STUDENTS' EPISTEMOLOGICAL BELIEFS ABOUT SCIENCE: THE IMPACT OF SCHOOL SCIENCE EXPERIENCE

Jarina Peer
Lourdusamy Atputhasamy
National Institute of Education
Nanyang Technological University
Singapore

The science epistemological beliefs of students have been found to play an important role in determining their learning orientations towards science. Conley, Pintrich, Vekiri, & Harrison (2004) developed a measure to examine the epistemology beliefs of students about science. The measure encompasses four dimensions about scientific knowledge: source, certainty, development and justification. The purpose of this study was to look at the reliability of this measure in the Singapore context and to find out the epistemological beliefs of Singapore students about science. The findings showed that the four scales have relatively good reliability in term of internal consistency. The alpha-coefficient of the scales ranged from .65 to .84. The scale reliability obtained with the Singapore sample is comparable to that obtained by Conley et al. (2004). With respect to the epistemological beliefs of students the mean scores on all the scales were above 4.5 on a 6-point scale. This indicates that the students in Singapore have fairly sophisticated beliefs about scientific knowledge. The article discusses some implications of the findings for science education.

INTRODUCTION

Currently, epistemological beliefs or beliefs about the nature of knowledge and knowing are targets of increasing research interest because there is a great deal of research evidence that show students' epistemological beliefs influence to a great extent the way not only how they learn but also their attitude towards learning (see literature review below). We are not aware of any study that has examined the science epistemological beliefs of students in Singapore schools. This study was undertaken first to examine the reliability of the scales developed by Conley, Pintrich, Vekiri and Harrison (2004) for use in the Singapore classrooms and second to examine the epistemological beliefs about science of students in lower secondary level. In addition we also examined the association of these beliefs to gender. The findings may help us to rethink in designing our science teaching in our schools to help our students have a more sophisticated view of science knowledge and how it ought to be acquired.

EPISTEMOLOGY AND EPISTEMOLOGICAL BELIEFS

Epistemology is an area of philosophy concerned with the nature and justification of human knowledge. In the 1950's Piaget used the term genetic epistemology to describe his theory of intellectual development. Piaget's work led Perry (1970) to conduct two longitudinal studies, which resulted in a developmental scheme of the abstract structural aspects of knowing and valuing. Psychologists and educators have now become interested in personal epistemological development and epistemological beliefs, and how the beliefs influence the cognitive processes of thinking and reasoning. Recently, students' beliefs about the nature of knowledge and learning have been investigated with the idea that they are part of the underlying mechanism of metacognition (Schommer 1990). The term epistemological belief has now come to be used widely for over a decade to refer to a specific belief about knowledge. Schommer (1990) proposes five independent beliefs pertaining to knowledge: certain knowledge (i.e., absolute knowledge exists and will eventually be known), simple knowledge (i.e., knowledge consists of discrete facts), omniscient authority (i.e., authorities have access to otherwise inaccessible knowledge), quick knowledge (i.e., learning occurs in quick or not-at-all fashion, and innate ability (i.e., the ability to acquire knowledge is endowed at birth). Hofer and Pintrich (1997) however, refer to epistemological beliefs as the individuals' conceptions about both the nature of knowledge and the nature or process of knowing in their work.

In the study of students' epistemological beliefs, Schommer (1993) found epistemological beliefs to be strong predictors of students' cognitive performances and affective responses. That is, students' epistemological beliefs affect students' involvement in learning, and the pedagogies aimed at creating an engaged learning environment (Baxter Magolda, 1992). Likewise, Hofer (2001) states that epistemological perspectives are related to learning in various ways, like influencing reasoning and judgment. This has implications for teaching hence the study of epistemological beliefs, about the nature of knowledge and knowing, is critical to education.

Epistemological beliefs have also been shown to vary with respect to discipline-specific learning cultures. For example students in 'soft science tend to believe more than students in 'hard' science that knowledge is uncertain, acquired through independent reasoning, and not acquired in orderly process (Jheng, Johnson & Anderson, 1993).

Bell & Linn (2002) found that students' beliefs about science inquiry are shaped by a myriad of things which include the textbook descriptions, scientific articles and internet materials. Beliefs about scientific inquiry broadly include images of the nature of science, the purposes and activities of scientists, the goals of science courses, and the learning strategies appropriate for understanding scientific material. Research shows that students' epistemological beliefs about science play an essential role in determining their learning orientations towards science and the ways of organizing cognitive structures of scientific knowledge (Tsai, 1998, 1999). Similarly, Edmondson (1989) also states that the students' epistemological beliefs about science play an essential role in determining their learning orientations towards science.

An integration of literature indicates that epistemological beliefs affect the degree to which individuals (Schommer, 1994) actively engage in learning, persist in difficult tasks, comprehend written material and cope with ill-structured domains. All these findings suggest that epistemological beliefs may either help or hinder learning. Elder (2002) conducted a study to describe the fifth grade students' beliefs about the nature of scientific knowledge. She found that students' epistemological beliefs about science reflected both mature and naïve understandings with students endorsing relatively sophisticated statements about the changing nature of science. Conley et al. (2004) studied fifth grade students during a nine week science unit and looked at the four dimensions of belief (source, certainty, development and justification) and noted that students became more sophisticated in their beliefs about source and certainty of knowledge over time.

To measure epistemological beliefs, Schommer (1990) developed a 63-item questionnaire to assess individual epistemological beliefs. Schommer's work was developed in terms of five dimensions of epistemological beliefs: *stability, structure, source, speed of acquisition* and *control*. Hofer and Pintrich (1997) suggested four general epistemological dimensions. The first three of these dimensions parallel those proposed by Schommer (1990); *certainty of knowledge* (stability), *simplicity of knowledge* (structure), and *source of knowing* (authority). The fourth dimension proposed was *justification.* Elder

(2002) has provided some empirical support for these dimensions in both college and young student samples. Recently, Conley et al. (2004) followed Hofer (2000) and Elder (2002) and focused on four dimensions of epistemological beliefs that have to do with nature of knowledge and knowing in science (*source, certainty, development* and *justification*).

Conley's four dimensions represent two general areas that Hofer and Pintrich (1997) argue are at the core of individuals' epistemological theories: beliefs about the nature of knowing and beliefs about the nature of knowledge. The *source* and *justification* dimensions reflect beliefs about the nature of knowing whereas the *certainty* and *development* dimensions reflect beliefs about the nature of knowledge. The *source* dimension is concerned with the source of knowledge and the *justification* dimension is concerned with the ways in which students use evidence and evaluate claims. The *certainty* dimension reflects a less sophisticated stance with the belief in a right answer towards a sophisticated view that there may be more than one answer to complex problems and the *development* dimension is concerned with a belief that recognizes science as an evolving subject and that ideas and theories can change on the basis of new data and evidence.

Conley et al. (2004) adapted the questionnaire items from Schommer (1990) and Elder (2002) and came up with a 26-items questionnaire to measure the science epistemological beliefs. They used these questionnaire items and open-ended interview questions to describe students' beliefs in science. Items were rated on a 5-point Likert scale (1= strongly disagree; 5= strongly agree) and all questions were worded to have students focus on the domain of science. The numbers of items in the four scales are: source (five items), certainty (six items), development (six items) and justification (nine items). High scores reflected more sophisticated beliefs.

THE PRESENT STUDY

Participants

The study was done with three classes of eighth graders (Secondary 2) in October 2004. The students were completing their eighth grade in a month's time and would be moving to the ninth grade in January 2005. A total of 104 students participated in this study of which 47 (45.2%) were males and 57 (54.8%) were females. The average age of the students was 14.9 years. The students were from two neighbourhood schools thus most students in these schools were from the neighbouring HDB (Housing and Development Board) flats and were from average SES (social economic status). In terms of academic ability based on the PSLE (Primary School Leaving Examinations); which is a standard baseline for Singapore schools; the students who participated in this survey scored an average of 231 points where the maximum is 300 points. PSLE is a national examination, which all pupils are required to take at the end of primary education. The purpose of PSLE is to assess pupils' suitability for secondary education and to place them in one of the appropriate secondary school courses, which match their learning pace, ability and inclination (MOE, 2005).

Measures

Epistemological beliefs of the students were measured using the four dimensions 26-item instrument developed and used in previous work with elementary students by Conley et al. (2004). We administered the measure as "My Beliefs in Science Learning". Items were rated on a 6-point Likert scale (1= strongly disagree; 6= strongly agree), and all questions were worded to have students focus on science. The questionnaire assessing epistemological beliefs asked students to indicate how much they agreed or disagreed with 26 Likert-scaled items (e.g. The ideas in science books sometimes change). Sample questions representing the constructs of epistemological beliefs about science are shown in Table 1 below. Items addressed issues of the changing nature of science (*Development*), role of experiments for doing science (*Justification*), coherence of scientific knowledge (*Certainty*), and authority figures and materials as sources of scientific ideas (*Source*).

Table1
Dimensions of Epistemological beliefs and sample items

Construct	Description	Example Item
Source (Source of knowledge)	Concerned with beliefs about knowledge residing in external authorities	Everybody has to believe what scientists say.
Certainty (Coherence of Knowledge)	Referred to a belief in a right answer	All questions in science have one right answer.
Development (Changing nature of knowledge)	Measured beliefs about science as an evolving and changing subject	Some ideas in science today are different than what scientists used to think.
Justification (Role of experiments)	Concerned with the role of experiments and how individuals justify knowledge	Ideas about science experiments come from being curious and thinking about how things work.

A 6-point scale was chosen instead of the 5-point scale used by Elder (2002) and by Conley et al. (2004) as this would deal with those students who tend to 'sit on the fence', Brown (2000), and make them express a definite opinion one way or the other. As Brown (2000) also mentions, there is a great tendency for students to take a neutral opinion when given the possibility of a neutral opinion in the case of a five- point scale. Thus having a six-point scale will thus 'force' students to express a 'definite opinion one way or other'.

Also as suggested by Conley et al., (2004) due to the way the statements were worded, in the *source* and *certainty* scales the scores were reversed so that for each of the scales, higher scores reflected more sophisticated beliefs.

DATA COLLECTION AND ANALYSIS

The questionnaire was distributed to the students in class and they were given 20 minutes to complete the questionnaire. The students were reminded to read each statement carefully and circle the appropriate number to respond. The data were then keyed into the SPSS: PC Window Programme for analysis.

The reliability of each of the scales was determined by calculating the alpha reliability coefficient for each scale. The scale mean and standard deviation for each scale were also calculated to examine the level of science epistemological beliefs of the students. T-test analysis was performed to determine the influence of gender on science epistemological beliefs. The level of significance was set at 0.05 level.

RESULTS AND DISCUSSION

Reliability of scales

With the data collected in the present study Cronbarch-alpha reliability coefficients were calculated for the four subscales of science epistemological beliefs. For the justification scale, all items had a corrected item-total score correlation coefficient of 0.4 and above. The alpha value was 0.84 for the scale. For the development scale, the internal consistency coefficient was 0.65 higher than that obtained by Conley et al. (2004) but the analysis showed that item ("There are some questions that even scientists cannot answer") had a low corrected item-total score correlation coefficient value (0.11). Removing this item from the scale increased the alpha value for the scale from 0.65 to 0.76. So we decided to remove the item "There are some questions that even scientists cannot answer" from the development scale and use the reduced 5 items scale in further analysis. The source scale had an alpha coefficient of 0.73 and the certainty scale had an alpha of 0.65 with all the items having item-total score correlation coefficients above 0.30. The results show that all scales have a very satisfactory internal consistency. The findings compared favourably with those reported by Conley et al. (2004).

Table 2
Alpha value of present study and Conley et al. (2004)

Scale	Alpha value present study	Alpha value Conley et al. (2004)
Source (5 items)	0.73	0.81
Certainty (6 items)	0.65	0.78
Development (5 items)	0.76	0.57 (six items)
Justification (9 items)	0.84	0.65

SCIENTIFIC EPISTEMOLOGY OF STUDENTS IN SINGAPORE

For the four scales of scientific epistemology, the scale means and standard deviations were calculated and are shown in comparison to Conley et al. (2004) in Table 3. In the Conley et al. (2004) study a 5-point Likert scale was used. For the purpose of comparing the mean scores of the two samples the mean scores of their sample were converted to a six point scale.

Table 3
Item means and std deviation for the subscales and results from Conley et al. (2004)

Scale	No of items	Scale Mean (Std dev) present study	Scale Mean (Std dev) Conley et al. (2004)
Source	5	4.71 (0.73)	4.42 (0.53)*
Certainty	6	4.80 (0.63)	4.06 (0.39)*
Development	5	4.64 (0.72)	4.68 (0.83)*
Justification	9	4.88 (0.66)	5.11 (0.89)*

*The scale mean was converted to a six point scale

Figure 1 below displays the comparison of the two sets of results graphically. In interpreting the results we have to keep in mind that while the respondents in the present study were grade 8 students the respondents in Conley's et al. (2004) study were grade 5 students.

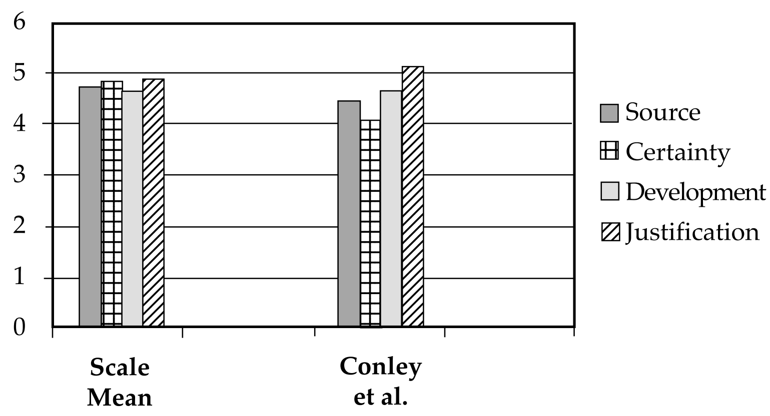

Figure 1: A comparison of the scale mean from the present study with Conley et al. (2004)

The results show that students in Singapore have higher scores in the "source" and "certainty" index of scientific epistemology than students in the Conley et al. (2004) study. This is as would be expected as the respondents in this study have had three more years of exposure to science education and much more mature and we would expect them to be more sophisticated in their beliefs about science. The result of the lower scores with respect to "justification" and "development" dimension of scientific epistemology is not as expected. Singapore students seem to have a lower appreciation of experimentation as a means to justify scientific knowledge. This may be due to the way science experiments are used in teaching science in Singapore. Generally in the Singapore science curriculum a set of standard experiments are prescribed for students to work on. Students carry out the experiments in a routine way and have little opportunity to investigate and find a solution to a problem. This however tallies with research carried out by Lawrenz (1990) which shows that in a typical 50-minute class session for seventh- and eighth-graders, 26% of the time (about 13 minutes) would be spent on lectures, 18% of the time (9 minutes) on discussion, and 16% of the time (8 minutes) working on hands-on-materials. The remaining 40% of the time (20 minutes) would be spent on completing worksheets and watching demonstrations. Similarly, in Singapore schools students spend very little time carrying out experiments thus justifying our students' low appreciation of experimentation.

The students in the present sample also do to subscribe to the view about the changing nature of scientific knowledge to an extent greater than grade 5 students in Conley et al. (2004) study. Here again the way in which students learn science may have an effect on the beliefs of students on the nature of science knowledge. As Lee (2002) points out in traditional science teaching science to many of our students is just a subject which has a great deal of information to be memorized and experiments are more of a task to be accomplished thus it is not surprising that our students do not subscribe to the changing nature of science.

GENDER AND SCIENTIFIC EPISTEMOLOGY

Table 4 lists the results of the t-test analysis to examine the relationship between gender and subscales of scientific epistemology. Though the mean scores of the female students were slightly higher in the four subscales none of the difference was statistically significant at the .05 level. Statistically there is no significant difference in the epistemological beliefs about science between male and female students. Both the groups have gone through the same science learning experience, hence experience rather than gender may be the influence in developing epistemological beliefs.

Table 4
Mean, standard deviation, t-value and 2-tailed probability

Gender		Mean	Std. Deviation	t	Sig (2-tailed)
Source	Male	4.7053	.77881	-.012	.991
	Female	4.7070	.68761	-.012	.991
Certainty	Male	4.8180	.71009	-.475	.636
	Female	4.9368	.54914	-.464	.644
Development	Male	4.5830	.73524	-.716	.476
	Female	4.6842	.70300	-.713	.478
Justification	Male	4.8180	.71613	-.925	.357
	Female	4.9368	.61385	-.911	.365

CONCLUSION AND IMPLICATIONS

Based on the data collected in Singapore classrooms and analysed in this study the four scales were found to be stable measures of science epistemological beliefs of students. It can be used with confidence in Singapore classrooms. We made an adjustment only to the development scale. The item "There are some questions that even scientists cannot answer" did not fit well into the scale. We noticed that the alpha coefficient obtained by Conley et al. (2004) for this scale was also rather low 0.56. It is quite possible that the same item was the problem then. So we decided to remove the item for the scale to get a more reliable scale.

In general the mean scores obtained for the four dimensions of science epistemological beliefs were above 4.5 on a six point scale. This indicates that the students in the sample had fairly sophisticated beliefs in all the four dimensions of science epistemological beliefs. However, in comparison with the Conley et al. (2004) sample, the sample in this study showed lower belief in the role of experiments in the justification of science knowledge and as the source of science knowledge. The students in the present sample also did not subscribe to the view about the changing nature of scientific knowledge to an extent greater than grade 5 students in Conley et al. (2004) study. This may be due to the approach used in science teaching in Singapore schools.

What is the implication of this finding to science education? To promote a more sophisticated view of the nature of science knowledge and how science knowledge is acquired it is important that students are encouraged to construct shared understanding through investigation and dialogue in collaborative contexts in which the teacher serves as collaborator and facilitator. If science is seen from a realist view that it is an objective body of knowledge that is best taught by experts (teachers) via transmission then there is less chance of students developing more sophisticated beliefs about science knowledge and how this knowledge is acquired. Teachers' world views of teaching have to be change from an idealist world view to a constructivist world view. Teachers with a constructivist world view would not be too over concerned with the transmission of knowledge but would also give equal attention to the process students use to construct their knowledge (for more on teachers' world views read Schraw and Olafson, (2004)). This will help the students to appreciate how knowledge in any field is generated.

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