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PRE-SERVICE TEACHERS' SCIENTIFIC EPISTEMOLOGICAL BELIEFS: DOES THE DISCIPLINE MATTER

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Abstract

The purpose of this study was to examine whether chemistry and social science pre-service teachers have different scientific epistemological beliefs. A multi-dimensional instrument developed by Elby, Frederiksen, Schwartz and White, was used to assess differences in pre- service teachers' scientific epistemological beliefs regarding various dimensions of EBAPS. A total of 71 pre-service teachers of chemistry (n=33) and social sciences (n=38) attending University of Munich participated in this investigation. Results indicated that chemistry pre- service teachers have statistically significantly different and more sophisticated beliefs than social science pre-service teachers on dimensions of structure of knowledge and knowing, nature of knowing and learning and real life applicability. On source of ability to learn and evolving knowledge dimension, the difference between chemistry and social science (Psychology, economics & social studies) domains was not statistically significant. Findings of this study imply that chemistry pre-service teachers have more understandings about limits, nature and assumptions of scientific knowledge of physical sciences because they are more knowledgeable about physical science content.

Introduction

According to (Mason & Broome, 1997), Epistemological beliefs can be defined as the general beliefs about the nature of knowledge and knowing. Schommer has also included nature of learning in her definition of epistemological belief (Schommer, 1993). Research on teachers epistemological beliefs did not cover each and every domain comprehensively and still a lot of work has to be done to get to the point of knowledge which can be used to compare and contrast epistemological belief differences between and within different academic domains (Hofer & Bendixen, 2012). We can achieve this when we know the background of the teachers' epistemological beliefs in their respective domains (Hellmann et al, 2014).

The interest of educational psychologists in the area of epistemological development has been increased in the last two decades (Hofer, 2001). According to (Nicholas & Williams, 2010), one main question which became the focus of inquiry in the epistemological developmental research was that, Is there any implications of epistemological development on learner motivation, student achievement and other areas of development including teaching and learning? What kind of instructional practices are linked to different epistemological beliefs across various academic domains. Is there any relationship between teachers' instructional practices and students' epistemological belief development.

Exploring and knowing about the pre-service teachers' epistemological beliefs in their respective academic domains and other than their own not only give more validity and successful implementation to the constructivists teaching programs (Lee & Schallert, 2016) but also enable the student teachers to compare and contrast different epistemic beliefs related to

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various domains of knowledge . This meta-reflection of epistemological beliefs give them more clarity about their own beliefs. What kind of influences this interdisciplinary epistemological awareness will have on instructional practices of teachers and students' epistemological development is a promising future research area (Muis et al, 2006).

The studies conducted by Jehng, Johnson and Anderson (1993) & Paulsen & Wells (1998) reports that contradiction exists among the researchers over the issue of academic domain specificity. The researchers in favor of social science majors states that the social science major students hold sophisticated beliefs about the certainty of knowledge i.e they consider knowledge of science to be uncertain as compared to the natural science students . Whereas the results of the study conducted by schommer shows that students in natural science majors hold more sophisticated views as compared to the social science majors (Liu & Tsai, 2008). The studies conducted by Chandler, Horvath and Backus (2003); Buehl, Alexander and Murphy (2002); Knight and Mattick (2006) on the students' epistemological beliefs across different disciplines have found evidence in favor of the domain specific nature of epistemological beliefs.

Royce & Mos (1980), also found epistemological differences as well as differences with respect to nature, limits and justification of knowledge after administering PEP to university professors. Professors from literature & arts leans towards metaphoric epistemology, of natural sciences i.e chemistry and biology towards empirical epistemology and of physics and mathematics towards rational epistemology.Research showed similarities and differences among academic domains on various epistemological dimensions. For example, experts of Physics and Psychology have similar epistemic beliefs about source of knowledge and justification of knowing but they differ on dimensions of certainty and structure of knowledge (Jehng et al, 1993).

There is plenty of research conducted to assess the epistemological beliefs of the students of different soft and hard domains (Buehl & Alexander, 2001, 2004; Buehl et al, 2002). However, not much attention has been given to the research on scientific epistemological beliefs of pre-service teachers' (Fives & Buehl, 2004). The association between teachers' scientific epistemological beliefs and their corresponding teaching practices has been well established from the past body of literature on scientific epistemological beliefs (Chen, Morris & Mansour, 2015). According to Tsai (2006), taiwanese science teachers' who have relativists views about the nature of knowledge and knowing are more adapted to using constructivists teaching practices like inquiry and learner centered teaching whereas teachers with the dualists beliefs spend most of their time imparting knowledge to students through lectures, tutorials and drilling.

Constructivists oriented teaching programs can also be made successful if the background of the teachers epistemological beliefs will be known to us (Cohen, 1988). The purpose of this study is to examine scientific epistemological beliefs of pre-service teachers' from both chemistry and social science domains (Psychology, economics & social studies). The findings of the study can be used to see how and which kind of epistemological beliefs in different academic domains can interact and interplay with constructivists teaching programs . Moreover, the research will also contribute to foster interdisciplinary epistemological awareness in pre-service and in-service teachers' of different academic domains.

The researchers have found a significant effect of the epistemological belief construct on the teaching and learning processes (Schommer, 1990). The nature of epistemological beliefs of the teachers have a profound effect on instructional approach taken by the teacher in the classroom (Richardson, 2003). According to Kang & Wallace (2004), teachers views on the dimension of certainty of knowledge predicts the involvement of students in the classroom activities as passive or active learners. In the classroom of a teacher who believes that knowledge in science is certain, involvement of student cognition is almost negligible whereas problem solving and reasoning on behalf of students and teachers is the hallmark of

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classroom in which teacher views knowledge in science as evolving .The study conducted to see the effect of sophistication of epistemological beliefs on the learning approaches of Pre-service teachers concluded that teachers' who think that learning comes through effort adopt constructivists learning approaches whereas those who accepts the dominance of authority with respect to knowledge and learning go for superficial teaching and learning approaches Adak & Bakir (2017; as cited in Chan, 2002).The Critical aspect of the above mentioned studies is that they examined the relationship between general epistemological beliefs and learning outcomes, whereas, these relationships need to be re-examined in the light of domain specificity of epistemological beliefs (Buehl & Alexander, 2004). There is a correlation between teachers' epistemological beliefs and personal teaching efficacy (Anderson, Greene & Loewen, 1988). Teachers' high personal teaching efficacy is the prerequisite on behalf of teachers to have a diverse and interdisciplinary approach to instruction (Fives & Alexander, 2004).

Research Purpose

This research measured scientific epistemological beliefs about physical sciences of chemistry and social sciences (Psychology, economics & social studies) Pre-service teachers. Moreover, this research also intends to explore the differences in their level of sophistication about scientific epistemological beliefs and domain specificity of chemistry and social sciences pre-service teachers' beliefs. EBAPS is used to measure scientific epistemological beliefs about physical sciences. Statistical analysis with SPSS is used to see significant differences between chemistry and social sciences pre-service teachers' beliefs. Further analysis is done to know about differences in correlation within EBAPS dimensions of chemistry and social science pre-service teachers. Following questions are the focus of investigation in this research study.

1. What are the scientific epistemological beliefs held by Pre-service teachers' of Chemistry, Psychology, Economics & Social studies?
2. Are beliefs held by chemistry pre-service teachers about science significantly different (more or less sophisticated) than those of social science teachers?

Hypothesis

In reference to research question # 2, it is hypothesized that chemistry pre-service teachers have significantly different and more sophisticated scientific epistemological beliefs as compared to social science pre-service teachers. As the content of the survey measures views about physical sciences, it is assumed that chemistry teachers being more knowledgeable about physical science content as compared to social science teachers expect knowledge of science as changing and evolving in nature. According to Buehl & Alexander (2004), domain specificity of epistemological beliefs of students in their sample is related to their difference in exposure to content knowledge in respective domains.

Method

Sample

This study utilized a sample of 71 secondary pre-service teachers from the University of Munich attending summer semester 2019. Of these 71 pre-service teachers,33 are chemistry pre-service teachers whereas 38 comprised of pre-service teachers from social sciences i.e psychology, economics & social studies.

Among social sciences sample include psychology(n= 16) , economics (n= 12) & social studies (n= 11) . With regard to gender difference 58.8% of the sample are females and 41.2 % are males. All of the pre-service teachers took general physics, chemistry and biology courses in their college years.

Instruments

Numerous instruments have been developed for the assessment of scientific epistemological beliefs of individuals at high school, college and undergraduate level. Among the cluster of questionnaires, including short version of Schommer and others are influenced by Schommer epistemological belief questionnaire, uses a likert scale to measure epistemological belief dimensions. Schommer epistemological

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belief questionnaire assesses four dimensions of epistemological belief which include simple knowledge, certain knowledge, innate ability and quick learning (Schommer, 1990). Chan & Elliots' (2002) questionnaire, epistemic belief inventory (Bendixen, Schraw & Dunkel, 1998), Epistemological beliefs survey (Kardash & Wood, 2002) are the result of researchers dissatisfaction with using Schommer epistemological belief questionnaire. According to Buehl & Alexander (2006), innovation, creativity is needed in the development of Epistemological belief measures which help in exploring the belief pattern of individual in natural and meaningful ways.

Pre-service teachers' Scientific epistemological beliefs about physical sciences were examined by using Epistemological Belief Assessment for Physical Science (EBAPS), developed by Elby, Frederiksen, Schwartz and White. EBAPS consisted of three parts comprising of 30 items in total. Part 1 comprised of items which can be responded on a scale from strongly agree to strongly disagree as per the beliefs of participants. Part 2 includes six multiple choice questions which are embedded in specific contexts. Part 3 is also based on seven multiple choice questions that are also embedded in particular contexts but questions are presented in the form of dialogues between two students having different opinions on concerned matter. This instrument has five dimensions: Structure of scientific knowledge (2,8,10,15,17,19,20,23,24,28), nature of knowing and learning (1,7,11,12,13,18,26,30),real life applicability (3,14,19,27), evolving knowledge (6,28,29), source of ability to learn (6,28,29). Pulmones (2010) scored each item on a scale of 0 (least sophisticated) to 4 (most sophisticated).

The reliability of EBAPS was evident from the fact that this instrument specifically measure scientific epistemological beliefs in the context of physical sciences (Elby & Hammer, 2002). The items in EBAPS are valid enough to measure scientific epistemological beliefs of individuals separately from their expectations about a particular course, their goals as learners, their own study habits etc (Elby & Hammer, 2002). The instrument used in the study is the adapted version of original EBAPS instrument. Three students of LMU Munich 28 were selected for pilot study who answered the survey and provided their reasoning for each questions. The items were revised based upon the suggestions of pilot sample with respect to improvement in clarity about wording, structure and meaning of items. For example, the wording "Big ideas" of item 15 part 1 is replaced by 'meta knowledge' similarly improvements in item 5, 8 and 13 are followed from the suggestions of pilot sample.

71 study participants out of which 33 chemistry pre-service teachers completed online surveys whereas rest of 38 social science pre-service teachers from psychology, economics & social studies completed and returned hard copy questionnaire. Information about participants' gender, age, discipline, EB term comprehension and excellence in english language is taken via social demographic part of the survey. To examine the effects of the gender binary variable FEMALE was created and coded as 1 for males and 0 for females.

Procedure

Data collection was done through online as well as paper and pencil method. The participation in the study was voluntary. Chemistry pre-service teachers were approached via professor of chemistry whom I have contacted through email for help. Data regarding the sample of chemistry pre-service teachers were collected form three seminars. The survey link was written on board and student teachers were asked to follow the link on their PC's or mobiles phones. Social science sample was approached by researcher himself by visiting cafes of respective departments and peer support was taken in this context. Return of the survey was considered as consent to participation on behalf of participants with regard to social science teachers. All surveys were assigned identification number before handing it over to participants so that researcher would know about missing one while collecting surveys.It was estimated that survey will take no more than 22 minutes for completion.

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Data Analysis

For research question 1, descriptive statistics (Means & Standard deviations) were calculated. A comparison of the difference in sophistication of Scientific epistemological beliefs (SEB) about physical sciences between chemistry and social science pre-service teachers was done to address question 2. To test the hypothesis , independent t test is used to compare the difference in the means of SEB dimensions between chemistry and social science Pre-service teachers. A bivariate correlational analysis was conducted to analyse correlation among EBAPS dimensions. To see gender differences in EBAPS dimensions, independent t test was performed to see any significant differences between males and females. Each item is scored on a scale of 0 (least sophisticated) to 4 (most sophisticated).Higher scores are interpretative of sophisticated epistemology.

Results and Discussions

Differences in Scientific Epistemological Views

The research question 1 is addressed by calculating means and standard deviations of pre-service teachers' beliefs regarding their field of study on the dimensions of structure of knowledge (Structure), nature of knowledge and learning (Nature), Evolving knowledge (Evolving), Source of ability to learn (Source) and real life applicability (Reality). See Table 1

Table 1. Means and Standard Deviations of SEB subscale scores of different major Pre- service Teachers

SEB Domains Major field	Structure	Nature	Evolving	Source	Reality
Chemistry (*n*= 33)	2.56 (0.52)	2.63 (0.47)	2.50 (0.89)	2.79 (0.69)	3.09 (0.67)
Psychology (*n*= 16)	2.21 (0.44)	2.36 (0.46)	2.31 (0.89)	2.50 (0.53)	2.89 (0.66)
Social studies (*n*=11)	2.25 (0.49)	2.32 (0.74)	2.42 (0.79)	2.56 (0.69)	2.76 (0.66)
Economics (*n*=12)	2.06 (0.55)	2.33 (0.52)	2.16 (0.95)	2.80 (0.57)	2.56 (0.71)

Higher values for the SEB subscale scores indicate more 'sophisticated' beliefs while the lower values represents 'naive' beliefs with 0 as least sophisticated to 4 as most sophisticated. As shown in the Table 1, chemistry (M=2.56, *SD*=0.52) pre-service teachers have more or less sophisticated (neutral) beliefs on structure of knowledge dimension against less sophisticated beliefs of psychology (M=2.21, *SD*=0.44), social studies (M=2.25, *SD*= 0.49) and economics (M=2.06, *SD*= 0.55) pre-service teachers. On the dimension of nature of knowledge and learning, chemistry (M=2.63, *SD*=0.47) pre-service teachers have more sophisticated beliefs against less sophisticated beliefs of psychology (M=2.36, *SD*=0.46), social studies (M=2.32, *SD*= 0.74) and economics (M=2.33, *SD*= 0.52) pre-service teachers. On the evolving knowledge, chemistry (M=2.50, *SD*=0.89) pre-service teachers have more or less (neutral) sophisticated beliefs against less sophisticated beliefs of psychology (M=2.31, *SD*=0.89), social studies (M=2.42, *SD*= 0.79) and economics (M=2.16, *SD*= 0.95) pre-service teachers.

Chemistry (M=2.79, *SD*=0.69) and economics (M=2.80, *SD*=0.57) pre-service teachers have more sophisticated beliefs as compared to more or less sophisticated (neutral) beliefs of Psychology (M=2.50, *SD*=0.53) and social studies (M=2.56, *SD*=0.69) pre-service teachers on the dimension of source of ability to learn. Likewise, on the dimension of real life applicability, chemistry (M=3.09, *SD*=0.67), psychology (M=2.89, *SD*=0.66) and social studies (M=2.76, *SD*=0.66) student teachers have more sophisticated beliefs as compared to economics (M=2.56, *SD*=0.71) pre-service teachers having more or less sophisticated (neutral) beliefs.

Five Independent t tests were conducted on the five subdimensions of scientific epistemological beliefs to compare differences in the means of SEB subscale scores between chemistry and

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social science pre-service teachers. Additionally, the assumption of homogeneity of variance was tested for each of the independent t test. The independent t tests analysis revealed that students SEBs were statistically significantly different on three (structure, nature & reality) out of five dimensions (Table 2).

A review of Table 2 shows that on structure of knowledge sub-dimension, chemistry pre-service teachers (M=2.56, SD=0.49) gained statistically significantly higher scores as compared to social science pre-service teachers (M= 2.18, SD= 0.52); $t(69)$=3.14, p= 0.00.

Table 2 Comparison of SEB scores between Chemistry and Social science Pre-service teachers

Subscale	Major	M	SD	p
Structure	Chemistry	2.56	0.49	0.00*
	Social sciences	2.18	0.52	
Nature	Chemistry	2.63	0.47	0.02*
	Social sciences	2.34	0.56	
Evolving	Chemistry	2.50	0.89	0.28
	Social sciences	2.27	0.87	
Source	Chemistry	2.79	0.69	0.23
	Social sciences	2.61	0.59	
Reality	Chemistry	3.09	0.67	0.04*
	Social sciences	2.76	0.68	

Notes: Chemistry n=33 , Social science n= 38,*$p < 0.05$

On the nature of knowledge and knowing, there was a statistically significant difference in the scores of chemistry (M=2.63, SD=0.47) and social science (M= 2.34 SD=0.56) pre-service teachers;$t(69)$=2.34, p= 0.02, chemistry pre-service teachers having more sophisticated scores. The analysis on evolving knowledge sub-dimension found that there were no statistically significant difference in the scores of chemistry (M=2.50, SD=0.89) and social science (M= 2.27 SD=0.86) pre-service teachers;$t(69)$=1.08, p= 0.28. These results contradict our hypothesis that chemistry pre-service teachers' beliefs about evolving knowledge dimension are statistically significantly different as well as more sophisticated than social science pre-service teachers.Similarly, with respect to source of ability to learn dimension, the analysis revealed that there were no statistically significant difference in the scores of chemistry (M=2.79, SD=0.69) and social science (M= 2.61, SD=0.59) pre-service teachers;$t(69)$=1.20, p= 0.23. The assumption of homogeneity of variance was satisfied via Levene's F test $F(69)$= 0.99, p= 0.32. On the real life applicability dimension, there was a statistically significant difference in the scores of chemistry (M=3.09, SD=0.67) and social science (M= 2.76, SD=0.68) pre-service teachers;$t(69)$=2.02, p= 0.04, chemistry 32 pre-service teachers having more sophisticated scores.

Table 3 Analysis of gender differences on the sub-scales

Subscale	Gender	M	SD	p
Structure	Male	2.40	0.61	0.69
	Female	2.34	0.49	
Nature	Male	2.42	0.57	0.61
	Female	2.49	0.53	
Evolving	Male	2.27	0.86	0.41
	Female	2.45	0.92	

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Source	Male	2.78	0.66	0.45
	Female	2.66	0.62	
Reality	Male	2.84	0.84	0.43
	Female	2.98	0.58	

Note: male *n*= 28 , female *n*= 40.

In the present study, conducted with the sample of pre-service teachers of chemistry and social sciences, no statistically significant difference was found between male and female on any of the sub-dimension of scientific epistemological beliefs (Table 3).

Gender differences in scientific epistemological beliefs is scarce especially when it come to pre-service teachers. However there are some studies which found females to have sophisticated epistemological beliefs as compared to men , for example (Hofer, 2000), in a study found that women have more sophisticated epistemological beliefs on the dimensions of evolving knowledge and source of knowledge as compared to men. On the dimensions of fixed ability and quick learning, Paulsen & Wells (1998), study revealed that men have naive beliefs on these dimensions as compared to women. Similarly, there are some studies including Chan (2003) and Strobel et al (2004), which found no statistically significant differences in scientific epistemological beliefs between men and women.

Correlation among the EBAPS dimensions

Table 4 Correlations among SEB dimensions

	Structure	Nature	Evolving	Source	Reality
Structure	-	0.00**	0.00**	0.00**	0.00*
Nature	0.00**			0.00**	0.00**
Evolving	0.00**				
Source	0.00**	0.00**			0.01*
Reality	0.00**	0.00**		0.01*	

Note: *$p < 0.05$, **$p < 0.01$.

The table 4 representing correlation matrix about EBAPS dimensions indicated that the structure of knowledge dimension is significantly correlated with nature of learning, evolving knowledge, source of ability to learn and real life applicability dimensions. In other words, it means that those pre-service teachers who have sophisticated beliefs on structure of knowledge dimension are more likely to understand the nature of knowledge, source and uncertainty of knowledge as well as realize the real life dimensions. Correlations were also significant between nature of knowledge and structure of knowledge, source of ability to learn, real life applicability. Similarly, the correlation between source of ability and structure of knowledge, nature of knowledge, real life applicability is also evident from the significance of p value. Results of the correlational analysis implied that structure of knowledge dimension is the most important element of the Scientific epistemological beliefs of preservice teachers. However, it is to be noted that inspite of the significance of correlations, coefficients of the correlations are of moderate level. See Table 4.

Conclusion and Implications

The results of the present study revealed differences in scientific epistemological beliefs of pre-service teachers of chemistry and social sciences. Consistent with Schommers (1993) findings and our initial assumption, this study showed that chemistry pre-service teachers have more sophisticated scientific epistemological

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beliefs than social science pre- service teachers. Jehng et al.'s (1993) study found that the social science major students hold sophisticated beliefs about the certainty of knowledge i.e they consider knowledge of science to be uncertain as compared to the natural science students. Although, the results of this study are inconsistent with Jehng et al's findings on evolving knowledge dimension as chemistry pre-service teachers comes out to have neutral beliefs on the evolving knowledge dimension against less sophisticated beliefs of social science pre-service teachers but the difference is not significant . However, on the dimensions of structure of knowledge, nature of knowledge and knowing and real life applicability, results indicated that chemistry pre-service teachers gained statistically significantly higher scores than social science pre-service teachers. The level of sophistication of pre-service chemistry teachers did not touched the most sophisticated point of 4 on any of the sub dimensions. Based on this fact it can be suggested that students' epistemological awareness needs to be promoted at secondary and post secondary level of education (Liu & Tsai, 2008).

One possible interpretation of the result that chemistry pre-service teachers tended to hold more sophisticated beliefs than social science pre-service teachers is their difference in exposure to content knowledge about physical science domains (Buehl & Alexander,2004). In other words, chemistry pre-service teachers could have more understandings about limits, nature and assumptions of scientific knowledge of physical sciences because they are more knowledgeable about physical science content.

This study used EBAPS instrument to assess scientific epistemological beliefs about the physical science and found significant differences in the epistemological beliefs of chemistry and social science pre-service teachers. According to Hammer & Elby (2001), measurement of sophistication of epistemological beliefs by EBAPS is contextualized. However, more diverse methods can be used, For example, Interviews with special cases or longitudinal sample studies which can be more elaborative regarding scientific epistemological beliefs of pre-service teachers or students (Liu & Tsai, 2008).

The results of the present study revealed that chemistry pre-service teachers have statistically significant and more sophisticated scientific epistemological beliefs than social science pre-service teachers, however, chemistry pre-service teachers were unable to gain most sophistication on any of the sub dimensions of EBAPS. Expecting these pre-service teachers to be future potential teachers, the respective departments should start some programs which are intended to raise the sophistication of scientific epistemological beliefs to the most sophisticated level (Paulsen & Wells, 1998). On the contrary, some 'Interdisciplinary professional training programs should be arranged for social science pre-service teachers in their respective departments which can raise epistemological awareness about scientific epistemological beliefs, which can make them eligible to teach science courses or successfully take part in constructivists oriented reform programs as wells as improve inquiry oriented teaching practices.

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