Epistemological Beliefs about Science in Malaysian Context

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Abstract: The present study attempted to investigate the epistemological beliefs about science held by Malaysian students through gender, socio-economic status, and problem solving ability. A total of 713 students (form 4) participated in the present study. Data analysis revealed that: Students tended to hold more sophisticated beliefs about science, Epistemological beliefs about source of knowledge, Certainty of knowledge, Justification of knowledge significantly related to gender, students' epistemological beliefs about science are unrelated to Social-economic Status (SES) and to the interaction between SES and gender, and the four dimensions of epistemological beliefs are predictors of problem solving ability.
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1. Introduction

Epistemological beliefs have been defined in two different ways. In one definition, researchers define epistemological beliefs as developmental stages (Kegan, 1982; King & Kitchener, 2004; Perry, 1970). In this definition, researchers view personal epistemological beliefs as one-dimensional constructs in which individuals pass through these stages based on their cognitive development. Other researchers define epistemological beliefs as collections of beliefs/ multidimensional perspective (Schommer, 1988; Schraw, Dunkle, & Bendixen, 1995; Schommer & Walker, 1997). Hofer and Pintrich (1997) proposed that epistemological beliefs consisted of four dimensions: Certainty of Knowledge, Simplicity of Knowledge, Source of Knowledge and Justification for Knowing.

Previous studies across different countries investigated students' beliefs about nature of knowledge and knowing and focused on the factors affecting students' beliefs in the learning process. Among them gender, age, grade level, ethnicity, socioeconomic status, fields of study, academic performance, learning approaches, learning environments, attitudes toward science, self regulated learning strategies, self-efficacy, and performance beliefs have received great attention from researchers (e.g., Conley et al., 2004; Elder, 2002; Paulsen & Wells, 1998; Schommer, 1993; Schommer & Dunnell, 1994).

The growing body of research evidence indicates that students' epistemological beliefs about learning influence their various learning processes, problem solving ability, formation of conceptual understanding, and coping with ill-structured questions or tasks (Schommer, 1994). According to King and Kitchener (1994), individuals can solve well-defined problems without making epistemic assumptions. However, when they solve ill-structured problems, their personal epistemological beliefs affect "the processes used to reach a solution" as well as "the legitimacy of the solution" (Schraw et al., 1995). In other words, all individuals reach different solutions because of their personal epistemological assumptions. Therefore, epistemology is one of the strongest factors influencing problem solving ability.

In the present study, gender and socioeconomic status were used together to better understand the effect of these variables on students' epistemological beliefs about Science. Rennie (1998, p. 959) argued that "if the issue of gender is to be considered effectively in Science teacher education, account must be taken of the way gender is constructed in terms of ethnicity, class, religion, race and often other variables as well". Accordingly, the gender issue had been investigated in relationship with other variables such as cognitive abilities, attitudinal variables, socio-cultural variables, and home-family variables (Kahle & Meece, 1994). It was indicated that females and males develop their understanding about different aspects of Science teaching and learning under the influence of those variables. That is to say, gender differences show heterogeneous findings across different variables (Topc & Yilmaz-Tuzun, 2009). Some findings from past studies suggested that students' epistemological

development is a function of the surrounding culture. For examples, Jehng, Johnson, and Anderson (1993), and Perry (1968) concluded that learning beliefs are a product of the activity, the culture, and the context in which they are cultivated. Such previous findings suggested that further analyses of learning beliefs in a broader social and cultural context or with more diverse populations would be necessary for a better understanding of the nature of learning beliefs.

Malaysian society is undergoing a rapid social and cultural change in response to external influences, especially those of Western societies. A simple consideration of the Malaysian high school classroom situation may allow us to have a glimpse of the impact of such changes on Malaysian high school students. Recently, increasing numbers of high school teachers complained about their students changing attitudes toward their teachers and other students; the students are said to have become more individualistic and they tend to show no respect for their teachers or no concern for other classmates. Such attitudinal change may be a reflection of the so-called school collapse phenomenon (Youn, Yang, & Choi, 2001).

Schommer (1994) suggested that the need for a better understanding of the nature of epistemological beliefs would increase as a society becomes highly industrialized where high level learning and critical, independent, and creative thinking of individuals become increasingly more important. Malaysian society is becoming more technologically advanced. The transition to a highly industrialized society through technological advances would be a key for Malaysian society's survival when faced with increased international competition in the near future. In order to lead such a transition successfully, education may need to take a more important role, due to the limited natural resources available to Malaysia. As mentioned already, if Schommer's suggestion (1994) turns out to be true in the near future, and if Malaysian society is to be more highly industrialized, it may be necessary for Malaysian teachers to understand better the nature of epistemological beliefs about Science. Also they may need to find ways to facilitate the development of Malaysian students' learning beliefs. If learning beliefs are to be developed from early on, that is, while students' mind habit or brain function is more plastic and flexible, then the development could be accelerated or achieved with more ease (Youn et al., 2001).

Since the nature of learning beliefs about Science with Malaysian high school population has rarely been analyzed, the validation of the epistemological model and the scale with Malaysian high school students should be the preceding step over the analyses of the relations between students' beliefs and their developmental factors. To date, to the best of our knowledge, no studies have been conducted in the Malaysian context to measure relationships among secondary school students' gender, SES, and problem solving ability with their epistemological beliefs about Science. As such, the present study will fill the gap in this area.

Based on the Hofer and Pintrich (1997) model, the present study tried to determine students' epistemological beliefs through four dimensions: (i.e., Source, Certainty, Development, and Justification) of knowledge as function of gender and socio-economic status, and to investigate their relations to problem solving ability in science. Specifically, the present study attempted to test the following null hypotheses: (1) Epistemological beliefs about science would not be significantly related to gender; (2) Epistemological beliefs about science would not be significantly related to socioeconomic status (SES); (3) Epistemological beliefs about science would not be significantly related to the interaction between gender and SES; and (4) Epistemological beliefs about science would not be significantly related to problem solving ability.

2. Methodology

Sample

A total of 713 form four students attending public secondary schools in a large district of Kuala Lumpur participated in the study. Cluster random sampling integrated with convenience sampling was used to obtain the representative sample from the accessible population. Thirty three percent (33%, n = 236) of the participants were females while sixty seven percent (67%. n = 477) were males.

Socio-economic status (SES) was determined by asking participants to answer seven separate questions about mother's educational level, father's educational level, family income, presence of computer at home, daily newspaper at home, and presence of private study room at home. Then, sudents' responses to these questions were converted to standardized scores and added up to obtain a total SES score. Based on SES scores, students were grouped as having low, moderate, and high SES. The cut off points in the data set were considered while deciding different SES groups. That is, the students below the 27 percentile (n = 192) were grouped as having low SES, whereas the students above the 73 percentile (n = 192) were classified as high SES students. The students between the 27 and 73 percentile (n = 329), on the other hand, were considered as the moderate SES group.

Instruments

Epistemological Belief Questionnaire

The Epistemological Belief Questionnaire developed by Conely et al. (2004) was adopted and validated in the Malaysian context to determine

students' epistemological beliefs through four dimensions: Source, Certainty, Development, and Justification. The questionnaire originally consisted of 26 items. Items were rated on a 5-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree). In order to measure the students' epistemological beliefs, the items of the Source and Certainty dimensions were reversed so that, for each of these dimensions, higher scores reflected more sophisticated beliefs.

Principal Component Analysis was employed aiming at empirically revealing and demonstrating the hypothesized, underlying structure of the preliminary model of the questionnaire. Examination of the item loadings, of items with substantial loadings on more than one factor, and of the actual wording of items that ended up being grouped together led to the determination of the Four-factor solution as the best. The overall percentage of variance extracted (49.37%) supported the assertion that the four factors were deemed sufficient and conceptually valid in their correspondence to the existing theory. All items had pattern coefficients higher than .40. Further, reliability coefficients for each factor all exceeded the threshold of .80 for acceptance (Stevens, 2002). EFA results indicated that 6 items of 26 should be discarded. Accordingly, the Malaysian version of the epistemological beliefs questionnaire comprised of twenty items.

Confirmatory Factor Analysis (CFA) was conducted to test the fit between the four–factor model and the data. Multiple goodness-of-fit tests were used to evaluate the fit between the hypothesized model and the data to determine if the model being tested should be accepted or rejected. These are Normed Fit Index (*NFI*; Bentler & Bonett, 1980), the Comparative Fit Index (*CFI*; Bentler 1990), the Root Mean Square Error Approximation (*RMSEA*; Steiger & Lind, 1980), and the minimum fit function Chi–square ratio degrees of freedom (*CMIN/DF*, Marsh & Hocevar, 1985).

NFI and *CFI* greater than 0.90 indicates a good fit to the data, and the RMSEA of about 0.05 indicates a close fit of the model and 0.08 represents a reasonable error of approximation. *CMIN/DF* valve in the range of 2 to 1 or 3 to 1 are indicative of an acceptable fit between the hypothetical model and the sample data (Arbuckle, 2006). All coefficients are significant at $p < .01$. *NFI* = 0.96; *CFI* = 0.97; *RMSEA* = 0.05; *CMIN/DF* = 1.86.

Problem solving test

Five open-ended problem solving tests were developed to assess students' quantitative problem solving skills in the basic concepts of force and motion. For this purpose, the content of the form four physics text book was analyzed. These five open-ended problems involved a variety of important content areas, such as kinetics, dynamics, momentum and energy. The test was tried out on a sample of 144 males and females, to find out its psychometric properties. Accordingly, item analysis revealed levels of difficulty from 0.26 to 0.60 and levels of discriminate ability from 0.29 to 0.49. Data about validity of the scale were collected through item analysis and logical judgment by experts, and content have been validated. In order to collect data about the reliability of the test, Cronbach alpha method was used (alpha = .87). The test booklet was administered within one class period during the second semester of the school year 2010/ 2011.

3. Results

Mean scores and standard deviations were used to explain the students' epistemological beliefs profile. As can be seen in Table 1, the results of the descriptive statistics indicated that students generally had sophisticated epistemological beliefs as indicated by the mean scores ranging from 3.52 to 3.66 on a five point Likert scale. Development dimension had the highest mean value (M = 3.66, SD = 3.23), followed by Source (M = 3.60, SD = 2.67), and then by Justification (M = 3.55, SD = 3.47). The lowest mean score appeared for the Certainty dimension (M = 3.52, SD = 2.09). When descriptive statistics results were examined with respect to gender, and socio-economic-status, it was seen that, in general, mean scores of all variables were above the middle point of the five-point scale.

Table 1. Descriptive Statistics for Epistemological Beliefs Dimensions by Gender and Socio-economic Status.

Variable			Justification	Certainty	Development	Source
Gender	Male	Mean	3.63	3.59	3.72	3.72
		Std	5.53	1.97	3.26	2.57
	Female	Mean	3.51	3.48	3.63	3.54
		Std	5.42	2.14	3.20	2.69
SEM	Low	Mean	3.56	3.58	3.66	3.63
		Std	5.36	2.08	3.17	2.58
	Moderate	Mean	3..54	3.49	3.66	3.59
		Std	5.36	2.03	3.07	2.72

	High	Mean	3.57	3.53	3.65	3.54
		Std	6.04	2.20	3.74	2.79
Total		Mean	3.55	3.52	3.66	3.60
		Std	5.47	2.09	3.23	2.67

A multivariate analysis (two way MANOVA) was conducted to investigate the effects of gender and socioeconomic status on participants' beliefs about science. The results indicated statistically significant effect of gender on the combined dependent variables (F (4, 708) = 2.94, Hotellings' Trace = .02, partial Eta = 0.02, $p < .05$). Also, results indicated that no statistically significant effect for Socio-economic status on the combined dependent variables (F (12, 701) = 1.27, Wilks lambda = 0.98, partial Eta = 0.01, $p > .05$). Moreover, results revealed no statistically significant effect for the interaction between gender and SEM on the combined dependent variables (F (12, 701) = 2.43, Wilks lambda = 0.96, partial Eta = 0.01, $p < .05$).

As seen in Table 2, males and females are similar in their beliefs about the Development of knowledge (F(1, 711)= 2.99, $p > .05$), whereas, males scored higher than females in their beliefs about Justification of knowledge (F(1, 711)= 5.11, $p < .05$); Certainty of knowledge (F(1, 711)= 4.27, $p < .05$); and the Source of knowledge (F(1, 711)= 11.14, $p < .05$). Students in different socioeconomic status are similar in their beliefs about Justification of knowledge (F (2, 710) = .77, $p > .05$); Certainty of knowledge (F(2, 710) = 1.63, $p > .05$); Development of knowledge (F(2, 710) = .67, $p > .05$), and the Source of knowledge (F(2, 710) = 2.56, $p > .05$). Furthermore, results revealed that epistemological beliefs are unrelated to the interaction between SEM and gender.

Table 2. Results of MANOVA Analysis for Differences between the Means of the Participants Beliefs about Science with Respect to Gender, and Socio-economic Status.

Source		Type III Sum of Squares	*df*	Mean square	*F*-value	*p*-value
Gender	Justification	152.22	1	152.22	5.11	.02
	Certainty	18.64	1	18.64	4.27	.04
	Development	31.19	1	31.19	2.99	.08
	Source	78.51	1	78.51	11.14	.00
	Justification	45.97	2	22.98	.77	.47
	Certainty	14.30	2	7.15	1.63	.20
SEM	Development	14.05	2	7.02	.67	.51
	Source	36.50	2	18.25	2.56	.08
	Justification	102.47	3	34.16	2.01	.11
SEM*Gender	Certainty	44.87	3	34.14	2.00	.10
	Development	44.88	3	14.96	1.44	.23
	Source	30.40	3	10.13	1.45	.23

In the present study, the correlation coefficients among the variables were extracted. As seen in Table 3, a substantial relation (Davis, 1971) was between problem solving ability and Justification of knowledge ($r = .526$; $p < .01$), Certainty of knowledge ($r = .504$; $p < .01$), Development of knowledge ($r = .601$; $p < .01$), and Source of knowledge ($r = .566$; $p < .01$).

Table 3. The Correlation Matrix between Independent Variables and Dependent Variable.

Variable	Problem solving	Justification	Certainty	Certainty
Justification	.528**			
Certainty	.504**	.493**		
Development	.601**	.488**	.386**	
Source	.566**	.468**	.381**	.363**

The standard multiple regression with a direct method entry was used to measure the relationships among the variables. The results indicated that 67% of the variance in problem solving was explained by the independent variables. The test statistic was significant (F (4, 708) = 141.107; $p < .05$) (Table 4).

Table 4. ANOVA: Regression Significance

	Sum of Squares	Df	Mean Square	*F*	Sig.
Regression	44167.62	4	11041.91	141.11	.00
Residual	55402.24	708	78.25		
Total	99569.86	712			

Table 5. Regression Coefficients of Standard Regression Model

Variable	Unstandardized Coefficients		Standardized Coefficients		
	B	Std Error	Beta	*t*- value	Sig
Constant	18.39	2.39		7.69	.00
Justification	.92	.20	.15	4.70	.00
Certainty	.76	.21	.13	3.64	.00
Development	1.22	.15	.33	8.36	.00
Source	.95	.18	.21	5.35	.00

Table 5 shows that: Justification of knowledge was a significant predictor of problem solving in Physics (t = 4.703, *Beta* = .145; $p < .05$); Similarly, Certainty of knowledge (t = 3.639, *Beta* = .134; $p < .05$); Development of knowledge (t = 8.362, *Beta* = .333; $p < .05$); and Source of knowledge (t = 5.345, *Beta* =.214; $p < .05$) were also significant predictors of problem solving in Physics.

4. Discussions

A combination of EFA and CFA factor analysis showed that the Malaysian students' epistemological beliefs were explained by the Conley et al. (2004) model which consisted of Source, Certainty, Development, and Justification of Knowledge. The results of the factor analysis obtained from the current study supported to the multidimensional theory proposed by Schommer (1990) and showed that the Malaysian students' epistemological beliefs about science are explained with four distinct factors.

Results revealed that Malaysian students generally had fairly sophisticated beliefs about nature of knowledge and knowing. For each dimension (i.e., Justification, Development, Certainty, Source) students obtained a mean value that was higher than the mid-point of the five-point scale, implying that participants generally tended to believe that (a) using data and experiments are necessary to construct knowledge, (b) knowledge can change in time and science is an evolving and changing subject, (c) knowledge is not certain, and (d) knowledge is not constructed only by authority (e.g., teachers, books). Conley et al. (2004) reported that students began their study with fairly sophisticated beliefs about Certainty of Knowledge and Source of Knowledge and over time more strongly endorsed the beliefs that knowledge is not constructed by only teachers and other experts and knowledge is not certain and there may not be just one right answer in science.

Students' sophisticated beliefs about Science may be due to the Science curriculum and teaching and evaluation processes. For instance, science textbooks pay more attention to relating scientific problem solving to real life situations with which the students are familiar. The contents are introduced through the description of real life situations and a number of open-ended questions are included in the textbooks. This enables students to understand more clearly that scientific problem solving skills are dynamic and closely related to real life. Furthermore, participants of the present study were taught with the new Science curriculum which is more constructivist-oriented. For instance, the importance of the constructivist learning environment in which the students construct their own knowledge was emphasized rather than the traditional learning environment in which the knowledge is constructed by the teachers and the textbooks. Moreover, new arrangements made in the Malaysian science curriculum focused on students' active learning environment, their attitude toward Science, classroom environment, and learning approaches.

MANOVA results showed males had more sophisticated beliefs and tended to believe that the experiments and using data are necessary to construct knowledge compared to females, that knowledge is not constructed by authority (i.e., teachers, textbook), that knowledge is not certain. Furthermore, males and females were similar in their beliefs on the development of knowledge. Earlier studies reported that due to effects of different variables (e.g., home-family variables, educational variables) males had a superior success in and attitudes toward science over girls (Kahle & Lakes, 1983; Kahle & Meece, 1994). According to Schommer (1993), girls were more likely to show less confidence in their understanding and were more accurate in their comprehension monitoring. She also stated that the girls' beliefs in gradual learning may prevent them from explaining conclusions which they understand. Schommer (1993) stated that girls were less likely to believe in fixed ability and quick learning. The present study failed to indicate a statistically significant difference between girls and boys with respect to Development of Knowledge. This result is encouraging in terms of reducing the gender gap in Development of Knowledge.

These results seem to be inconsistent with some earlier findings (e.g., Conley et al., 2004; Elder, 1999; Schommer-Aikins & Easter, 2006). For instance, Conley et al. (2004) found that boys and girls were not different with respect to Source of Knowledge, Certainty of Knowledge, and Justification of Knowledge. On the other hand, Elder

(1999) reported that there were no differences between girls and boys with respect to authority, certainty, and development of learning. The findings of the current study are inconsistent with Ozkan (2008) who reported that girls tended to have more sophisticated beliefs in Justification dimension compared to boys

In contrast to the previous studies reporting SES differences in epistemological beliefs, the results of this study were unable to confirm a relation between socio-economic variables and epistemological beliefs. For instance, Trutwein and Ludtke (2007) suggested that certainty beliefs correlated significantly and negatively with SES. Similarly, Schommer (1990, 1993) reported significant positive relationships between epistemological beliefs and parents' level of education. Additionally, Topcu and Yılmaz-Tuzun (2009) indicated that students having educated parents tended to hold more sophisticated epistemological beliefs compared to others. According to Schommer (1989), epistemological beliefs are influenced by home and educational background. Conley et al. (2004) also showed that students from low SES families have lower scores on source, certainty, development and justification compared with average SES students. Furthermore, the present study revealed the beliefs were unrelated to the interaction between SEM and gender. Since the participants are from Kuala Lumpur, the researchers attribute these findings to the homogeneity of the participants, that is to say, the data about SEM is convergent. As such, there is a need to study the effect of SEM among heterogeneous samples. Moreover, the findings revealed a need to focus on the specific SES related variables such as parents' educational level, parents' occupation, family income, and characteristics of family structure to better understand the relation between SES and epistemological beliefs.

Correlation analysis revealed that all dimensions of beliefs about Science are positively correlated with problem solving ability. As such, the development of more sophisticated epistemological beliefs resulted in better use of problem solving ability. Furthermore, multiple regression analysis revealed that the four dimensions of epistemological beliefs are predictors of students' problem solving ability. These results seem to be consistent with previous studies (e.g., Conley et al., 2004; Schommer, 1990, 1993; Schommer-Aikins et al., 2005). For instance, Schommer (1990) demonstrated that the development of more sophisticated epistemological beliefs resulted in better use of mathematical problem solving skills and comprehension of complex text. The researchers attribute these findings to the nature of science textbooks. As mentioned earlier, science textbooks pay more attention to relating scientific problem solving to real life situations familiar to the students.

The results indicated significant relationships between epistemological beliefs about Science and problem solving ability. Accordingly, teachers may be able to help the students with poor problem solving ability become more interested in problem solving by cultivating their Science beliefs. One implication of these findings is that the investigating beliefs are important since they are behind students' attitudes toward Science activities and achievement. In particular, students with low problem solving ability may be unaware of their implicit, maladaptive representations about their beliefs about Science, and be less able to modify them, so these beliefs negatively affected their learning and problem solving ability. Also, adequate educational interventions should be developed and implemented in science instruction to gradually change naïve representations about the nature and acquisition of knowledge in Science. Finally, in order to modify students' naive beliefs about Science, Science teachers should emphasize students' understanding of concepts, effort that increase problem solving ability, and control over learning process and problem solving ability.

In conclusion, this study can be considered as one of the initial attempts to provide information about the students' beliefs about the nature of knowledge and knowing to arrange the conditions of the learning and teaching of Science. Therefore, teachers are encouraged to try to enhance student's beliefs about Science. One implication of these findings is that the Science teachers may consider the apparent gender differences in their efforts to encourage the epistemological development of the students. The teachers may then act accordingly to help both boys and girls develop their epistemological beliefs. It seems likely that both the teachers and the classroom environment can influence the development of epistemological beliefs of boys and girls. First of all, teachers should be informed about the meaning and the importance of epistemological beliefs, and also how to measure and develop them in the classroom. Teachers and policy makers may collaborate for this purpose through organizing small workshops and meetings as a part of their in-service training. Having sufficient background knowledge, teachers may then adopt special teaching methods and instructional strategies (Ozkan & Tekkaya, 2011).

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