to test the adapted questionnaire's factorial structure, suggesting that the four dimensions of beliefs proposed by Conley et al. (2004) should form distinct factors. Hence only confirmatory factor analyses (CFA) in AMOS were used to assess measurement model fit using the ratio of chi-square to degrees of freedom (χ^2/df), root-mean-square error of approximation (RMSEA), standardized root mean square residual (SRMR), Tucker-Lewis index (TLI) and comparative fit index (CFI) as fit indices (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Teo, 2013). CFA was chosen because our study intended to test the 4-factor SEB model proposed by Conley et al. (2004).

CFA provides a rigorous test of equivalence across groups (Salta & Koulougliotis, 2015) hence measurement invariance testing process was employed by way of a multi-group CFA in order to examine whether the items' factor loadings and intercepts were invariant across female and male participants. Three levels of measurement invariance were tested, starting with configural invariance, metric invariance, and scalar invariance (Chen, 2007). Configural invariance tests whether the overall factor structure holds for the two groups. Metric invariance ascertains the extent to which the relationships between factors and items are equivalent across the two groups. If metric invariance is supported, it can be concluded that male and female participants interpreted the items in the same way.

Scalar invariance assesses the equality of intercept terms. This assessment is necessary to establish whether the two groups used the response scale similarly. Scalar invariance must be supported before interpreting mean differences between the groups or else the validity of inferences drawn by comparing groups could be questionable (Campbell, Barry, Joe, & Finney, 2008). Model fit criteria suggested by Hu and Bentler (1999) that include CFI and TLI values $\geq .90$, SRMR $\leq .08$, and RMSEA $\leq .06$ were used. The ratio of the chi-square to degrees of freedom (χ^2/df) in the range of 1.0-3.0 criterion (Glynn et al., 2011; Garson, 2015) was used. For measurement invariance, a change in CFI $\leq .01$ between nested models was used a criterion for invariance. Independent samples t-test was conducted to examine the difference in SEBs in terms of gender and one-way analysis of variance (ANOVA) was done to examine the differences in SEBs in terms of year of study (year 1 to year 4).

Results and discussion

The first research question sought to establish the reliability of the adapted instrument. The reliability of the adapted SEB questionnaire was estimated using Cronbach's alpha coefficient. Reliability is a measure of internal consistency of respondents' responses across the items on a multiple-item measure. Essentially, all the items on such measures should reflect the same underlying construct thus respondents' scores on those items should be correlated with each other (Wieland, Durach, Kembro, & Treiblmaier, 2017).

Table 2: Reliability comparisons of original and adapted SEB questionnaires (N=457)

Dimensions	No. of items		Alpha (α)	
	Original	Adapted	Original	Adapted
Source	5	4	.82	.59
Certainty	6	5	.79	.51
Development	6	6	.66	.71
Justification	9	7	.76	.73

Overall reliability (α)	26	22	-	.74

The reliabilities of the scores from the four dimensions in the questionnaire for this study were assessed using Cronbach's alpha coefficient. The reliability of scores from individual dimensions ranged from α = .51 to .73 (Table 2). The overall reliability of the scores on the adapted SEB questionnaire was α= .74. This suggests that the questionnaire had reasonable overall reliability for the sample used although not all dimensions showed reliability values above the recommended minimum threshold of α= .70 (Streiner, 2003). The overall reliability of the original SEB questionnaire was not reported; however, based on what was reported, the two dimensions, source and certainty in the adapted SEB appeared to be less reliable. It should be noted that dimensions source and certainty were assessed with reverse-coded items and were subsequently reverse-scored during data analysis. However, this could result in response bias. Response bias refers to answering patterns on questionnaires that do not reflect the respondents' actual state or opinion (van Sonderen, Sanderman, & Coyne, 2013). Although reverse coding items can be used in a questionnaire and can be reverse scored, it might lead to confusion among respondents. Respondents who are not careful may fail to miss the reversing or the negative form and may incorrectly respond to the item (Weijters, Baumgartner, & Schillewaert, 2013) and this could affect the reliability of the questionnaire.

It is also important to indicate that the original SEB questionnaire was administered to elementary school students while the adapted one in the present study was administered to pre-service science primary school teachers. The mode of administration was also different. In the original questionnaire, items were orally read out to students while in the present study, respondents used self-reporting questionnaires. Conley et al. (2004) reported that there was considerable redundancy in the original SEB questionnaire due to very high correlation between the source and certainty dimensions (r = .92) which made it difficult to differentiate between the two concepts logically. However, our correlation analysis of the four dimensions (Table 3) showed that though related, they were not too similar thus, mitigated any significant redundancy of items.

Table 3: Correlation of adapted SEB dimensions (N=457)

Dimensions	M	SD	1	2	3	4
Source	3.2	.77	-####			
Certainty	3.2	.73	.445**	-		
Development	3.9	.68	.170**	.056	-1	
Justification	4.3	.56	.075	-.005	.489**	-

Note. **. Correlation is significant at the 0.01 level (2-tailed).
M= mean SD= Standard deviation

The overall level of beliefs was fairly low for the two dimensions; source (M = 3.2, SD = .77 and certainty (M = 3.2, SD = .73) but were slightly higher for the dimensions; development (M =3.9, SD = .68) and justification (M= 4.3, SD = .56). Though these results were similar to the findings in the original questionnaire, it is difficult to interpret respondents' beliefs accurately due to the cross-sectional nature of the present study. Source and certainty were reverse scored so that high scores on them indicates sophisticated beliefs. Reverse items can negatively affect respondents' opinion if they miss the reversing. The low scores on the two dimensions could be explained by this technicality. Although cross-sectional study can possess characteristics of longitudinal studies of incremental groups (e.g. year of study) drawn simultaneously from the population (Cohen, Manion, & Morrison, 2007), another assessment after an intervention could perhaps clarify this better as one would be able to ascertain whether there were any changes in their beliefs over time.

Confirmatory factor analysis of the SEBs dimensions

The second research question sought to assess the four dimensions hypothesised in the original instrument. The 4-dimension structural model fitted adequately with the present data since all the fit indices were within acceptable ranges thus confirming construct validity of the adapted SEB questionnaire in the Namibian context. The factor loadings were all above the acceptable values. The overall goodness of fit of the measurement model were: the ratio of chi-square to degrees of freedom (χ^2/df) = 1.754, RMSEA = 0.041, CFI = 0.92, TLI = 0.91, SRMR = 0.047. These results indicated that the measurement model fitted the data well. However, five items were removed to achieve good model fit. This means the final adapted instrument should have only seventeen items as shown in Table 5.

Table 4: Tests of Invariance of the Adapted SEB Questionnaire across gender

Model	χ^2	*Df*	$\Delta\chi^2$	Δdf	RMSEA	CFI	ΔCFI
Configural: Factor structure constrained to be equal	308.7	226	-	-	0.028	.93	-
Metric: Factor loadings constrained to be equal	325.3	243	16.6	17	0.027	.94	.01
Scalar: Intercepts constrained to be equal	356.3	260	31.0	17	0.029	.92	-.02

Note: CFI = comparative fit index, RMSEA = root mean square error of approximation, ΔCFI = change in comparative fit index

After obtaining the good fit statistics, we set out to examine measurement invariance of the instrument among male and female pre-service science teachers to ascertain whether male and female respondents interpreted the items of the adapted SEB questionnaire similarly. This is an important pre-requisite for meaningful cross-group comparisons (Cheung & Rensvold, 2002). Three levels of measurement invariance were tested, starting with Configural invariance, metric invariance, and scalar invariance (Chen, 2007). Configural invariance was first established using baseline models for male and female respondents. The Configural model serves as the comparison standard for subsequent tests (Campbell et al., 2008). Metric invariance and scalar invariance were compared with the Configural model and significant differences between these models were computed using changes in CFI (ΔCFI) (Wang & Wang, 2012). This method is believed to be more efficient and reliable compared to the chi-square difference test alone (Cheung & Rensvold, 2002). Wang and Wang (2012) recommended that a change in CFI less than or equal to .01 between nested models is considered a criterion of invariance. As evident in Table 4, the adapted SEB questionnaire demonstrated strong measurement invariance because the changes in CFI were less than .01. Based on this, the mean comparisons based on the gender of pre-service science teachers could be performed with more confidence. Respectively these findings answered the third research question, which sought to assess measurement invariance in terms of gender.

Table 5: Adapted SEB Questionnaire: Items and factor loadings resulting from CFA on the two samples of male and female.

Item Number	Item Statement	Factor loadings Male	Factor loadings Female
Source of Knowledge			
2	In science, you have to believe what the science books say about things	0.46	0.45
3	Whatever the teacher says in science class is true	0.62	0.60
4	If you read something in a science book, you can be sure it is true	0.59	0.58
Certainty of Knowledge			
7	Scientists know everything about science; there is not much more to know	0.58	0.58
8	Scientific knowledge is always true	0.46	0.47
9	Once scientists have the result from an experiment, that is the only answer	0.48	0.48
Development of Knowledge			
10	Some ideas in science today are different than what scientists used to think	0.53	0.54
11	The ideas in science books sometimes change	0.55	0.56
12	There are some questions that even scientists cannot answer	0.45	0.44
13	Sometimes scientists change their minds about what is true in science	0.37	0.42
14	Existing ideas in science may change as scientists come up with new ones	0.67	0.65
15	Scientific ideas may change because technology may lead to new findings	0.66	0.62
Justification of Knowledge			
16	Ideas about science experiments come from being curious and thinking about how things work	0.57	0.58
17	In science, there can be more than one way for scientists to test their ideas	0.55	0.61
18	One important part of science is doing experiments to come up with new ideas about how things work	0.62	0.60
20	Ideas in science can come from your own questions and experiments	0.41	0.38
21	It is good to try experiments more than once to make sure of your results	0.72	0.66

Note. Item numbers 1, 5, 6, 19 and 22 were removed.

Differences in SEBs in terms of gender

In response to the fourth research question, which asked whether there were differences in mean levels of SEBs in terms of gender, independent samples t-test was conducted for each dimension. The study found that there was no statistically significant difference in SEBs in terms of gender (M_{male} = 3.75, SD = .49; M_{female} = 3.80, SD = .43), t(455) = -1.042, $p > .05$. These findings were in line with Pintrich (2002) who asserted that there were no important differences in epistemological thinking in terms of gender. However, the same findings contradicted what Cano (2005) reported, although using different instruments, it was found that females' epistemological beliefs about knowledge and learning, at all school levels, were more realistic than for the males. The original study (Conley et al., 2004) also reported that boys and girls in the fifth grade appeared to have similar scientific epistemic thinking, as they did not find evidence suggesting the effects of gender nor any moderating effects of gender over time.

Differences in SEBs in terms of year of study

With regards to the year of study and to answer the second part of the fourth research question, a one-way ANOVA was conducted to examine whether there was a statistically significant difference in SEBs. There was statistically significant difference in beliefs about source and justification of knowledge between years of study at $p< .05$ level for the four-year groups. For source of knowledge [$F(3, 453) = 6.76$, $p< .05$], the post-hoc comparisons using the Tukey HSD test showed that the mean score for Year 1 ($M = 3.15$, $SD = .81$) was statistically significantly different from Year 2 ($M = 2.88$, $SD = .66$) and did not significantly differ from Year 3 ($M = 3.25$, $SD = .89$) and Year 4 ($M = 3.47$, $SD = .85$). This was not expected because the assumption was that Year 2 pre-service teachers were more senior to the Year 1 pre-service teachers and hence should possess more sophisticated beliefs about scientific knowledge. However, Year 1 teachers showed beliefs that were more advanced about source of knowledge than Year 2 teachers. Year 2 was also statistically significantly different from Year 3 and Year 4. Considering that the epistemic aspect of scientific literacy is not given attention directly in the training of pre-service teachers, these findings conform to the hypothesis that senior pre-service primary school teachers should possess more sophisticated beliefs about the nature of scientific knowledge.

For justification of knowledge [$F(3, 453) = 3.72$, $p = .012$], the post hoc test indicated that the mean score of Year 1 ($M = 4.33$, $SD = .41$) was statistically significantly different from Year 3 ($M = 4.14$, $SD = .78$) and did not significantly differ from Year 2 ($M = 4.33$, $SD = .47$) and Year 4 ($M = 4.16$, $SD = .72$). These findings showed that Year 1 teachers possessed more sophisticated beliefs about the justification of knowledge than Year 3 teachers. This was also not expected for the same reason as with source knowledge. We assumed that senior pre-service teachers should have more advanced beliefs than junior pre-service teachers. These findings point to the need to examine the characteristics of Year 1 pre-service teachers to establish why they seemed to have more advanced beliefs than their senior pre-service teachers. A pre-test post-test kind of assessment could also help in unravelling this discrepancy. However, for the purpose of this study, such was not possible due to limited access to the respondents. There were no statistically significant differences between the mean score of all year groups in terms of certainty and development of knowledge dimensions.

Implications for pre-service teachers' training

The teachers' epistemic beliefs about science have been found to affect their students' beliefs about scientific knowledge (Kaya, 2017). There is a multitude of potential benefits for students when they learn about the nature of scientific knowledge as can be found in the literature such as that understanding of the nature of science can help students to understand the process of science, make informed decisions on socio-scientific issues, appreciate science as a pivotal element of contemporary culture, be more aware of the norms of the scientific community, and learn science content with more depth (Driver, Leach, Millar, & Scott, 1996; Kaya, Erduran, Aksoz, & Akgun, 2018). For students to enjoy these benefits, they must be made aware of them first and it's the responsibility of their teachers to create that awareness.

The national curriculum for basic education (Ministry of Education, 2010) advocates for understanding of the nature of scientific knowledge but science subject specific curricula advise teachers to integrate scientific processes skills (by implication, nature of science) in other content areas without clear guidance as to how such integration could be done especially at primary school level. This integration can only be achieved if science teachers themselves have a clear understanding of how to integrate the nature of scientific knowledge ideas in their teaching practices. At the moment even in-service science teachers appear to have mixed views about the nature of scientific knowledge. This might be pointing to a gap in the primary science teacher education programmes themselves. Document analysis showed that no reference is made to nature of scientific knowledge in the curriculum of the primary pre-service science teachers at university in Namibia. The curriculum developers for science may have an impression that science teachers understand how to integrate scientific processes or nature of scientific knowledge ideas in different topics without explicit guidelines for teaching and learning.

It can be noted in the literature that teaching and learning of the nature of scientific knowledge may be difficult because it's a meta-concept that demands higher-order thinking in science (Kaya, Erduran, Aksoz, & Akgun, 2018). However, its absence in science teacher education only exacerbates the disjuncture between teacher training and practice in this regard. Pre-service science teacher education programmes should incorporate the epistemic aspect (nature of science) of scientific literacy. Pre-service primary school science teachers should acquire adequate understanding of the nature of scientific knowledge in order to be able to integrate it in their teaching and learning practices.

Conclusion

This study set out to validate the scientific epistemic beliefs (SEBs) questionnaire using the Namibian sample of pre-service primary school science teachers from two campuses of a university in Namibia. The overall level of beliefs was fairly low for the two naïve dimensions; source and certainty but was higher for the sophisticated dimensions; development and justification. Though these results are similar to the findings in the original questionnaire, it is difficult to interpret pre-service science teachers' beliefs accurately due to the cross-sectional nature of this study. Source and certainty were reverse scored because their items were reverse-coded, so that high scores on them indicated beliefs that were more sophisticated. Although reverse-coded items might help mitigate response bias, it can also lead to confusion among respondents. Respondents, especially second language speakers, who are not careful may miss the reversing or the negative form and may incorrectly respond to the reverse-coded items (Weijters, Baumgartner, & Schillewaert, 2013). Although cross-sectional study can possess characteristics of longitudinal studies of incremental groups for instance in the case of the present study; the year of study, drawn simultaneously from the population (Cohen et al., 2007), another assessment following an intervention could perhaps clarify why pre-service teachers responded the way they did. Ultimately, one would be able to ascertain whether there would be any changes in their beliefs over time. The instrument showed reasonable reliability in terms of alpha coefficient although the estimates for two naïve dimensions; source and certainty were below the preferred cut-off point of $\alpha = .70$. Similarly, the findings from this largely methodological study showed that the adapted SEBs questionnaire had adequate construct validity as evidenced by good structural model fit and strong measurement invariance. This study further found that there was no statistically significant difference in SEBs in terms of gender. This finding corroborates the outcome of measurement invariance assessment, which showed that both male and female pre-service teachers responded to the items similarly. Such findings allowed for the comparison of mean scores of the two groups more confidently (Campbell et al., 2008).

Further analyses showed that there was a statistically significant difference in beliefs about source and justification in terms of year of study. It was assumed that more senior pre-service teachers should have more sophisticated beliefs than junior pre-service teachers. However, this study found that Year 1 pre-service teachers showed more sophisticated beliefs about the source dimension than Year 2 pre-service teachers and also more sophisticated than Year 3 pre-service teachers for the justification dimension. It could not be established whether this failure to confirm the hypothesis was due to chance or there were underlying characteristics of Year 1 pre-service teachers that put them ahead of their seniors. Further research could perhaps unravel this phenomenon. Meanwhile no statistically significant differences were found in the mean scores of the other two dimensions of beliefs (certainty and development) in terms of year of study.

Understanding the nature of scientific knowledge has been shown to be beneficial in learning science. Understanding what scientific knowledge and practices entail is critical to developing pre-service science teachers' epistemic insight. For this reason, pre-service science teachers should be exposed to the epistemic aspect of scientific literacy during their training. With such knowledge, such teachers will be better equipped to seamlessly integrate ideas about scientific process skills and the nature of scientific knowledge in their science teaching and learning practices.

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