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Senior Secondary School Students' Epistemological Conceptions of Mathematics in China: Characteristics and Development Process[1]

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This paper reports findings from a survey of senior secondary school students' epistemological conceptions of mathematics with the adaption of the instrument of the "Conceptions of Mathematics"—Inventory in China. The survey included a sample of 414 Grade 10 students, 441 Grade 11 students, and 400 Grade 12 students from three provinces. Descriptive statistics, one-way ANOVA, and T-test were employed to analyze data in this study. It was found that senior secondary school students mainly focused on objectivity and reality of mathematics, without highlighting the characteristics of sociality, subjectivity, and creativity of mathematics. In addition, besides gender differences, differences were identified among students from different grades, different areas, taught by teachers with different teaching experience and experience in using reformed curriculum.

Keywords: senior secondary school students; epistemological conceptions of mathematics; characteristics; development process
MESC Classification: C24
MSC2010 Classification: 97C20

1. INTRODUCTION

There have been mathematics curriculum reforms in most of countries in the past decade or so with a main goal to improve students' mathematics achievement and enrich students' mathematics learning experience. One common characteristic of this round of mathematics curriculum reform is the advocate of constructivist views of mathematics and its teaching and learning, which are substantially different from those in traditional mathematics curriculum. Under this view, mathematics knowledge is not acquired simply

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by memorizing definitions and rules, but through students' active inquiry or exploratory activities so as to construct their individual ways of knowing and understanding of mathematics (Cobb, 1996).

Under the influence of this view, there also has been a mathematics curriculum reform at senior secondary school level since 2003 in China. In the latest senior secondary school mathematics curriculum in China, the main goal of mathematics learning and teaching is described as to develop students the ability to mathematically articulate, analyze and solve problems and the ability to apply mathematics in real world context (Ministry of Education, 2003). More importantly, the fundamental meaning of mathematics underlying the mathematics curriculum has also been reformed in this curriculum reform (Sun & Xie, 2004). Traditionally, mathematics has been regarded as an abstract and rigorous subject in China for a long time (Li, Huang & Shin, 2008). Logical deduction and formal mathematical operations have been emphasized as the essential parts of learning mathematics in China (Li, Huang & Shin, 2008; Zhang, Li & Tang, 2004). In this curriculum reform, mathematics has been defined as dynamic and a creative activity of human being, a scientific language, and an effective tool to describe natural and social laws other than the over emphasis of logical deduction and formal mathematics (Ministry of Education, 2003).

In practice, if the reformed ideas have been effectively implemented by the teachers, it could change students' experience of mathematics learning and the ways to construct mathematics understanding. This could further influence students' opinions about mathematics knowledge and the ways to learn it. That is, students may develop a sophisticated epistemological conception of mathematics gradually (Schommer, 1994). Epistemological conception in this study refers to the "beliefs and assumptions about the nature of knowledge and knowing that exist at varying levels of sophistication and commitment" (Star & Hoffmann, 2005, p. 25). Epistemological conception, which is also referred to epistemological belief by other researchers (e.g., Hofer & Pintrich, 1997; Schommer, 1990), has long been one of the important cornerstone themes in educational and psychological research fields (Topcu, 2012). As to epistemological belief, it has been generally accepted as a multidimensional model in educational research (Buehl & Alexander, 2006; Muis, 2004). For example, Schommer (1990) once proposed a multidimensional framework of epistemological belief, which consists of five dimensions, namely certainty of knowledge, structure of knowledge, source of knowledge, innate ability, and quick learning. Furthermore, in Schommer's (1990) opinion, these five dimensions are more or less independent rather than developing concurrently.

Schommer's (1990) work has been generally treated as the pioneer work in this area (Buehl & Alexander, 2006; Muis, 2004) and after that, there has been an ever increasing research interest to investigate students' epistemological beliefs. However, the research

on students' epistemological beliefs during the early stage was conducted under the assumption that they are domain general (Muis, 2004). Until recently, researchers have challenged the theoretical foundation of the past research and started to differentiate beliefs about knowledge and knowing in different academic domains (Buehl & Alexander, 2005, 2006). That is, during the past years, the general focus of research in this field has shifted from domain-general to domain-specific epistemological beliefs. Since students' epistemological beliefs might be different to a certain degree in different subjects (Hofer, 2000), it is necessary to investigate students' epistemological beliefs about mathematics. Considering the characteristic of multidimensionality of students' epistemological beliefs, epistemological conception of mathematics in this study also includes multiple dimensions, such as composition of mathematical knowledge, structure of mathematical knowledge, status of mathematical knowledge, and validating ideas in mathematics (Grouws, 1994; Star & Hoffmann, 2005).

In addition, findings in previous studies suggest that students' conceptions of the nature of mathematical knowledge and knowing will not only influence students' affective outcomes of mathematics learning, such as confidence in learning mathematics, but also a factor that influences student's mathematics performance. For example, students' epistemological mathematics beliefs were found to be a factor which will further influence students' other beliefs, like beliefs about effort in learning mathematics (Schommer-Aikins et al., 2005). In the meantime, in the same study, it was identified that students' epistemological mathematics beliefs could influence students' academic performance as well. More specifically, Liu (2010) found that students espousing sophisticated and active beliefs about mathematical knowledge and thinking performed quite well in tests while those who held naive and conventional epistemological beliefs in mathematics performed poor.

Due to the importance of epistemological conception of mathematics, in practice, only fully understand students' epistemological conception of mathematics, like its characteristics and development process, can make effective suggestions to how to develop students' epistemological conception, the revision of mathematics curriculum, textbook development, and teacher training program. Therefore, it is necessary and meaningful to explore the characteristics and development process of epistemological conception of mathematics held by students, particularly under the present curriculum reform background. However, so far, there is a lack of research effort to investigate senior secondary school students' epistemological conception of mathematics in international literature in mathematics education in general (e.g., Colby, 2007), and in the Chinese context in particular. In the meantime, there is no systemic research on its development process and influences (e.g., teachers) of senior secondary school students' epistemological conception of mathematics. In view of this, this study aims to:

1) Investigate senior secondary school students' epistemological conception of mathematics in China, like its characteristics and development process; and

2) Influences to its characteristics and development process. Findings of this could make contribution to the design of teacher training program and the revision of mathematics curriculum so as to enhance the effectiveness of mathematics curriculum at senior secondary school level.

2. RESEARCH METHODS

2.1. Participants

With the consideration of factors such as students from different regions and taught by teachers with different experiences (e.g., years of teaching (average 10.35 years of teaching), experience of using reformed curriculum (average 3.45 years of using reformed curriculum), this study involved a survey of 1255 senior secondary school students from 36 classes in 6 schools in three different provinces, Shandong, Guangdong, and Zhejiang. Shangdong and Guangdong Provinces started to use the informed mathematics curriculum in the year of 2004, while Zhejiang Province started to use it in 2006. Table 1 describes the background information of sample in the study.

Table 1. Background characteristics of the participants

		Frequency (*N*)	Percentage (%)
Gender	Boys	677	53.9
	Girls	578	46.1
Grade	Grade 10	414	32.9
	Grade 11	441	35.1
	Grade 12	400	32.0
Provinces	Guangdong	564	45.0
	Shandong	205	16.3
	Zhejiang	486	38.7

2.2. Instrument

The Conceptions of Mathematics Inventory (CMI) developed by Grouws (1994) were adapted in this study. This questionnaire has been used by researchers (e.g., Colby, 2007; Star & Hoffmann, 2005) in previous studies to investigate senior secondary school students' epistemological conceptions of mathematics under the reformed curriculum background. In the meantime, the CMI was one of the very few scales designed specifically to investigate students' epistemological conception of mathematics. Its validity and reliabil-

ity have been justified in previous studies (e.g., Colby, 2007; Star & Hoffmann, 2005). In view of this, the questionnaire was adapted as the main instrument to collect data in the present study. The questionnaire includes 7 scales: composition of mathematical knowledge, structure of mathematical knowledge, status of mathematical knowledge, doing mathematics, validating ideas in mathematics, learning mathematics, and usefulness of mathematics. In total, in this study, 33 items were adapted from the original CMI based on the choice of the author and two experienced senior secondary school mathematics teachers because of their suitability to the actual situation of mathematics teaching in China.

Table 2. Scales of CMI

Scales	Descriptions	Sample Item
Composition of mathematical knowledge	Mathematical knowledge is composed of either concepts, principles, and generalizations or facts, formulas, and algorithms.	Computation and formulas are only a small part of mathematics
Structure of mathematical knowledge	Mathematics is structured either as a coherent system or a collection of isolated pieces.	Most mathematical ideas are related to one another.
Status of mathematical knowledge	Mathematics as either a dynamic field or a static entity.	The field of mathematics is always growing and changing.
Doing mathematics	Doing mathematics is either a process of sense-making or a process of obtaining results.	Solving a problem in mathematics is more a matter of understanding than remembering.
Validating ideas in mathematics	Validating ideas in mathematics occurs either through logical thought or via mandate from an outside authority.	Justifying the statements a person makes is an important part of mathematics.
Learning mathematics	Learning mathematics is either a process of constructing and understanding or a process of memorizing intact knowledge.	Learning mathematics involves more thinking than remembering information.
Usefulness of mathematics	Mathematics is viewed as either a useful endeavor or as a school subject with little value in everyday life or future work	Students need mathematics for their future work.

The finial modified version of questionnaire was constructed with a six-point Likert-type response scale, with "1" expressing strong disagreement and "6" expressing strong agreement. For the scales, if the scores are relatively high, it indicates that students are more likely to agree that mathematics is composed of a useful, coherent, and dynamic system of concepts and ideas. In addition, learning mathematics is a process of sense

making. By contrast, if the scores are low, it suggests that students think mathematics is static, irrelevant, unchanging collection of isolated facts and procedures. At the same time, learning mathematics is a process of handing down from textbook or teacher or other authorities. A detailed description of what each CMI scale measures and sample item are presented in Table 2. The internal consistency of each modified CMI scale was estimated using the Cronbach alpha reliability coefficient, which ranged from 0.596 to 0.854, which shows the questionnaire has high internal consistency and certain reliability.

2.3. Data analysis

Data were analyzed by descriptive statistics, one-way ANOVA, and T-test. To obtain a sample description of senior secondary school students' epistemological conception of mathematics, mean score of each scale with standard deviation was computed. Next, a one-way multivariate analysis of variance was undertaken to explore differences among students from different grades, provinces, and taught by teachers with different teaching experience and different experience in using reformed curriculum. T-test was performed to examine gender differences.

3. FINDINGS

3.1. General situation of senior secondary students' epistemological conception in China

The item mean scores of the scale of "usefulness of mathematics" and "status of mathematical knowledge" are 4.50 and 4.87, which are in the middle of "agree" and "somewhat agree" as investigated. This shows that the participants tend to agree that mathematics knowledge is made up by concepts and theories, and is in the state of continuous development. The item mean scores of the scales "validating ideas in mathematics" and "doing mathematics" are close to 4.67, which implies that participants to a certain degree agreed that mathematics knowledge can be verified through logical reasoning rather than setting by authorities and doing mathematics is a process of meaning construction, not only a process of obtaining results, and mathematics knowledge can be used in real life. However, the degree of agreement is not high (the item mean score of each item is a little higher than 4.5). This suggests that students to a certain degree also consider mathematics knowledge in textbooks is correct, and once the mathematics knowledge is confirmed, the accuracy is beyond doubt and students can hardly find new mathematics knowledge themselves.

Table 3. Sub-total mean scores and standard deviations for the seven scales of CMI

Scales	Item No.	Mean Score	Standard Deviation
Composition of mathematical knowledge	5	23.69	3.66
Structure of mathematical knowledge	5	25.17	3.54
Status of mathematical knowledge	5	24.34	3.91
Doing mathematics	4	18.62	3.13
Validating ideas in mathematics	5	23.28	3.51
Learning mathematics	4	20.56	3.08
Usefulness of mathematics	5	22.50	5.54

3.2. Difference among students in different provinces

With a vast territory, there exist slight differences in teaching conditions and ways of evaluation in different provinces in China. In addition, the latest senior secondary school mathematics curriculum was not implemented in all the provinces in the same year. The study surveyed epistemological conception of mathematics of students in Guangdong and Shandong, provinces firstly used the reformed senior secondary school curriculum in 2003, and students in Zhejiang, a province began to use reformed curriculum in 2006. One-way MANOVA was conducted to examine differences among students in these three provinces (Table 4 reports the results). As shown in Table 4, the mean scores of the seven scales of students in Guangdong and Zhejiang are higher than that of students in Shandong. One-way MANOVA results show that there were significant differences among students in the three provinces, especially for the scale of "structure of mathematical". A Scheffe post hoc test[2] was then employed to examine differences between students in each of two provinces. Results show that:

1) Significant differences were found to be existed between students in Shandong and Guangdong for the scales of "composition of mathematical knowledge", "structure of mathematical knowledge", and "doing mathematics";
2) For the scales of "composition of mathematical knowledge", "structure of mathematical knowledge", and "learning mathematics", significant differences were found between students in Guangdong and Zhejiang; and
3) For the scales of "structure of mathematical knowledge", "validating ideas in mathematics" and "usefulness of mathematics", significant differences were found between students in Shandong and Zhejiang.

[2] In statistics, Scheffe's method is a method for adjusting significance levels in a linear regression analysis to account for multiple comparisons. It is a single-step multiple comparison procedure which applies to the set of estimates of all possible contrasts among the factor level means, not just the pair wise differences

Table 4. Mean, standard deviation, and F value for province differences for each CMI scale

Scales	Shandong (M±SD)	Guangdong (M±SD)	Zhejiang (M±SD)	F
Composition of mathematical knowledge	22.98±3.89	23.76±3.56	23.92±3.65	5.005**
Structure of mathematical knowledge	24.24±4.18	25.61±3.25	25.05±3.48	11.855***
Status of mathematical knowledge	23.95±3.63	24.54±4.02	24.20±3.84	4.680**
Doing mathematics	18.19±3.46	18.87±2.88	18.51±3.24	4.044*
Validating ideas in mathematics	23.16±3.74	23.56±3.54	23.00±3.35	3.499*
Learning mathematics	20.04± 3.56	20.50±2.93	20.83±3.02	4.987**
Usefulness of mathematics	22.05±5.67	22.69±5.39	22.94±5.42	3.599*

*<0.05; **<0.01; ***<0.001.

3.3. Gender differences

As shown in Figure 1, there are differences in boys' and girls' epistemological conception of mathematics. For the seven scales, the development process of boys and girls is also different. T-test was further performed to examine gender differences. The result shows that boys' mean scores are significantly higher than that of girls at the scales of "composition of mathematical knowledge" ($t = 7.696$, $p < 0.01$), "validating ideas in mathematics" ($t = 4.321$, $p < 0.05$), and "usefulness of mathematics" ($t = 6.343$, $p < 0.05$). This suggests that compared with girls, boys tended to think mathematics knowledge is made up by theories, can be verified through logical reasoning rather than set up by authorities, and can be used in real world context. Girls' mean scores of the scale of "doing mathematics" ($t = 5.335$, $p < 0.05$) were found to be significantly higher than that of boys. This indicates that compared with boys, girls tended to think "doing mathematics" is to construct meaning and understanding.

3.4. Grade differences

In order to explore the development process of senior secondary school students' epistemological conception of mathematics, the study compared the grade differences among Grade 10, Grade 11, and Grade 12 students. One-way MANOVA was employed to examine grade differences (Table 5 summarizes the results). The results show that there exist significant differences among students from these three grades, especially for the scale of "composition of mathematical knowledge". A Scheffe post hoc was further conducted to

examine differences between students at any of the two grades. Results show that:

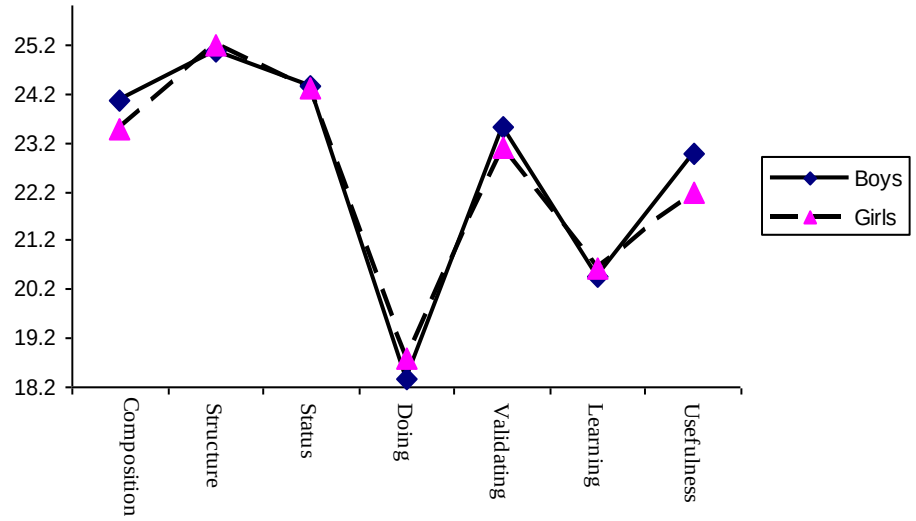

Figure 1. Gender Differences

1) There existed significant differences between Grade 10 and Grade 11 students expect at the scale of "doing mathematics";
2) There existed significant differences between Grade 10 and Grade 12 students at the scales of "compostion of mathematical knowledge", "doing mathematics", "validating ideas in mathematics", and "learning mathematics"; and
3) There existed significant differences between Grade 11 and Grade 12 students at the scale of "doing mathematics".

In addition, as shown in Table 5, except for the scale of "doing mathematics", the mean scores of other scales of Grade 11 and Grade 12 students are higher than that of the Grade 10 students. Together with the differences identified among the three grades, this indicates that students' epistemological conception of mathematics has a change along with the rise of grade and the increase of learning mathematics experience. However, even though no significant differences were found to be existed between the mean scores of Grade 11 and Grade 12 students, as shown in Table 5, the mean scores of Grade 12 students are lower than those of the Grade 11 students at all the seven scales. This suggests that there exist a negative change of epistemological conception of mathematics between Grade 11 and Grade 12 students.

Table 5. Mean, standard deviation, and F value for grade differences for each CMI scale

Scales	Grade 10 (M±SD)	Grade 11 (M±SD)	Grade 12 (M±SD)	F
Composition of mathematical knowledge	22.95±3.68	23.80±3.45	24.34±3.74	15.395***
Structure of mathematical knowledge	24.79±3.52	25.45±3.45	25.27±3.63	3.926*
Status of mathematical knowledge	23.97±3.78	24.63±3.87	24.40±4.06	3.192*
Doing mathematics	18.92±2.93	18.73±3.14	18.16±3.27	6.457**
Validating ideas in mathematics	22.80±3.53	23.52±3.33	23.50±3.63	5.706**
Learning mathematics	20.13± 3.01	20.83±2.86	20.68±3.35	6.070**
Usefulness of mathematics	22.00±5.67	23.01±5.22	22.45±5.72	3.587*

*<0.05; **<0.01; ***<0.001.

3.5. Difference among students taught by teachers with different teaching experience

Due to the differences of teachers' qualification and teaching experience, their mathematics classroom practice might be different to a certain degree. Correspondingly, students' experience in mathematics learning is also different. In order to explore the influence from teachers, according to a standard set by Lian (2008) for Chinese teachers' qualification and expertise, this study categorized teachers' teaching experience and qualifications into the following three groups: 1-5 years of teaching experience (beginning teacher), 6–15 years of teaching experience (proficient teacher), and 16 or more years of teaching experience (expert teacher). As shown in Table 6, for the mean scores of students taught by the three groups of teachers, there exits an increasing trend along with the increase of teachers' teaching experience at some scales (e.g., "status of mathematical knowledge" and "learning mathematics"). While for some other scales, such as "structure of mathematical knowledge" and "doing mathematics", there is a process of increasing first, then decreasing.

One-way MANOVA was conducted to examine differences among students taught by the three groups of students. As shown in Table 6, there exist significant differences at all the seven scales, especially at the scale of "structure of mathematical knowledge". A Scheffe post hoc was further performed. Results show that:

1) There existed significant differences between students taught by beginning teachers and students taught by proficient teachers only at the scale of "usefulness of mathematics";

2) There existed significant differences between students taught by beginning teachers and expert teachers at the scales of "composition of mathematical knowledge", "structure of mathematical knowledge", and "doing mathematics", and "learning mathematics "; and

3) There existed significant differences between students taught by proficient teachers and expert teachers at the scales of "structure of mathematical knowledge", "doing mathematics", and "validating ideas in mathematics".

Table 6. Mean, standard deviation, and F value for differences among students taught by teachers with different teaching experience for each CMI scale

Scales	0–5 (M±SD)	6–15 (M±SD)	>=16 (M±SD)	F
Composition of mathematical knowledge	23.39±3.80	23.69±3.73	24.13±3.26	3.126*
Structure of mathematical knowledge	25.14±3.47	24.86±3.69	25.95±3.13	8.935***
Status of mathematical knowledge	24.07±3.94	24.29±3.95	24.83±3.63	3.208*
Doing mathematics	18.59±2.98	18.43±3.18	19.09±3.17	4.130*
Validating ideas in mathematics	23.18±3.62	23.10±3.51	23.84±3.29	4.385*
Learning mathematics	20.19± 3.06	20.59±3.17	20.97±2.83	4.901**
Usefulness of mathematics	21.78±5.80	22.79±5.35	22.79±5.58	4.276*

*<0.05; **<0.01; ***<0.001.

3.6. Difference among students taught by teachers with different experience in using reformed curriculum

It is reasonable that it takes some time for teachers to get familiar with ideas in the reformed mathematics curriculum and the degree to which a teacher is familiar with and accept the reformed mathematics curriculum would influence her/his teaching practice. Therefore, teachers' experience in using reformed curriculum may be another factor that will influence the development of students' epistemological conception of mathematics. To explore this influence, this study categorized teachers' experience in using reformed curriculum into the following 3 groups: 1-2 years, 3-5 years, and 6-8 years. As shown in Table 7, the mean scores of students taught by teachers with one or two years of experience in using reformed curriculum are lower than that of students taught by teachers us-

ing reformed curriculum for more than 3 years. However, the mean scores of students taught by teachers using reformed curriculum for more than 6 years are lower than that of the students taught by teachers with experience in using reformed curriculum between 3 years to 5 years.

One-way MANOVA was conducted to examine differences among students taught by teachers with these three types of experience in using reformed mathematics curriculum. As shown in Table 7, there exist significant differences at the scales of "composition of mathematical knowledge", "structure of mathematical knowledge", "validating ideas in mathematics", and "learning mathematics". A Scheffe post hoc test results further show that:

1) There existed significant differences between students taught by teachers using reformed curriculum for one or two years and students taught by teachers using reformed curriculum 3-5 years at the scales of "composition of mathematical knowledge", "structure of mathematical knowledge", "validating ideas in mathematics", and "learning mathematics";
2) There existed significant differences between students taught by teachers using reformed curriculum for one or two years and students taught by teachers using reformed curriculum for more than six years at the scale of "validating ideas in mathematics"; and
3) There exist differences between students taught by teachers using reformed curriculum 3-5 years and students taught by teachers using reformed curriculum for more than six years at the scale of "composition of mathematical knowledge".

Table 7. Mean, standard deviation, and F value for differences among students taught by teachers with different experience in using reformed curriculum for each CMI scale

	1–2 years (M±SD)	3–5 years (M±SD)	6–8 years (M±SD)	F
Composition of mathematical knowledge	22.79±3.73	24.17±3.58	23.33±3.63	13.971***
Structure of mathematical knowledge	24.56±3.61	25.43±3.46	25.03±3.60	5.230**
Status of mathematical knowledge	23.95±3.63	24.54±4.02	24.20±3.84	2.120
Doing mathematics	18.73±2.74	18.49±3.29	18.78±3.03	1.197
Validating ideas in mathematics	22.51±3.41	23.45±3.48	23.38±3.56	5.846**
Learning mathematics	19.95± 3.03	20.84±3.02	20.37±3.17	7.453**
Usefulness of mathematics	22.02±5.56	22.75±5.58	22.32±5.45	1.613

<0.01, *<0.001

4. DISCUSSION

4.1. Overall characteristics of senior secondary school students' epistemological conceptions of mathematics in China

With the adaption of the Conceptions of Mathematics Inventory, this study investigated senior secondary school students' epistemological conceptions of mathematics in China. As reported in Table 3, for the seven scales as investigated in the study, the item mean scores of the scales of "structure of mathematical knowledge" and "learning mathematics" are larger than 5, which correspond to "agree". This suggests that under the background of using reformed mathematics curriculum, senior secondary school students can realize that mathematics is constructed as a coherent system rather than by some isolated facts and algorithm, and they also can realize that learning mathematics is to pursue the understanding of mathematics knowledge rather than memorizing facts or definitions. While for other scales, item mean scores are lower than 5. This suggests that although students can realize the development of mathematics knowledge is dynamic, and mathematical knowledge is composed by principals and generalizations, they also think that mathematics knowledge is determined by authorities. In addition, they also think that it is difficult for students themselves to discover new mathematics knowledge by their own hard work and there is no strong connection between mathematics knowledge and real life.

This kind of epistemological conception indicates that, to a certain degree, their conceptions are still limited in a view that mathematics is absolute and unchanged. In other words, although the reform of reformed curriculum in senior secondary school has been used in China for several years, students' epistemological conceptions of mathematics is still mainly focus on the objectivity of mathematics knowledge. To a certain degree, they still do not realize the sociality and subjectivity of mathematics knowledge, especially mathematics as a creative activity of human being. This further reflects a factor that senior secondary school students in China do not completely develop a modern and dynamic conception of mathematics as advocated in the latest mathematics curriculum, such as mathematics is an effective tool, mathematics is the foundation to other sciences, or mathematics is an important constituent of human culture (Ministry of Education, 2003). Instead, to a large degree, senior secondary school students still think that mathematics knowledge is absolute and certain, which has been emphasized in mathematics education for many years in China (Sun & Xie, 2004).

4.2. Development process of senior secondary school students' epistemological conceptions of mathematics in China

As reported above, this study found that the development of senior secondary school students' conception is a recursive process and each dimension is not equally and evenly developed during senior secondary school period. In particular, it also found that compared with Grade 10 students, there exists a significant development for Grade 11 and Grade 12 students' epistemological conception, while there is a negative change for Grade 12 students' conception. The findings are similar to what have been identified in previous studies. For example, it has been argued by Schommer (1990) that the development process of students' epistemological conception is a recursive process and for the dimensions included in epistemological conception, they will not necessarily develop in a unified way.

Meanwhile, as Schommer (1990) pointed out that the development process is not only influenced by students' formal educational experience, but also influenced by student's life experience. Thus, due to the reason that Grade 12 student need to prepare for their College Entrance Examination, it might be possible for them to focus more on how to get a right answer and ignore "doing mathematics" is a process of pursuing understanding. Moreover, perhaps along with the increase of grade, mathematics teachers are increasingly focused on emphasizing mathematics knowledge. This may also cause that students tend to believe that "doing mathematics" aims for obtaining a result. Of course, due to the limitation research condition, the study did not follow the development process of senior secondary school students' epistemological conceptions of mathematics. Therefore, findings like this have their own limitation. Future studies could follow a certain number of students for a number of years so as to more deeply reveal the development characteristics of students' epistemological conceptions of mathematics.

4.3. Gender and sub-cultural differences

As reported above, similar to findings in previous studies (e.g., Lodewyk, 2007; Schommer, 1993), gender differences were also identified in this study. For some scales, such as the scales of "status of mathematical knowledge" and "validating ideas in mathematics", the mean scores of boys are higher than that of girls. However, for some scales, such as the scales of "doing mathematics" and "learning mathematics", the mean scores of girls are higher than that of boys. Differences like these may indicate that the development of different dimensions of girls' epistemological conceptions of mathematics is not as same as that of boys. Therefore, mathematics teachers should consider the difference between boys and girls during their teaching. At the same time, the differences should also be considered when design mathematics curriculum. In addition, due to the possible differences of teaching culture and evaluation in these three participant provinces, significant differences were identified among students from different provinces as well in

the study.

In addition, as argued in previous studies (e.g., Buehl & Alexander, 2006), knowledge is considered to be embedded in and shaped by a particular socicocultural context. Previous studies indeed identified the cultural differences in students' epistemological beliefs (e.g., Chai et al., 2012; Sutherland & Dennick, 2002). In the present study, due to the sub-cultural differences among the three participant provinces, students' epistemological conceptions of mathematics were also found to be different. Even though the Chinese teaching culture has been described as being dominated by examination culture as mentioned above (Zheng, 2006), among the three provinces, it has been generally accepted that the examination pressure in Shandong is relatively higher. Under this pressure, it might be possible that mathematics teaching in Shandong is more examination-oriented. Therefore, even though the latest reformed senior secondary school mathematics curriculum was firstly used in Shandong province in 2003, students did not state that mathematics is useful or they have plenty of experience in doing mathematics. This further suggests that when investigate students' epistemological conceptions of mathematics in a large country like China, sub-cultural differences should be considered.

4.4. Influences of teacher qualification

As argued by Schommer (1990), teacher's quality is a major influence for students' epistemological conceptions. Similarly, as reported above, the study also found that teachers' experience and qualification are major factors that influence students' epistemological conceptions of mathematics. However, this study found that there are no huge differences between students taught by teachers with 6-15 years of teaching and students taught by teacher with 1-5 years of teaching. For some scales, such as "structure of mathematical knowledge", "doing mathematics", and "validating ideas in mathematics", item mean scores of students taught by beginning teachers are even higher. Possibly because the beginning teachers newly graduated from universities and during their pre-service teacher training in universities, they have already been taught the ideas advocated in the latest mathematics curriculum reform and are required to practice these ideas. For those experienced teachers with more than 15 years of teaching, due to their expertise (including teaching and mathematics knowledge) and their study of curriculum reformed ideas, they are more able to demonstrate the inherent logicality and consistency of mathematics knowledge in their teaching, and design activities to let students experience the process of doing mathematics. Thereby, students could develop relatively sophisticated epistemological conception of mathematics (Schommer, 1994). As found in previous studies (e.g., Guo & Song, 2008), compared with proficient teachers and beginning teachers, expert teachers prefer to ask open questions that require students to think them from multiple

perceptive and deeply. Indeed, students' experience in their mathematics classroom is a very important factor that influences the development of their epistemological conception (Schommer, 1990). Therefore, students' epistemological conception of mathematics can be changed along with the change of teachers' teaching methods. Therefore, one possible way to make students develop an epistemological conception of mathematics as advocated in reformed mathematics curriculum is to enhance teachers' professional development. As long as teachers have sufficient professional knowledge and expertise of mathematics and mathematics teaching, and they accept the reformed ideas, they can implement the reformed ideas in their practice so this could make students gradually develop a dynamic mathematics conception.

Furthermore, the study found that teachers' experience of using reformed curriculum is also a major factor that influences the students' epistemological conceptions of mathematics. As reported above, generally speaking, compared with students taught by teachers using reformed curriculum for one or two years, students taught by teachers using reformed curriculum for 3 or more years are scored higher in each scale. This indicates that teachers may have a deeper understanding of reformed curriculum theories and ideas after using reformed curriculum for a period. But, the mean scores of students taught by teachers using reformed curriculum for 6 or more years started to fall, and in most scales, significant differences were identified between that of students taught by teachers beginning to use reformed curriculum. The possible reason was that teachers' beliefs and teaching methods again began to change along with the increase of years of using reformed curriculum. Thus, in the training for teachers, there is a need to strengthen the training for teachers with more years of using reformed curriculum, and special attention should be paid to the pertinence and adequacy of the training content.

5. CONCLUSION AND RECOMMENDATION

With the adaption of Grows' questionnaire on students' epistemological conceptions of mathematics, the study investigated 1255 senior secondary school students' epistemological conceptions of mathematics in China who using reformed curriculum in Shandong, Guangdong, and Zhejiang. This study firstly identified that senior secondary school students' epistemological conceptions of mathematics mainly focus on objectivity, certainty and reality, without highlighting the sociality and subjectivity, especially without reflecting mathematics as a creative activity of human being that emphasized in the reformed curriculum. Secondly, as found in previous study, this study found that the development of each dimension of epistemological conceptions is not in a unified way, and the development process is a recursive one rather than a linear. In addition, grade differences were

identified in the study, particularly between Grade 10 students and Grade 11 students, and Grade 10 students and Grade 12 students. Differences existed in different sub-cultures was also found to be a factor that influences students' epistemological conceptions of mathematics. Significant differences were identified among students from different provinces in China in this study. Thirdly, gender differences were also found in this study. Finally, teachers' qualification and experience were also found to be major factors that influence students' epistemological conceptions of mathematics. Significant differences were found to be existed among students taught by teachers with different teaching experience and different years of using reformed curriculum.

Since there has a lack of research effort to investigate senior secondary school students' epistemological conceptions of mathematics in China, particularly under the present curriculum reform background, findings of this study to a certain degree filled the gap of this in China. Due to the limits of research condition, the samples in this research are all come from urban schools, thus the research findings may not be applicable for students in rural areas in China. Moreover, the research horizontally explored the development process of students' epistemological conceptions of mathematics, rather than follow the same cohort students for a certain period. Future studies could consider carrying out longitudinal studies on this topic. Findings could make more contribution to the understanding of the process development and change of epistemological conceptions of mathematics in China.

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