


THE IMPACT OF SCIENTIFIC EPISTEMOLOGICAL BELIEFS OF SRI LANKAN SENIOR SECONDARY STUDENTS ON THEIR APPROACHES TO LEARNING SCIENCE: A STRUCTURAL EQUATION MODELLING ANALYSIS




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ABSTRACT

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In recent years, there has been a growing interest among researchers on students' epistemological beliefs and learning approaches which are considered as important predictors of academic achievement. The aim of present study was to ascertain the relationship between Sri lankan senior secondary students' scientific epistemological beliefs and approaches to learning science. The sample included 415 students from western province of Sri Lanka. The partial least square-structural equation modelling (PLS-SEM) was employed to ascertain the relationships. The results revealed that sophisticated scientific epistemological beliefs of senior secondary students predict their deep learning approaches while less sophisticated scientific epistemological beliefs predict the surface approaches. The findings provide important implications for science learning – teaching process and curriculum reforms.

1. INTRODUCTION

Science education is essential for the betterment and development of every country. Science as a subject provides an essential component of core knowledge that every member of our society requires and it develops individual's abilities, creativity, curiosity, problem solving and abilities for facing challenges. It is commonly believed that science education should be effective and relevant for a large diverse group of the population. It can be achieved by modifying how students think, understand and apply the knowledge of science appropriately (Weiman, 2005). The Science as a subject in school system particularly at secondary level is very important for students of the 21st century as it is considered as the gateway to the opportunities and benefits of economic and social development and it is further considered as the "keystone of education system" (Iftekhhar, 2013). However, in general, the low academic performance of students for the subject science is considered as a vital issue in many countries specially in economically developing countries including Sri Lanka (ICSU, 2011). At the senior secondary level the subject 'Science' is considered as a core subject in which biology, physics and chemistry are integrated. It is reported that, Sri Lankan secondary student achievement rate for the subject Science at the G.C.E (General Certificate of Education) Ordinary Level (O/L) examination is considerably low (Department of Examination, 2016). It is alarming to comprehend that, still nearly 30% of students who sits for this examination is not able to obtain a mere simple pass. In addition, amongst the students who pass the examination, only a small percentage obtains the higher grades (DoE, 2016). Moreover, this situation is further confirmed by poor rank of Sri Lanka in terms of

science education. Hence, these students are lack of required scientific skills in applying their knowledge into practice (World Bank, 2014). Numerous studies have been conducted in many countries to empirically ascertain the reasons for the low level of achievements in science. It has been revealed that, among various factors that determine the outcome of any educational endeavour, cognitive factors such as students' epistemological beliefs, conceptions of learning and approaches to learning are similarly important for student performances (Savoji *et al.*, 2013; Arslantaş, 2015). Moreover, there is overwhelming evidences for the notion that students' epistemological beliefs determine their learning orientation and academic achievement (Kadivar *et al.*, 2011). Nevertheless, studies in exemplifying the relationship between epistemological beliefs and learning approaches related to science learning are still scant and deficient in the non-western cultural contexts resulting in a great demand of such studies. In the context of Sri Lanka, less attention has been paid by researchers and curriculum developers to these psychological factors which can cause low achievement of students. If epistemological belief systems of students is ignored, naive beliefs drive learner to view science as an infallible knowledge and a body of absolute facts or received knowledge. It also can lead to ineffective learning strategies and learning outcomes. Similarly, if the teaching-learning process becomes a trend of rote memorization, it will be resulted in students with lack of scientific and innovative skills (Tsai, 1998). Hence, such studies are of prime importance with respect to improvement of academic achievement of students. Conversely, it is reported that an effective transition from traditional to constructivist epistemology and pedagogy is a timely need. Hence, the curriculum developers will be able to take necessary actions to change the existing syllabi and teachers' guides of the subject science based on the findings of present study. The findings of the study provides awareness for teachers and other relevant personnel of education system in order to improve the achievement rate of students and strengthen them with scientific and innovative skills. Similarly, the findings provides implications to improve teacher quality by giving special attention to these psychological factors during training of teachers.

1.1. Epistemological Beliefs

Belief is a state or habit of mind in which trust or confidence is placed in some person or thing (Belief, n.d) Along similar lines, Bandura and Walters (1977) argues that the beliefs are stronger than the effects of experiences and particularly more effective than real experiences in building human behaviour. Hence beliefs are important in learning which can drives learner towards achievements. Students with favourable beliefs are more likely to achieve high learning gains. Students' epistemological beliefs are specifically related to their problem solving, conceptual change, reasoning modes, decisions and learning strategies when encountering a new situation (Lee and Yuan, 2012). Perry's work is the initial effort in 1990 to introduce epistemological beliefs and he put forwarded the view that epistemological beliefs are a core set of beliefs about knowledge and knowing that develop from simple and certain to complex and relativistic (Alsumait, 2015). Several theories have been developed based on Perry's model. Hofer and Pintrich (1997) have suggested four dimensions for epistemological beliefs namely, certainty of knowledge, development of knowledge, source of knowing and justification of knowing. Nature of knowing concerns the beliefs about how individuals acquire knowledge and it involves "source of knowing" and "justification of knowing". The "source of knowing" involves the beliefs about source from which the knowledge is acquired, whether it is from authority or individual construction. The believing that the knowledge come from reasoning, thinking and experimenting is related to "justification of knowing". Conversely, the beliefs about the nature of knowledge includes "certainty of knowledge" and "development of knowledge". The beliefs about "Certainty of knowledge" involves students' believing about the correct answers. Moreover, the beliefs about the evolving and changing nature of knowledge are involved in the dimension "development of knowledge" (Tabak and Weinstock, 2005; Otting *et al.*, 2010; Alsumait, 2015).

1.2. Scientific Epistemological Beliefs (SEB)

In addition to personal epistemological beliefs, there has been an increasing research on epistemological beliefs particularly in the field of science learning. The scientific epistemological beliefs of students have been found to play an important role in determining their learning orientations towards science (Kapucu and Bahçivan, 2015). It can shape their meta-learning assumptions and thus influences their learning orientations. Moreover, it has been found that students with more sophisticated SEBs have used more meaningful approaches to learning science and have more intrinsic motivation toward science learning than those with less advanced SEBs (Liang *et al.*, 2010). Thus it can be concluded that students' SEBs regulate the acquisition of their scientific knowledge and its process. The questionnaire named 'Scientific epistemological beliefs (SEB) survey' was developed in 2004 by Conley and others for large sample of students. The SEB survey was the tool most commonly used in studies to assess scientific epistemological in students as well as teachers. All these dimensions were basically consistent with Hofer and Pintrich's four general epistemological dimensions. The questionnaire includes a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The higher the score the more the sophistication of beliefs they hold. The source and certainty scales were reverse coded in order to obtain higher scores for more sophisticated beliefs (Conley *et al.*, 2004). This questionnaire has been used by researchers to study elementary or high school students' SEBs (Abedalaziz *et al.*, 2013; Kapucu and Bahçivan, 2015). Items under each dimensions are created in such a way that students are asked about how they believe in knowledge and knowing using simple statements.

1.3. Approaches to Learning Science (ALS)

Learning approaches refer to as how students perform learning, with their intentions (motives) and their methods or strategies applied for learning (Biggs, 2011). Since the approaches adopted by students for learning has been found to be a predictor of their academic achievement, it is an important factor to be considered in education context. Marton and Säljö (1976) used a phenomenographic method to ascertain qualitatively different ways in which students approach a reading task. Students were asked questions about the meaning of certain passages and how they set about reading the passages. Initially instead of using the term 'approaches to learning' the outcomes were referred as "levels of processing". It was subsequently changed to 'approach' which includes both process and the intention behind the process (Irving, 2010). They found that students' skills on reading comprehension depends on two different levels of processing; surface level processing and deep level processing. The surface level focuses on the text itself (the sign) and deep level focuses on the internal content of the learning material (what is signified) (Zeegers, 2001). The research findings of Marton and Saljo on learning approaches were substantiated by various researchers. Students who adapt surface approach used low cognitive activities when higher cognitive activities are required to perform a learning task. Hence, surface approach directs students to superficial retention of material for examination and it does not promote understanding or long-term retention of knowledge and information (Biggs and Tang, 2003). In the deep approach, the intension of the learner is to extract the meanings and it involves relating ideas and searching for patterns and principles (Entwistle, 2003). In general, learning approaches implies motive (intention to learn) and the use of learning strategies to fulfil this motive (Biggs, 1987). As such, it is further classified as Surface motive, Surface strategy, Deep Motive and Deep Strategy based on the components of motive and strategy.

Deep motive approach involves intrinsic study to actualize interest and competence in particular academic subjects. In contrast, surface motive approach is extrinsic and instrumental and main purpose is to meet requirement minimally (Biggs, 1987). Deep strategy involves utilizing more meaningful strategies such as making connections and coherent understanding. Surface strategy approach involves more rote-like strategies such as remembering or narrowing targets (Chiou *et al.*, 2012).

1.4. The relationship between Scientific Epistemological Beliefs and Approaches to Learning Science

Studies have shown that the students' epistemological beliefs influence on their learning approaches and subsequent learning outcomes (Rodriguez and Cano, 2007; Kizilgunes *et al.*, 2009; Ismail *et al.*, 2013; Lee *et al.*, 2016). Among these research, there has been a growing concern particularly on research related to the domain of science. Researchers revealed that the students with more sophisticated scientific epistemological beliefs tend to employ more meaningful approaches to learning science. It has been also revealed that the students with less complex epistemological beliefs were found to be more inclined using surface learning approaches (Rodriguez and Cano, 2007; Lee *et al.*, 2016). Nevertheless, most of these studies are focused on high school and university students but less focused on senior secondary students. Moreover, many studies were related to general learning while only few studies were related specially to the domain science. Conversely, the literature provides evidences for the relationship between scientific epistemological beliefs and approaches to learning science in different learning contexts.

2. DATA SOURCE AND VARIABLE MEASUREMENT

2.1. Source of Information

The study sample included 415 senior secondary (leading to General Certificate of Ordinary Level Examination) students from government schools in Western Province of Sri Lanka. Western Province represents comparatively highest number of senior secondary students (117,157) and it is nearly one third (28.4%) of total number of population of secondary students in Sri Lanka. Further, it represents all school types of Sri Lanka. The sample consisted of 38.9 % male students and 61.1% female students. Considering the grade level, 47.6% of students was in Grade 10 and 52.4% of students in Grade 11.

Stratified proportionate sampling was applied for the selection of schools from each district of western province as the first stage and for the selection of schools from each school type as the second stage. The next two stages of sampling were performed by simple random sampling method to select classes from each school and students from each class.

2.2. Variable Measurement

The main variables used in this study are scientific epistemological beliefs, conceptions of learning and approaches to learning science. The exogenous variable was scientific epistemological beliefs which included four dimensions; source of knowing, certainty of knowledge, development of knowledge and justification of knowing. The endogenous variable was approaches to learning science that consisted of dimensions surface approach and deep approach. Students' conceptions of learning was considered as the mediator variable that included two dimensions, reproductive conceptions and constructive conceptions.

The SEB survey developed by Conley *et al.* (2004) was used to explore scientific epistemological beliefs of students. The approaches to learning science (ALS) questionnaire developed by Lee, Johanson, & Tsai in 2008 was administered to these students to measure their approaches to learning science. Both questionnaires were translated into Sinhala language using translate and back-translate method. The SEB questionnaire consists of possible answers, ranging from 'strongly disagree' to 'strongly agree' provided on a 5-point Likert scale. The ALS questionnaire consists of questions with possible answers, ranging from 'never' to 'always,' provided on a 5-point Likert scale.

3. RESEARCH METHODOLOGY

The survey research design and quantitative approach was applied by the authors. It involved structured collection of data from a sizable population which were then subjected to rigorous quantitative analysis. The

Structural Equation Modelling by Partial Least Square (PLS-SEM) method was performed to analyse the measurement model and structural model using SmartPLS2.0. The SEM approach was used as it enables the researcher to analyse the relationships among several latent variables simultaneously. The analysis of the model mainly involved two steps. The first step includes the analysis of internal consistency reliability, the convergent validity and discriminant validity of the constructs. In the second step the structural model was analysed using bootstrapping and blindfolding methods.

4. STUDY FINDINGS

4.1. Levels of Senior Secondary Students' Scientific Epistemological Beliefs, Conceptions of Learning and Approaches to Learning Science

The mean value of scores for each dimension of scientific epistemological beliefs were calculated and presented in Table 1. The epistemological beliefs of the students can be categorized as Traditional (underdeveloped) beliefs for the scores 1.0 – 2.5; Mixed (Medium Level) beliefs for the scores 2.6 - 3.5 and developed (contemporary) beliefs for scores 3.6 - 5.0. However the mean value 4 or more is required to consider that individuals have sophisticated scientific epistemological beliefs (Ozbay and Köksal, 2016).

Table-1. Mean score for dimensions of Scientific Epistemological Beliefs

Variable	Dimension	Mean	Std.Deviation
Scientific Epistemological Beliefs	Source of Knowledge	3.20	0.113
	Certainty of Knowing	3.08	0.444
	Development of Knowledge	3.13	0.002
	Justification of Knowing	3.27	0.003
Approaches to Learning Science	Deep Motive	3.16	0.780
	Deep Strategy	3.21	0.808
	Surface Motive	3.27	0.897
	Surface Strategy	3.37	1.101

In the present study the mean values for each dimension of scientific epistemological beliefs were within the range of 2.5-3.5 and it indicates that in average, the beliefs of students are neither sophisticated nor developed but mixed (medium level). The mean values for learning approaches indicates that they have occasionally adapted both surface and deep approaches including motives and strategy resulted in a mixture of these four types of approaches (Table 1).

4.2. Evaluation of Measurement Model

4.2.1. Internal Consistency Reliability

The internal consistency of the items is determined by composite reliability and cronbach's alpha values. The composite reliability values between 0.70 and 0.90 can be regarded as satisfactory while the value below 0.6 indicates a lack of internal consistency reliability. In the present study composite reliability as well as Cronbach's alpha values of all items were above 0.7 which indicates the internal consistency reliability of the constructs (Table 2).

Table-2. The Quality Criteria of Measurement Model

Construct	AVE	Composite Reliability	R-Squared	Cronbach's Alpha
Source of Knowledge	0.5569	0.8621		0.7997
Justification of Knowledge	0.6326	0.9392		0.9271
Certainty of Knowledge	0.5681	0.8396		0.7454
Development of Knowledge	0.6081	0.9023		0.8695
Deep Motive	0.4976	0.8313	0.1292	0.7464
Deep Surface	0.5283	0.8169	0.1886	0.7048
Surface Motive	0.5723	0.8694	0.2921	0.812
Surface Strategy	0.5944	0.8539	0.2708	0.7758

4.2.2. Validity of the Constructs

The convergent validity is the extent to which a measure correlates positively with alternative measures of the same construct and it is established by the average variance extracted (AVE). Moreover, AVE is the degree to which a latent construct explains the variance of its indicators. The AVE value of 0.50 or higher indicates that, on average, the construct explains more than half of the variance of its indicators. Generally, indicators with outer loadings between 0.40 and 0.70 should be considered for removal from the scale only if the removing of the indicator leads to increase the composite reliability and AVE (Hair *et al.*, 2014). In the present study outer loadings for three indicators were between 0.4 and 0.7 and removal of them resulted in increased AVE (AVE>0.5) which confirms convergent validity of the construct. The extent to which a construct is truly distinct from other constructs is known as discriminant validity. It was determined by the comparison between outer loadings on the associated construct and outer loadings on other constructs which is referred to as cross loadings. The outer loadings on the associated constructs were greater than all of its cross loadings which is a criteria to be satisfied in order to get the discriminant validity (Hair *et al.*, 2014). Hence, based on the cross loadings it can be considered that the discriminant validity of the constructs of present study was confirmed.

4.2.3. The Structural Model

The relationships of the structural model is determined by path coefficients which represent the hypothesized relationships among the constructs. The path coefficient (Beta value) indicates the extent to which the exogenous construct is associated with the endogenous construct. However the significance of the association is determined by t-statistics which is calculated by bootstrapping with 5000 re-sampling as suggested. Significance of associations is indicated by the critical values for a two-tailed test that are, 1.65 (significance level = 10%), 1.96 (significance level = 5%), and 2.57 (significance level = 1 %) (Hair *et al.*, 2014). The T statistics of the respective hypothesis, beta value and standard error are shown in Table 3.

Specifically, considering the relationships, it is shown that the sophistication of beliefs about source of knowing and certainty of knowledge predict the deep motive approach. Sophisticated beliefs on justification of knowing predict both deep motive and deep strategy approaches while these beliefs negatively predict surface motive and surface strategy approaches. Comparing path coefficients, it is indicated that the justification of knowing has a greater positive effect on both deep strategy approach ($p=0.31$) and deep motive approach ($p=0.30$) than other beliefs. Moreover it also has a negative effect on surface strategy approach.

Table-3. Significant Testing Results of the Structural Model Path Coefficients

Path	Path Coefficient	T statistics
Source of Knowing -> Deep Motive	0.16	2.16**
Source of Knowing -> Deep Strategy	0.07	1.11
Source of Knowing -> Surface Motive	-0.51	9.65***
Source of Knowing -> Surface Strategy	-0.50	9.41***
Certainty of Knowledge -> Deep Motive	0.13	1.84**
Certainty of Knowledge -> Deep Strategy	0.04	0.67
Certainty of Knowledge -> Surface Motive	-0.05	0.87
Certainty of Knowledge -> Surface Strategy	-0.01	0.05
Development of Knowledge -> Deep Motive	0.04	0.61
Development of Knowledge -> Deep Strategy	0.15	2.34**
Development of Knowledge -> Surface Motive	-0.04	0.61
Development of Knowledge -> Surface Strategy	-0.04	0.63
Justification of Knowing -> Deep Motive	0.30	4.89***
Justification of Knowing -> Deep Strategy	0.31	5.00***
Justification of Knowing -> Surface Motive	-0.26	4.39***
Justification of Knowing -> Surface Strategy	-0.18	3.07***

* $p<0.1$ ** $p<0.05$ *** $p<0.01$;

SK-Source of Knowledge; CK-Certainty of Knowledge

DK-Development of Knowledge; JK-Justification of Knowing; DM-deep motive;

DS-deep strategy; SM-surface motive; SS-surface strategy.

In contrary, sophistication of source of knowledge and certainty of knowledge showed a greater negative effect on surface motive approach ($p = -0.51$) as well as on surface strategy approach ($p = -0.50$). These relationships are shown in the structural model of the present study (Figure 1).

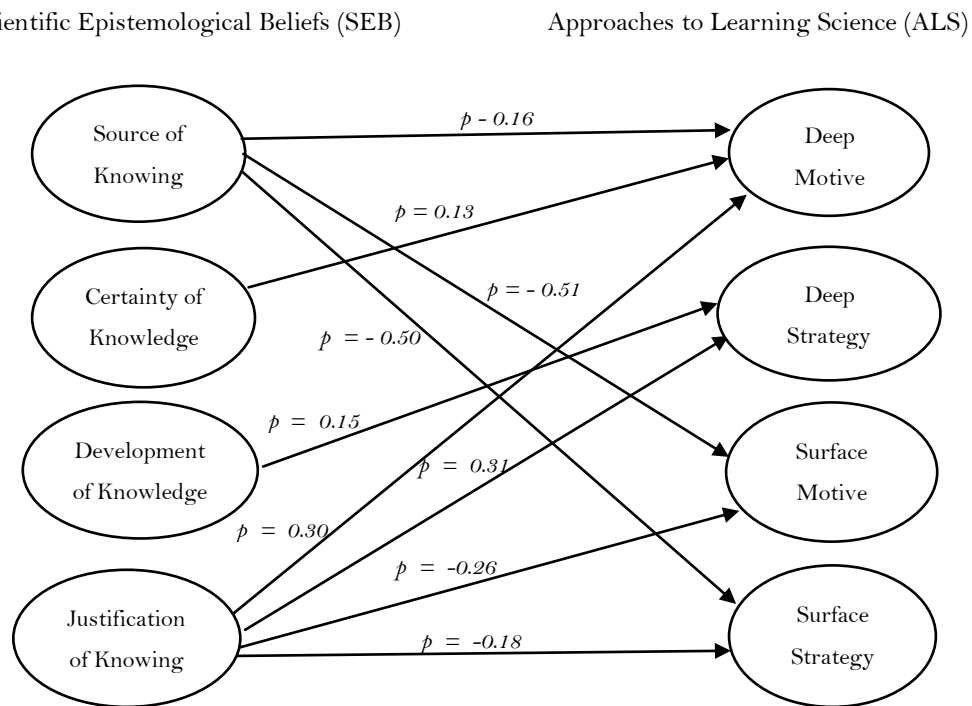


Figure-1. Structural Model with Path Coefficients

The coefficient of determination which is indicated by R^2 , is critical for evaluating a structural model (Memon and Rahman, 2013). The explaining power of the model is considered as substantial if $R^2 \geq 0.26$, moderate if $R^2 \geq 0.13$ and weak if $R^2 \geq 0.02$ (Cohen, 1988). As such, the structural model of the present study shows moderate level explaining power for deep motive and deep strategy approaches while it indicates substantial level power for surface strategy and surface motive approaches (Table 2). In order to evaluate how well the structural model predicts the data, the predictive relevance was calculated using blindfolding which was used to obtain cross-validated redundancy measures for each endogenous construct. The value for predictive relevance should be higher than zero (Hair et al., 2014). The endogenous constructs of the present study obtained the values higher than zero for predictive relevance (Table 4). Hence it indicates the ability of the model to predict the approaches to learning science.

Table-4. Construct Cross-validated Redundancy

Endogenous Construct	Predictive Relevance
Deep Motive	0.06
Deep Strategy	0.10
Surface Motive	0.17
Surface Strategy	0.16

5. CONCLUSIONS

The present study revealed that the senior secondary students' hold mixed scientific epistemological beliefs which are neither developed nor sophisticated. Similarly, these students adapted both surface and deep approaches occasionally. The analysis of the structural model resulted in significant relationships between Scientific Epistemological Beliefs and Approaches to Learning Science. Overall, the results showed that with the

advancement of these beliefs towards sophistication, students tended to adapt meaningful (deep) learning approaches. In contrast, with holding less sophisticated and naïve beliefs they have become more inclined to adapt surface approaches for learning science. It parallels the recent study on Taiwan College students in relation to biology learning (Lee *et al.*, 2016). Specifically considering the types of epistemological beliefs, it was found that the secondary students with less sophisticated beliefs about source of knowing i.e. believing that scientific knowledge is processed by authority/experts, have shown a tendency to adapt both surface motive and surface strategy approaches. Similarly, the students who have not believed that the knowledge is certain and always has a correct answer but believed the uncertainty of knowledge (less sophisticated beliefs on certainty of knowledge) tended to adapt deep motive approaches. This finding also parallels that of the study conducted by Liang *et al.* (2010) and Chan (2007). Furthermore, it is interested to report that the more the students believe that the scientific knowledge develop from reasoning, thinking and experimenting (justification of knowledge), the higher the frequency they adapt both deep motive and deep strategy approaches but lesser the frequency of adapting surface motive and surface strategy approaches. In addition, the more the student believe that science as an evolving and changing subject the higher the frequency of adapting deep motive and deep strategy approaches.

In Sri Lanka, curriculum is reformed in every 7 years. The learner-centered constructive learning-teaching methodology has been introduced in 2007 and still it is recommended to implement. However, besides these reforms still the class room learning-teaching process is dominant by teacher centered lecture method. Aforementioned educational environment which can develop students' naïve beliefs such as knowledge is derived from external source might have resulted in mix beliefs of senior secondary students. Researchers emphasize that, if the epistemological belief systems of students is ignored, then it can lead to ineffective teaching strategies and learning outcomes (Marra and Palmer, 2008). The present study reflects the need for improvement of students' scientific epistemological beliefs towards more sophistication beliefs system. Explicitly, the belief about development of knowledge which is the factor measures the belief about science as an evolving and changing subject and the belief about Justification of Knowledge which is the factor concerns the role of experiments and how individuals justify knowledge should be further developed in secondary students in order to direct them towards meaningful learning approaches. This study contributes to knowledge required for the education system including educationists, educational researchers and curriculum developer about the relationship of secondary students' scientific epistemological beliefs and approaches to learning science. Furthermore, it contributes to the development of science curriculum in secondary grades. The content of the science curriculum can be improved and recommended teaching-learning techniques can be revised in the way that it develops sophisticated beliefs. Effective lessons/activities can be integrated to the curriculum of teacher training courses in training colleges for guiding student-teachers to develop sophisticated beliefs and promote meaningful learning approaches. Findings further confirms the need for promoting and encouraging constructive learning-teaching process for science at secondary education which has been already recommended to the school curriculum in 2007. Teacher trainers can organize training programs addressing the importance of the relationship between scientific epistemological beliefs and approaches to learning science. The study further contributes to improve the assessment & evaluation methods in order to discourage the rote learning style of students. Similarly it contributes to provide an awareness for policy makers who take policy decisions regarding intervention programs to enhance the achievement of senior secondary students for the subject science. Overall, this paper provides a greater evidence for the importance of the relationship between students' scientific epistemological beliefs and their learning approaches and it contributes in existing literature.

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