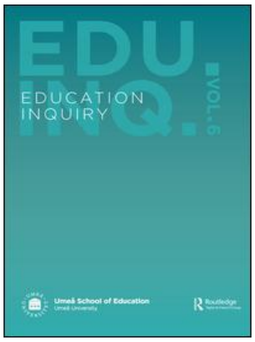

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Students' epistemological beliefs from grade level perspective and relationship with science achievement in Kenya

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ABSTRACT

This study investigated the influence of grade level on the development of science epistemological beliefs and the relationship between science epistemological beliefs and science achievement among co-educational secondary schools of Homa Bay County, Kenya. The study employed cross-sectional and correlational survey designs with purposive sampling. Epistemological Beliefs Questionnaire (EBQ) was used to measure science epistemological beliefs. The instrument was administered to 214 students from 2 co-educational schools (Grade 9, n = 116, Grade 12, n = 98). Students' achievement in Biology, Chemistry and Physics were computed for Science Achievement Scores (SAS). The data were analysed by grade level using independent sample t-tests and by dimensions and achievement scores using multiple regression analysis. The findings indicate statistically significant grade level differences in terms of source, certainty and development and non-significant grade level differences in terms of justification. The findings also indicate that certainty and justification dimensions were significant predictors of science achievement. It is concluded that grade level has an influence on development of epistemological beliefs (source, certainty and development) and certainty and justification dimensions were predictors of science achievement. Implications for practice and further research are herein explained.

KEYWORDS

Science epistemological beliefs; grade level; science achievement; co-educational; secondary schools

Introduction

One of the goals of science education in Kenya is to promote scientific knowledge about the natural world and to understand the connections between scientific knowledge and issues and problems of the modern society (Kenya Institute of Education, 2002). For this goal to be achieved, the students of science education need to have an understanding about the nature of scientific knowledge and the process of knowing science. Epistemological beliefs refer to beliefs about the nature of knowledge and knowing (Hofer & Pintrich, 1997). Science epistemological beliefs are therefore conceptions about the nature of scientific knowledge and the process of knowing science (Conley, Pintrich, Vekiri, & Harrison, 2004; Hofer, 2008; Hofer & Pintrich, 1997). In science education, epistemic competence is of particular significance since it is a determinant of

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acquisition of coherent knowledge that is of practical value in novel and real-life contexts. The acquisition of coherent knowledge is of strategic value especially at a time when greater premium is placed on transfer of knowledge and provision of solutions to problems in the society (Dede, 2007; Malamed, 2017; Orey, 2010; Ozbay & Koskal, 2016).

According to Conley et al. (2004) the developmental research in epistemological beliefs has over time raised important questions about what changes and how to describe the changes. In response to this discourse there are two main categories of models that have come to the fore, that is, developmental and multidimensional (Kaya, 2017). In the developmental models of epistemological beliefs, the construct is uni-dimensional and individuals move through a patterned sequence of developmental stages. According to Hofer (2001) in the developmental models, epistemological thinking begins with the objectivist view of knowledge to a situation where individuals begin to allow for uncertainty of knowledge then to extreme subjectivity followed by the ability to acknowledge relative merits of different points of view. For instance, Perry's model (1970) conceptualised epistemological beliefs as developing in successive stage-like fashion from dualism, to multiplism, relativism and finally commitment. According to Baxter Magolda (1992) epistemological beliefs progress in four stages known as absolute knowing, transitional knowing, independent knowing and contextual knowing. Boyes and Chandler (1992) concluded that young people move through a developmental sequence of naïve realism to a dogmatism-sceptism axis and finally to a post-sceptical rationalism. Kuhn, Cheney, and Weinstock (2000) proposed a developmental model in which epistemological beliefs progress in four levels as realist, absolutist, multiplistic and evaluatist. King and Kitchener (2004) proposed a reflective judgement developmental model of seven stages grouped into three levels characterised by pre-reflective thinking (stage 1–3), quasi-reflective thinking (stages 4–5), and reflective thinking (stages 6–7).

In contrast to the developmental models of epistemological beliefs, Schommer (1990) contended that personal epistemology is too complex to be captured in a uni-dimensional fashion and hence proposed that epistemological beliefs exist in a multidimensional system of more or less independent beliefs. This implies that there are multiple beliefs to consider and these beliefs may or may not develop synchronously. Accordingly, some dimensions may emerge or be positively related to learning earlier than others (Lodewyk, 2007). The implication is that one may be mature in one dimension of epistemological belief and quite immature in another. Conversely, one may be mature in one dimension of a specific domain but quite immature in the same dimension in another domain. In this model, people may hold sophisticated and naïve beliefs simultaneously. Consequently, Schommer (1990) developed a model of five dimensions as stability of knowledge (tentative to unchanging), structure of knowledge (isolated to integrated), source of knowledge (authority to observation or reason) speed of acquisition (quick or gradual) and control of acquisition (fixed at birth or lifelong improvement). Despite the existence of empirical evidence for the five dimensions, Hofer and Pintrich (1997) found some problems with some of Schommer's dimensions of speed of acquisition and control of acquisition. They held that these dimensions are concerned with the nature of learning and not the nature of knowledge and knowing. Hofer and Pintrich (1997) therefore suggested that there are four general epistemological dimensions including certainty of knowledge (stability), simplicity of knowledge (structure), source of knowing (authority), and judgement for knowing (evaluation of knowledge claims).

In addition to the developmental and the multidimensional models, other models have arisen. For instance, Hammer and Elby (2003) proposed a view of personal epistemology that is more situated and less stable and is referred to as the epistemological resources model. According to this model, individuals do not have a fixed set of beliefs but they rather have a range of resources for understanding knowledge. These resources are activated in different contexts and can be linked in a multiplicity of combinations. Chinn, Buckland, and Samarapungavan (2011) expanded a framework for models of epistemological beliefs based on the position of Hofer and Pintrich (1997) with a philosophical dimension. This framework consists of a network of interconnected cognitions that cluster into five distinguishable components. These are, epistemic aims and epistemic value; the structure of knowledge and other epistemic achievements; the sources and justification of knowledge of other epistemic achievements together with related epistemic stances; epistemic virtues and vices; reliable and unreliable processes for achieving epistemic aims.

The model by Conley et al. (2004) arose from other models (Elder, 2002; Hofer, 2000; Hofer & Pintrich, 1997) out of a desire to have a discipline-specific model that reflects what happens in science education where the use of evidence and justification of knowledge claims are an explicit focus of teaching. It marked the turning point towards a model with a specific focus in the domain of science. Scholars now opine that the multidimensional model of epistemological beliefs is significant in establishing whether views on science epistemological belief dimensions are separate and may develop in an asymmetrical fashion (Hofer, 2008; Kampa, Neumann, Heitmann, & Kremer, 2016; Lee, Liang, & Tsai, 2016; Lodewyk, 2007). The characteristics of students' science epistemological beliefs are intended to comprehend students' thinking and reasoning which may guide pedagogic practices in science classrooms. The present study, therefore, progresses in the model proposed by Conley et al. (2004).

Literature review

Literature in this section has been reviewed in terms of the relationships between epistemological beliefs and grade level and academic achievement.

Epistemological beliefs and grade level

Different studies have been carried out to establish the influence of grade level on the development of epistemological beliefs from a domain-general model perspective (Cano, 2005; Eren, 2007; Schuyten, 2005; Topkaya, 2015; Yenice, 2015). Cano (2005) carried out a study to investigate the changes in epistemological beliefs among Spanish secondary school students in middle, junior high and senior high grades using Schommer's questionnaire (Schommer, 1990). The findings indicated that throughout secondary education, epistemological beliefs undergo a change, becoming less naive and simplistic and more realistic and complex. Schuyten (2005) examined the influence of grade level on the development of epistemic beliefs in South California using multiple measures of Schommer-Aikins Questionnaire (Schommer-Aikins, Mau, Brookhart, & Hutter, 2000) and Conley et al.'s (2004) questionnaire among 6th and 8th graders in an urban middle school. The findings indicated little evidence that epistemic beliefs develop significantly across middle school years. A study by Eren (2007) examined the differences among epistemological beliefs of Turkish undergraduate year one and year two students who were pursuing fine arts teaching, physical education and business administration using Schommer's epistemological questionnaire (Schommer, 1990). The findings indicated that first years had more sophisticated effort beliefs than second years, while second years had more sophisticated unchanging truth beliefs than first years. Topkaya (2015) investigated how epistemological beliefs vary by grade level using Schommer's epistemological belief scale (1990) among Turkish pre-service teachers. The findings revealed significant differences between 1st and 4th graders in favour of first graders for social studies and science and technology pre-service teachers. Yenice (2015) carried out a study to investigate the relationships between epistemological beliefs of student teachers and grade level using a Turkish adapted version of Schommer's epistemological beliefs questionnaire (1990). The findings showed that grade level did not have a significant impact on the epistemological beliefs of the participants and their beliefs did not change based on grade level. The findings of these studies on the influence of grade level on epistemological beliefs are mixed and inconclusive.

Other scholars have endeavoured to carry out domain-dependent studies on epistemological beliefs particularly in science disciplines for instance Fatma (2009), Aydemir, Aydemir and Boz (2013), Shaakumeni (2019). Fatma (2009) set out to establish that epistemological beliefs are multidimensional and vary as a function of grade level among grade 6th, 8th and 10th among students of Ankara using the questionnaire by Conley et al. (2004). The findings revealed that epistemological beliefs develop over time. The 10th-grade students had more sophisticated beliefs in source of knowledge, certainty of knowledge and development of knowledge compared to 6th- and 8th-grade students. Aydemir, Aydemir and Boz (2013) carried out a study to investigate how Turkish grade 9 and 11 students change with grade level using the epistemological beliefs questionnaire by Conley et al. (2004). The results showed that students' epistemological beliefs became less sophisticated with respect to development and justification with an increase in grade level. On the other hand, 11th-grade students believed scientific knowledge may not always be correct (certainty). In a study by Shaakumeni (2019) to validate a questionnaire for assessing Namibian students' science epistemological beliefs grades 11 and 12 were examined using epistemological beliefs questionnaire by Conley et al. (2004). The findings indicated that there were statistically significant differences in beliefs about source and certainty in terms of grade level. The findings from these science domain-based studies are also equivocal. The uncertainty of the findings within the domain of science requires continuous investigation.

Epistemological beliefs and academic achievement

The relationship between epistemological beliefs and academic achievement have been studied using Schommer's domain general model of epistemological beliefs (Arslantas, 2016; Cano, 2005; Lodewyk, 2007; Ricco, Pierce, & Medinilla, 2010; Savoji, Niusha, &

Boreiri, 2013; Schuyten, 2005; Topcu & Yilmaz-Tuzun, 2009). Cano (2005) carried out a study to investigate the relationship between epistemological beliefs and academic achievement among Spanish secondary school students in middle, junior high and senior high grades using Schommer's questionnaire (1990). The findings indicated that epistemological beliefs influenced academic achievement directly. Schuyten (2005) examined the relationships among epistemic beliefs and academic performance for 6th and 8th graders in an urban middle school in South California using self-report measures of epistemic beliefs and students' science grades. The findings indicated that the development dimension was positively related to science grades. Lodewyk (2007) investigated the relationship between epistemological beliefs and academic performance using Schommer's questionnaire (1993) and students' academic scores from secondary school students of Western British Columbia. The findings indicated that the 'Fixed and Quick Ability to Lean' and 'Simple Knowledge' dimensions of the instrument were significantly related to the estimates of overall achievement. Topcu and Yilmaz-Tuzun (2009) carried out a study involving 4th-, 5th-, 6th-, 7th- and 8th-grade students to establish the relationship between epistemological beliefs and science achievement using the epistemological beliefs questionnaire of Schommer (1990). The findings revealed that the epistemological beliefs of students were associated with science achievement. Ricco et al. (2010) investigated the relationship between epistemological beliefs and science achievement grades among 6th-, 7th- and 8th-grade students of California using Schommers questionnaire (Schommer, 1990). The findings of regressions predicting science grade showed that the epistemic beliefs successfully predicted science achievement among early adolescents. Savoji et al. (2013) investigated the nexus between epistemological beliefs and high school students' academic achievement. The results of multiple regression analysis revealed that academic achievement can be predicted by dimensions of epistemological beliefs and motivational strategies. Among the dimensions of epistemological beliefs, knowledge stability and acquisition speed were negative predictors of academic achievement. Arslantas (2016) carried out a study aimed at identifying the relationship between teacher candidates' epistemological beliefs and academic achievement. An epistemological beliefs scale made of three dimensions was used. The findings showed that the teacher candidates' epistemological beliefs differed based on major. In addition, it was found that there was a statistically significant relationship between only one dimension of epistemological beliefs and academic achievement. The findings from the relationship between Schommer's domain-general model of epistemological beliefs and academic achievement revealed that different domains of epistemological beliefs were strongly related to academic achievement.

The relationship between epistemological beliefs and science achievement have also been investigated using Conley et al.'s (2004) domain-specific model of science epistemological beliefs (Chen & Pajares, 2010; Ozkan, 2008; Shaakumeni, 2019). Ozkan (2008) explored the relationships between elementary students' beliefs and their science achievement among 7th-grade students from Ankara. The findings indicated that students' epistemological beliefs predicted science achievement directly. Source and certainty dimensions predicted science achievement. Chen and Pajares (2010) investigated the relationships of epistemological beliefs with academic motivation and science achievement among 6th-grade students. The results from path analysis showed that epistemological beliefs played a mediating role between association of implicit theories of ability with achievement goal orientations, self-efficacy and science achievement. Greene, Cartiff, and Duke (2018) carried out a meta-analysis of non-experimental studies in literature and found epistemic cognition as measured predominantly in terms of beliefs was positively correlated with academic achievement, $r = 0.16$, $p < 0.001$and an effect size of 0.16 overall indicating small but meaningful relationship. Further, the instruments focussing on development and justification of knowledge had higher correlations with academic achievement than those focussed on constructs related to authority. In a study by Shaakumeni (2019) to explore the relationship between science epistemological beliefs and achievement in science, grades 11 and 12 were examined using Conley et al.'s (2004) epistemological beliefs questionnaire. The findings indicated the dimensions of certainty and justification statistically significantly predicted achievement in science. The findings of the reviewed studies have indicated varied relationships between different dimensions of epistemological beliefs and academic achievement. There is need for a continuous investigation of these constructs to unequivocally establish the relationships. There is also an implication of a research gap in this construct from an African perspective which is important for a holistic conception in terms of regions and at the same time further explore the epistemic beliefs versus achievement study.

Context of the study

The current structure of secondary education in Kenya consists of four years of secondary education and a minimum of four years of university education (Kenya Institute of Education, 2002) The schools implement a centralised national curriculum under the supervision of the ministry of education. After 4 years of secondary education, the students take a compulsory Kenya Certificate of Secondary Education (KCSE) examination which is administered by the Kenya National Examination Council (KNEC). Apart from summative assessment, clusters of schools organise joint assessment at the formative level. The performance of students in the national examination is a function of many factors and has been low. The table below shows students' percentage mean performance in Biology, Chemistry and Physics from the years 2013 to 2018.

As can be seen from the percentage mean performance above, the students' performance has been low for the six years. This implies that the students' scores in the years were more on the lower side of the distribution. This situation is of research significance to find out the correlates of learning and learning outcomes like science epistemological beliefs.

The current investigation

Contemporary researchers in epistemological beliefs have emphasised the significance of this construct in affecting cognitive and non-cognitive variables of learning either directly or indirectly in specific disciplines and general domains. At the same time, scholars in epistemological beliefs have in many instances sought to establish that changes in epistemological beliefs are as a result of age, grade level and time among

Table 1. Students performance in KCSE biology, chemistry and physics.

Subjects			
Year	Biology	Chemistry	Physics
2013	31.63	24.50	36.71
2014	31.82	32.15	31.31
2015	34.79	34.23	35.11
2016	29.18	23.71	39.76
2017	18.92	24.04	35.04
2018	25.69	26.88	34.27

Source: KNEC (2019).

other variables. The findings of most of these studies have been inconsistent. The current trend in epistemological research is to view the construct as multidimensional and variable in developmental trajectory. Secondly, it has been documented that students in Kenya continue to register low achievement in sciences as can be seen in Table 1 above. From a research perspective, it is significant to find out whether the nature of epistemological beliefs could be making a contribution to this low achievement in science. Not much research has been done in Africa and Kenya on this construct and its relationship to science achievement. The purpose of this study was to investigate the influence of grade level on the development of science epistemological beliefs and the relationship between science epistemological beliefs and science achievement among co-educational secondary schools in Kenya.

Research objectives

The study was guided by the following objectives.

(i) To determine the influence of grade level on the development of science epistemological beliefs
(ii) To identify the relationship between science epistemological beliefs and science achievement

Theoretical framework

There is a growing consensus that the concept of epistemological beliefs is multi-dimensional, multi-layered and context-sensitive (Buehl & Alexander, 2006; Hofer, 2016; Muis, Bendixen, & Haerle, 2006). That is, an individuals' epistemological belief system comprises multiple independent dimensions and may vary due to different levels of context specificity (Muis et al., 2006; Muis & Gierus, 2014; Schommer, 1990). In the same vein, Greene, Sandoval, and Braten (2016) recommended domain-specific approaches for doing these studies since there is evidence that epistemological beliefs may vary across different domains. The present study, therefore, limited its focus on students' epistemological beliefs in the science domain. In the domain of science, Conley and colleagues drawing from Hofer (2000) and Elder (2002) theorised that science epistemological beliefs consist of four dimensions and develop in asynchronous fashion (Conley et al., 2004). These dimensions are source of knowledge, certainty of knowledge, development of knowledge and justification of knowledge. These four dimensions represent two general areas at the core of individuals' epistemological theories. That is, beliefs about the nature of knowing and beliefs about the nature of knowledge. Source and justification dimensions reflect beliefs about the nature of knowing while certainty and development dimensions reflect beliefs about the nature of knowledge. Since the inception of Conley et al.'s (2004) model, most studies on science epistemological beliefs have been premised on their model, for instance Fatma (2009), Peer (2005), Aydemir et al. (2013), Sadi and Daygar (2015), Kampa et al. (2016), Lee et al. (2016) and Winberg, Hofverberg, and Lindfors (2019). The present study, therefore, adopted a multidimensional approach to personal epistemology in the context of science as theorised by Conley and colleagues and was conceptualised to be influenced by grade level and to be related to achievement in science.

Methodology

This section describes the research design for the study, the participants, the measures and the statistical analyses.

Research design

The study adopted a blend of cross-sectional and correlational survey designs. The cross-sectional survey model was significant in determining the developmental characteristic of epistemological beliefs in students of co-educational secondary schools at different grades (Fraenkel & Wallen, 2008; Gall, Borg, & Gall, 2003). This was done without manipulating variables. The correlational component was useful in establishing whether the variables of science epistemological beliefs and science achievement change together and their degree of change. Further, it was useful in identifying the predictive relationships of students' science epistemological beliefs and science achievement (Ary, Jacobs, & Razavieh, 1996; Fraenkel & Wallen, 2008).

Participants

The participants in this study were purposively drawn from two schools in Homa Bay County in grades 9 and 12. Purposive sampling is valuable where the characteristics of a population are known or abundant in the data intended for the study (Gall et al., 2003). This technique was used to ensure that only schools with requisite characteristics (grade 9 and 12) were part of the study sample. Since gender imbalances exist in some schools, care was taken during sampling to ensure that only schools that were balanced in terms of gender were included in the study. Data were therefore collected from grade 9 students at the point of entry in secondary education and grade 12 at the point of exit to establish change in epistemological thinking. There were 116 grade 9 students representing 54.20% and 98 grade 12 representing 45.80%. The same sample had 54.20% boys and 45.80% girls. The ages of grade 9 students ranged from 15 to 17 with a mean of 15.52 years. The ages of grade 12 students ranged from 18 to 20 with

Table 2. Sample size according to gender and grade level.

Grade	Gender	Total	Percentage
9	Boys	62	28.97
	Girls	54	25.23
12	Boys	54	25.23
	Girls	44	20.57
	Grand Total	214	100.00

a mean of 18.45 years. The sample for the study was therefore 214 students. Table 2 shows the sample size according to gender and grade level.

Measures

Two instruments were used in this study to collect data: Epistemological Beliefs Questionnaire (EBQ) and Science Achievement Scores (SAS).

Epistemological Beliefs Questionnaire (EBQ) was adapted from Conley et al. (2004) which was developed in the USA and was validated for use in Africa by Shaakumeni (2019). The validation involved rewording items to make them more meaningful in the African context. The questionnaire focused on science epistemological thinking. The questionnaire has 26 items with 4 dimensions as source (with 5 items), certainty (with 6 items), development (with 6 items) and justification (with 9 items). The participants rated the items on a 5-point Likert scale (with 1 = Strongly Disagree, 5 = Strongly Agree). The instrument was piloted in a school that was not participating in the study. Piloting revealed that the various dimensions had reliabilities as follows: source 0.83, certainty 0.80, development 0.71, and justification 0.78 giving an overall reliability of 0.78. The *source* dimension items measures beliefs about scientific knowledge residing in external authorities (for example, whatever the teacher says in science class is true). The *certainty* dimension refers to belief in a right or a wrong science answer (for example, all questions in science have one right answer). The *development* dimension concerns beliefs about science as an evolving and changing subject (for example, ideas in science books sometimes change). The *justification* dimension concerns the role of science experiments and how individuals justify knowledge (for example, it is good to try experiments more than once to be sure of your findings). The items for the *source* and *certainty* scales were reversed and consequently, scoring was reversed to reflect this. Higher scores in these scales, therefore, reflected epistemic competence. This instrument was administered to students in the two schools and in all the grades 9 and 12 and the investigator was assisted by the science teachers in the sampled schools. The instrument was administered for 30 min. The data were got in term 2 of the school calendar in Kenya.

Science Achievement Scores (SAS) were obtained from the schools where data were collected. The investigator obtained data about students' scores in Biology, Chemistry and Physics from official school documents. In Kenya, the practice is to examine students in all the subjects at the end of the term. It is also a common trend for a few schools to jointly evaluate students to enhance hard work and competition. In this regard, teachers come together, set exams, moderate and thereafter administer. The evaluation ends with joint marking and computation of results. The schools that were sampled did common standardised exams. A student's scores in Biology, Chemistry and Physics subjects were later computed/averaged to get a single Science Achievement Score (SAS).

Statistical analyses

The data from the questionnaire were subjected to statistical treatments according to the dimensions of the instrument. Each question in the questionnaire was worth a lowest score of 1 point and a highest score of five points. The highest scores were 25 for dimension of source, 30 for certainty, 30 for development and 45 for justification. Descriptive statistics were used to summarise raw data. Inferential statistics were used to test the research hypotheses. The hypotheses were accepted at a significance level of $\alpha = 0.05$. To determine the influence of grade level on the development of science epistemological beliefs, independent sample t-tests were carried out. The t-test is an inferential statistical procedure used to determine whether means of two samples are significantly different (Fraenkel & Wallen, 2008). The dependent variable (science epistemological beliefs) was data in ratio scale, the groups were mutually exclusive, there were no relationships between observations in each group and grade level consisted of two categorical independent groups. In this regard, independent sample t-test was appropriate for this analysis (Gall et al., 2003). To determine the relationship between science epistemological beliefs and science achievement, Multiple Regression Analysis was carried out (Fraenkel & Wallen, 2008; Gall et al., 2003). Multiple regression analysis was found robust in determination of the overall contribution of the dimensions of epistemological beliefs on achievement, the predictive ability of each of the dimensions of epistemological beliefs on science achievement and the significance of the epistemological beliefs in accounting for the variance in science achievement. Data analysis was conducted with the aid of Statistical Package for Social Sciences (SPSS) version 23.

Results

The first objective of this study was to determine the influence of grade level on the development of science epistemological beliefs. Pursuant to this, independent sample t-tests were carried out for each dimension of epistemological beliefs. Table 3 represents means, standard deviations, four separate independent sample *t*-tests for the four dimensions of science epistemological beliefs of grade 9 and 12 students, *p*-values and effect sizes.

Table 3. Independent sample t-tests by grade level and dimensions.

	Grade 9		Grade 12				
Dimensions	M	SD	M	SD	t-value	p-value	Cohen's d
Source	15.31	3.99	17.11	3.95	−3.28	0.001*	−0.441
Certainty	16.84	4.04	18.54	4.58	−2.87	0.004*	−0.387
Development	19.93	4.70	23.00	3.89	−5.12	0.000*	−0.665
Justification	34.29	5.12	35.37	5.28	−1.52	0.130	−0.207

*$p < 0.05$.

To test for the homogeneity of variances of the samples, Levene's test was used. The resulting p-values were greater than 0.05 showing that the variances of the samples were not statistically significant. Consequently, the t-tests are based on equal variances assumed. As can be seen from Table 3, the mean scores of the students in grades 9 and 12 were above the mid-points (12.5, 15, 15, and 22.5 for source, certainty, development and for justification, respectively) for all the dimensions. The scoring in the dimensions of source and certainty was done in the reverse. The grade 12 students had higher means scores compared to grade 9 students in all the dimensions of the epistemological beliefs. To determine whether these differences were statistically significant, independent sample t-tests revealed that there were statistically significant differences in terms of source of scientific knowledge $t\ (212) = -3.28$, $p < 0.05$; certainty of scientific knowledge $t\ (212) = -2.87$, $p < 0.05$; and development of scientific knowledge $t\ (212) = -5.12$, $p < 0.05$ all in favour of grade 12 students; However, there were no statistically significant differences between grade 9 students and grade 12 with regard to justification of scientific knowledge $t\ (212) = -1.52$, $p > 0.05$. The effect sizes as shown by Cohen's d values indicate that 44.1% of the variance in source of scientific knowledge, 38.7% of variance in certainty of scientific knowledge, 66.5% of variance in development of scientific knowledge and 20.7% of variance in justification of scientific knowledge were related to grade level.

The second objective of the study concerned identification of the relationship between science epistemological beliefs and science achievement. Pursuant to this, multiple regression analysis was done to establish the predictive ability of the various domains of epistemological beliefs on science achievement. A dichotomous variable of grade level (grade 9 and 12) was added to control for any grade level differences. Table 4 below shows the results of the output of multiple regression analysis with unstandardised coefficients (B-values) and standardised coefficients (β-values). These are unique variances that each of the predictors (dimensions of epistemological beliefs) made on science achievement. The t and p values are also shown.

Table 4 indicates that certainty ($\beta = 0.168$, $p < 0.05$), justification ($\beta = 0.162$, $p < 0.05$), and Grade level ($\beta = 0.198$, $p < 0.05$) positively predicted students' science achievement. On the other hand, source ($\beta = 0.041$, $p > 0.05$) and development ($\beta = 0.024$, $p > 0.05$) did not predict students' science achievement. The five predictors (Source, uncertainty, development, justification and grade level) taken together explained 13% of the variance in science achievement $F\ (5, 208) = 6.194$, $p < 0.05$. This shows that the regression model was a good fit for the data.

Table 4. Multiple regression analysis.

Variable	B-value	β-value	t-value	p-value
Source	0.120	0.041	0.566	0.572
Certainty	0.453	0.168	2.327	0.021*
Development	0.062	0.024	0.332	0.741
Justification	0.367	0.162	2.397	0.017*
Grade	1.564	0.198	2.846	0.005*

*$p < 0.05$.

Discussion

The descriptive statistics on the influence of grade level on the development of science epistemological beliefs have indicated that the participants of the current study generally had epistemic competence about the nature of knowledge and knowing. For each of the dimensions (i.e source, certainty, development and justification) the students obtained mean values that were above the midpoints. This might mean that the sampled students generally adapted their epistemic cognition to match their learning environment in all the dimensions of the epistemological beliefs. The effect sizes as shown by Cohen's *d* values indicated that there was a stronger relationship between the development of epistemological beliefs (source and development) and grade level. There were also statistically significant differences between grade 9 and 12 in epistemological beliefs in terms of source of scientific knowledge, certainty of scientific knowledge and development of scientific knowledge, but no statistically significant difference between grade 9 and 12 with regard to justification. The finding showed that grade level was related to source, certainty and development dimensions. This could be interpreted with caution in two ways: Since this study was carried in the context of learning environment, it is plausible to make interpretations in the light of the classroom context but with restraint. The characteristics of the learning environment are likely to have shaped the current epistemological beliefs. Previous studies have shown that the pedagogic environment in which learners are exposed contributes directly or indirectly to the development of epistemological beliefs (Schommer, 1993; Cano, 2005; Schommer-Aikins & Easter, 2006). Consequently, as students experienced the pedagogic environment, their epistemological beliefs are likely to have evolved. Secondly, since there were age differences between grade 9 and 12 students, this may have also contributed to the difference in students' epistemological beliefs. Previous studies have shown that age and level of education predict epistemic change (Schommer-Aikins et al., 2000; Schuyten, 2005). A finding of this study also indicates that grade 12 students showed more epistemic adaptiveness than grade 9 with regard to justification, however, this was not statistically significant. This finding was unexpected; However, it might be attributed to pedagogic experiences that the students were being exposed to. At grade 9 level in the Kenyan system of education, the students are being introduced to the nature of science in different domains of Biology, Chemistry and Physics. At the introductory level in these domains of science, the students are taken through the requirement that claims to scientific knowledge need to be justified through the process of experimentation (Kenya Institute of Education, 2002). This introduction of grade 9 students to the practical aspects of science could have contributed to their epistemic adaptiveness being proximal to grade 12 at this stage. This also supports previous findings that domains of epistemological beliefs have a non-symmetrical developmental trajectory.

These findings are consonant with the findings of Schuyten (2005) with regard to certainty of knowledge; Fatma (2009) with regard to source, certainty and development of scientific knowledge; Findings of Aydemir et al. (2013) with regard to source and certainty of scientific knowledge; and the findings of Roya and Abdorreza (2014) and Shaakumeni (2019) with regard to 'certainty of knowledge'. The finding of the current study departs from the findings of Aydemir et al. (2013) with respect to 'justification' and ‘development’ of scientific knowledge which indicated that students’ epistemological beliefs become less adaptive with an increase in grade level. The digression of this finding might be related to the specific classroom context in which this study was undertaken and the Turkish cultural context of the study (Buehl & Alexander, 2006; Greene et al., 2016; Muis et al., 2006).

The finding on the relationship between science epistemological beliefs and ‘science achievement’ indicated that certainty and justification dimensions of the epistemological beliefs were significant predictors of science achievement. On the other hand, source and development were not significant predictors of science achievement. This means that the students’ beliefs in uncertainty and beliefs in the significance of experiments in justification of knowledge claims positively predicted science achievement. The finding also means that the students’ beliefs about where scientific knowledge comes from and their beliefs on whether science is evolving or not did not predict their science achievement. Even though certainty and justification predicted science achievement, the correlational and cross-sectional nature of the study precludes making strong inferences. The findings are therefore carefully interpreted in relation to students’ curricular experience in the Kenyan secondary school context in two ways: First, there are usually no multiple choice questions in examinations that focus the students’ thinking on one correct answer as is the case in primary schools. Secondly, the science curriculum at the secondary school level emphasises data collection, making observations and making claims using evidence. It is possible that this kind of pedagogic setting contributed to epistemic competence in this dimension.

The non-predictive ability of source and development in this study was unexpected; It had been anticipated that epistemic adaptiveness would be associated with science achievement. The present findings indicate that relations between epistemological beliefs and achievement may be more complex than anticipated. This could also be interpreted in the light of independence of development of dimensions of epistemological beliefs as elucidated by Schommer (1990). Students may believe that scientific knowledge resides in authorities and at the same time believe that science is an evolving subject. This finding is in concurrence with other studies which have not revealed positive relationships with all the dimensions of epistemological beliefs. For example, Shaakumeni (2019) which revealed that ‘certainty’ and ‘justification’ positively predicted science achievement whereas ‘source’ and ‘development’ negatively predicted science achievement. Schommer (1990) found that ‘certain knowledge’ predicted appropriate absolute conclusions (achievement).

The current findings depart from other studies. For instance, Ricco et al. (2010) found out that the dimension of ‘knowledge as developing’ made significant contributions to science grades (achievement). Schuyten (2005) found that the dimension of ‘development of knowledge’ was positively related to students’ science grades (achievement). The findings of the relationship of the dimensions (certainty and justification) and science achievement in this study further support the earlier findings that epistemic competence contributes to higher academic achievement. The findings also support what extant literature indicates that different dimensions of epistemological beliefs correlate differently with academic achievement. This could be attributed to the differences in cultural and classroom contexts where the studies are done. The differences in positive relationships between different dimensions and science achievement further support the multidimensional and asymmetrical or asynchronous developmental characteristic of epistemological beliefs that have been documented in literature.

Conclusions and recommendations

The findings of the study point to the following conclusions: First, the science epistemological beliefs of the students in grade 12 were more adaptive than grade 9. Secondly, epistemological beliefs of the domains of certainty and justification were predictors of science achievement.

The study recommends the following for practice and research: First, for practice, there is a need for teachers to deliberately create learning environment experiences or contexts that engender epistemic competence. Barger, Perez, Canelas, and Linnenbrink-Garcia (2018) found out that constructivist learning environment can shape epistemic beliefs and serve as a way of fostering epistemic change. This can be done by providing for knowledge construction out of active, sensual and perceptive experiences of the learner (Kim, 2005). In a constructivist learning environment, the learners are engaged by teachers on inquiry activities in an effort to explore phenomena, construct and reconstruct models in the light of results of scientific investigations (Peffer & Ramezani, 2019). On the other hand, since there was a relationship between grade level and epistemic change, there is need to provide appropriate learning experiences within the grades to enable the learners to adapt their thinking to the norms of the classroom context at that time.

Secondly, in terms of research, more studies need to be done on specific science disciplines. Despite the fact that all science disciplines share certain commonalities in the path of knowledge generation, there are intra-discipline variations that can engender different pathways of epistemic development. These variations can only be elicited at the point of research. In the same vein, more multi-method studies based on longitudinal research designs need to be done to build a more comprehensive picture of relationship between science epistemological beliefs and grade level and science achievement.

Limitations

The utilisation of self-report measures that focus the learners on particular aspects of epistemological beliefs may have revealed more epistemic competence than would not have happened in the case of other instruments like interviews. The sampling was also purposively done in two co-educational schools and this limits the generalisability of the findings to the wider populations within the county. Generalisations to wider populations would also require more extensive studies across different schools. Lastly, the correlational and cross-sectional design of this study prevents making strong inferences and only allows for a restrained interpretation of the findings as has been alluded to earlier.

Disclosure statement

The author declares no competing interests in this study.

Notes on contributor

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