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Influences on Affect and Achievement: High School Students' Epistemological Beliefs about Mathematics

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In this study we identified Chinese high school students' (*n*=585) *mathematics belief a by exploring the use of a 22-item questionnaire with four dimensions. We also analyzed possible significant differences in beliefs related to grade (three years of senior middle school) and sex, as well as the relationship between beliefs and affect along with achievement in math. Results showed differences for three dimensions (knowledge structure; learning ability; learning style) statistically significant related to grade and no difference related to gender. It also emerged that the four dimensions predicted positive feelings, negative feelings and achievement in mathematics to different extents.*

***Key words*:** epistemological beliefs about math, achievement, math learning.

Muis (2004) stated that student's epistemological beliefs about math were concepts in the personal epistemology area, which refers to his/her naive views or opinions about the nature and acquisition of mathematics knowledge. It was like an invisible hand, deeply hiding behind an individual's behavioral expression, cognitive process and emotional experience, but deeply affecting the learning process and thus the performance (Debacher & Crowson, 2006; Ivar & Helgel, 2005; Muis, 2004). Research on students' beliefs was considerably absent in China in contrast with western countries. Since the social beliefs accumulated in a certain time and region profoundly influence students' epistemological beliefs, as indicated by a cross-cultural research on beliefs (Chan & Elliot, 2003), there was a need to examine whether the Chinese students' epistemological beliefs about math were the same as they were in other countries demonstrated in Muis and Ivar and Helgel.

The present study addressed the following issues: (1) high school

students' existing epistemological beliefs about mathematics, and (2) the relationship between epistemological beliefs and affect as well as performance in mathematics learning. These issues were addressed through questionnaire survey and case analyses.

Method

Participants

All 603 students from a senior middle school in southwest city in China were involved. Only 585 questionnaires were taken back, including 200 in Grade 1 with 95 male students and 105 female students, 195 in Grade 2 with 75 male students and 120 female students, and 190 in Grade 3 with 97 male students and 93 female students.

Materials

A Mathematics Epistemological Beliefs Scale designed by Tang (2007) for junior middle school students was used as a reference when establishing the present questionnaire, because exploratory and confirmatory factor analyses suggested that it was reliable and valid. Thirty students were selected at random for open-ended task interviews respectively from those above, on and below the average math performance. According to the interviews and based on the above scale, we constructed a closed-end questionnaire comprising 39 items, 5 points for each item from a negative valence such as "strongly disagree", to a positive valence, such as "strongly agree". Through factor analysis, 22 items remained, and the reliability was 0.81.

The questionnaire consisted of a beliefs scale and an affect scale. The sub-scale on epistemological beliefs comprised four dimensions: knowledge structure (Cronbach's α =0.58), learning ability (Cronbach's α =0.55), learning style (Cronbach's α =0.58), and knowledge stability (Cronbach's α =0.42). Knowledge structure was reflected in 3 items, for example, "School mathematics as experienced in the classroom is useless for everyday life," including the following aspects:

(1) Math knowledge is made of tiny concepts isolated from each other;

(2) Math knowledge is closely related to both the knowledge in other areas and daily life.

Learning ability was also displayed with 3 items, for example, "Most students can learn mathematics well provided they make the effort," including

the aspects as follows:

(1) One's ability for learning mathematics is doomed;

(2) One's mathematics learning ability can be improved through hard work.

Learning style was manifested with 3 items also, for instance, "Active learning by yourself is more meaningful than passively accepting what teachers or others say about mathematics." It contained two opposite beliefs:

(1) Mathematics study relies on passive acceptance and rote learning;

(2) Mathematics study dependent on active construction and rational learning.

Knowledge stability was expressed in 3 items, for instance, "Mathematical formulas, theorems, etc. are eternal truths that will not be questioned". It was made up of two reverse beliefs:

(1) Mathematics knowledge is eternal truth

(2) Mathematics knowledge may be wrong, and it can be developed and modified.

The sub-scale on mathematics learning affect included two dimensions: Positive feelings of enjoyment and success, for example, "Each time when I work out a math problem, I am very happy," and negative feelings of frustration and anxiety, for instance, "Every time when I do math, I am frustrated." The reliability was 0.89 and 0.60 respectively.

Although the reliability of each dimension were on the low side, the total reliability of the questionnaire was high, which conformed to the statistical analysis standard. Furthermore, we recorded participants' marks in two standard performance measures. For students in Grade 1, we employed the mean value of the scores in the entrance examination, and in the examination at the end of the first month after admission. For the students in Grade 2 and Grade 3, we used the mean value of the scores in the final exam in the last term and in the exam after a month in the new term.

Procedure

Students were asked to respond to the questionnaire with their names written in order to ensure the authenticity of the data. Time was limited to 30 minutes.

Results

Gender Differences on Epistemological Beliefs about Math

Means and standard deviations of students' beliefs and each dimension of belief are reported in Table 1. There is no statistically significant difference between male students and female students regarding the epistemological beliefs.

Table 1

Mean and Standard Deviation of Scores for Male Students and Female Students (*n*=585)

Gender	Belief	Knowledge Structure	Learning Ability	Learning Style	Knowledge Stability
Male					
Mean	46.26	11.44	11.27	12.52	11.03
SD	4.62	2.27	1.90	1.76	2.03
Female					
Mean	46.05	11.22	11.29	12.51	11.04
SD	4.47	2.12	1.87	1.80	1.72
t-test	0.55	1.22	-0.09	0.05	-0.05

Grade Differences in Epistemological Beliefs about Math

As is shown in Table 2, the scores of beliefs about math decrease significantly from Grade 1 to Grade 3, [F=30.42, P<0.01]. Post hoc Tukey's Honestly Significant Difference test (HSD) reveals statistically significant differences in grades for the first three dimensions -- knowledge structure, learning ability and learning style. Beliefs in both knowledge structure dimensions decrease fairly linearly from the first year to the third year, [F=42.41, P<0.01]. Concerning learning ability, the scores of Grade 1 are significantly higher than Grade 2 and Grade 3, [F=7.44, P<0.01]. Concerning learning style, the scores of Grade 1 are significantly higher than Grade 3, [F=5.71, P<0.01].

Table 2

Means and Standard Deviations of Scores for Grades 1 to 3 (*n*=585)

Grade	Epistemological Beliefs	Knowledge Structure	Learning Ability	Learning Style	Knowledge Stability
Grade 1					
M	47.91	12.33	11.68	12.78	11.13
SD	4.42	1.78	1.90	1.73	1.87
Grade 2					
M	45.95	11.15	11.16	12.57	11.06
SD	4.35	2.23	1.86	1.75	1.89
Grade 3					
M	44.51	10.43	10.98	12.18	10.91
SD	4.20	2.13	1.81	1.82	1.84

Correlations between Belief and Affect and Achievement

As can be seen in Table 3, there are statistically significant correlations between each dimension of beliefs and negative feelings. With the exception of knowledge stability, there are significant correlations between the other dimensions of beliefs and positive feelings. As for achievements, there is small correlation between beliefs and achievement in Grade 1. However, there is significant correlation between dimensions of knowledge structure and learning style and achievement in Grade 2, and the same is true for Grade 3.

Table 3

Correlations between Dimensions of Belief and Affect and Achievement

	Negative feelings	Positive feelings	Achievement for Grade 1	Achievement for Grade 2	Achievement for Grade 3
Knowledge Structure	0.39**	0.18**	0.06	0.32**	0.20**
Learning Ability	0.11**	0.18**	−0.07	0.11	0.05
Learning Styles	0.18**	0.16**	−0.04	0.17*	0.23**
Knowledge Stability	0.14**	0.04	0.06	0.11	0.09

Regression Effect of Beliefs onto Affect and Achievement

According to the results of a stepwise regression analysis (as shown in

Table 4), all dimensions except learning ability predict negative feelings, and all dimensions except knowledge stability predict positive feelings.

In terms of achievement, students' performance in Grade 1 cannot be predicted by any dimension of epistemological beliefs; students' performance in Grade 2 are regressed on the scores of knowledge stability regarding the overall dimensions, and students' achievement in Grade 3 are regressed on the scores of both knowledge stability and learning style.

Table 4

Multiple Regression Analysis of Dimensions of Beliefs to Affect and Achievement

		Knowledge Sructure	Learning Ability	Learning Style	Knowledge Stability
Negative feelings	*β*	0.36		0.10	0.08
	t	9.44**		2.48*	2.17*
Positive feelings	*β*	0.15	0.14	0.10	
	t	3.60**	3.53**	2.50*	
Achievement for Grade 1	*β*				
	t				
Achievement for Grade 2	*β*	0.32			
	t	4.75**			
Achievement for Grade 3	*β*	0.18		0.21	
	t	2.52*		2.93**	

Discussion

Gender and Grade Differences on Epistemological Beliefs

The findings in Table 1 show that there is no significant difference between male students and female students regarding the validity of epistemological beliefs and the overall dimensions; the scores are above the average, which indicates that on one hand male students' and female students' beliefs about math are in substantial agreement, and on the other hand their beliefs need further development towards the orientation in favor of mathematics learning. Concretely, scores of male students' beliefs on the dimensions of knowledge structure and learning style are slightly higher than those of female students', but on the dimensions of learning ability and knowledge stability there is no statistically significant difference. One possible explanation was the common existence of the bias that female students were

not born to learn mathematics. Students' beliefs about learning style are more valid than beliefs in the other dimensions. This means that they tend to aquire math knowledge by active learning. In comparison, the scores of beliefs of knowledge stability are somewhat lower. It calls for further development.

As for beliefs about math, there are significant differences between grades 1, 2 and 3, which follow in a descending order. In detail, statistically significant differences in grades exist on the dimensions of knowledge structure, learning ability and learning style except knowledge stability.

Beliefs bout Knowledge Structure

As the grade increases, students perceive the abstract and logical characteristics of math more and more, but they do not appreciate the widespread utility of math. Thus they believe that mathematics is almost completely unrelated to other subjects and everyday life. This is proved by the individual interviews. When students were asked to demonstrate their opinions about views that mathematics had few obvious connections with everyday life, and that learning mathematics was just for getting into a good school, the higher the grade, the more students agreed with the latter. For example, students in Grade 1 considered that real life was full of mathematics, and that fundamental calculation was useful, which could also exercise thinking ability; students in Grade 2 acknowledged the existence of mathematics related with reality, but they thought that it was absent in their study after all, so they held an opinion that math in senior grades was nearly useless; and students in Grade 3 took mathematics as a system of signs; they believed that learning math was just for the university entrance examination, and people would survive without math. One possible interpretation for these opinions concerns abstractness and the logic structure of math textbooks, and formal discipline in math teaching. The only demonstration of mathematics application in the textbook would be rejected by a "test culture." Teachers were merely focused on finishing the content which would appear in the standard examination, and entirely ignored the reading materials, practical work and research tasks for learning in textbooks, not to mention math applications beyond the textbooks, which implicitly broke the connection between mathematics and reality.

Beliefs about Learning Ability

Beliefs on the learning ability of students in Grade 1 are more positive

than those of students in Grade 2 and 3. It differed from the results of Schommer (2005) who pointed out that students attached importance to endeavor and willpower more and more as they were promoted to the next grade. Analysis from individual interviews supported the findings. Students in the first year were winners in the entrance examination, holding the conviction that diligence made up for one's dullness, while students in the second year wavered in their faith because of the frustration from increasing difficulty in mathematics learning and selection between arts and science, and the views that diligence is nothing even emerged among students. When students entered in their third year, sprinted for the university entrance exam, they need to review piles of materials for the test, therefore, the students who had low achievement on the tests changed their beliefs about learning ability to a more negative one. As a consequence, high school students' beliefs on learning ability were influenced by both internal cognition and external environment.

Beliefs about Learning Style

Students in the first year hold more positive beliefs than those in the third year regarding to the learning style. Although new curriculum reform characterized with active learning has been going on for some time, what students experienced in the math classroom was mainly receptive learning, in that high schools accelerated the teaching pace, speeded up the learning process and thus compressed the time and space for thinking as a result of the "test culture," from the first year. Learning mathematics by rotting was a more popular viewpoint among students in the second year than those in other years (Li, Wu, & Li, 2001). It was so especially for students in the third year, when pressure expanded suddenly because of collections of abundant exercises, so receptive learning increased inevitably in spite of valuing active thinking. The interviews not only confirmed the above standpoints, but also found that what students believed wasn't consistent with their behaviors. For example, a great many students mentioned they had to surrender into the context of the current examination system, although they extremely agreed with the views that learning math depended on understanding rather than plenty of exercises. The "Test culture" was so strongly impressed on students that it twisted their beliefs and behaviors.

As a whole, students' epistemological beliefs changed from valid and positive to invalid and negative towards mathematics learning in the ascending grades, and their beliefs developed in a certain order and stage as time went on.

The development did not always advance forward. It even demonstrated regression owing to various factor.

Influences on Math Affect and Achievement from Beliefs

All dimensions of beliefs are significantly correlated with negative effect, and knowledge structure can predict the negative feelings (r=0.36). Those who believed that math was useless lost heart in math learning and wouldn't make efforts any more (Tang, 2007). Learning style and knowledge stability can predict negative feelings, too. Due to some misunderstanding about mathematics, students might find it difficult to realize the powers, appeal and value in math. Therefore they did rote learning, and performed poorly, being full of fear, anxiety and sick of math. Learning style and knowledge stability can also predict positive affect. But in comparison with the prediction towards negative feelings, the predictive power of knowledge structure towards positive feelings was weaker. Accordingly, it could be said that beliefs about knowledge structure and learning style had two sides: on the one hand they led to negative feelings, and on the other hand, they caused positive feelings. Implications were drawn regarding curriculum design and teaching modes—we should obtain a balance between the structure and non-structure of mathematics knowledge, and between acceptance and construction of learning styles. Moreover, positive feelings can be predicted significantly by beliefs of learning ability. Individual interviews showed that the more firmly students think about the contribution of diligence to mathematics learning, the more confidently they deal with mathematics study, and thus can conquer anxiety and frustration accompanying mathematics learning.

Different from Western research results, however, epistemological beliefs cannot predict mathematics achievement very well. Mason (2003) indicated that the strongest predictor was belief regarding perceived ability to solve math problems. The more students believe in their ability, the better their math grades. Muis (2004) revealed that beliefs could strongly predict math achievement. The more students believed in the conviction that math knowledge was isolated and eternal, the worse their math performance. Achievement of students who believed in the relativity and constructed nature of math, was better than that of those who believed in dualism and accepted nature. But it was not the case in this thesis. Concerning students in Grade 1, beliefs are not correlated significantly with achievements. A few students held positive epistemological beliefs, but their performance in mathematics was

really poor. In contrast, some students did well in mathematics, though their beliefs seemed negative. That means positive beliefs don't lead to good grades. Concerning students in Grade 2, despite the statistically significant correlation between achievement and knowledge structure as well as learning style, it is only the former that can make a prediction toward grades. Concerning students in Grade 3, both knowledge structure and learning style can predict math performance. Hence we can conclude that some dimensions of epistemological beliefs did predict math achievement, although the prediction seemed indirect. As was demonstrated in numerous research studies, the influence of beliefs onto achievement was primarily through affect, motivation, behavior and cognition as the medium.

In addition, a stepwise regression analysis was limited as a research method to explore the influences, which called for more appropriate approaches such as structure equation modeling. The inconsistency with the western findings may be interpreted from the social culture and research approaches.

Conclusions

Conclusions were as follows: (1) There is no statistically significant difference between male students and female students regarding epistemological beliefs; (2) students' epistemological beliefs change from valid and positive to invalid and negative towards mathematics learning according in ascending grades; (3) beliefs are not correlated significantly with achievements for students in Grade 1, knowledge structure can make a prediction towards grades for students in Grade 2, and both knowledge structure and learning style can predict math performance for students in Grade 3.

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